

2017 Carl Moyer Program Guidelines

EXAMPLE CALCULATIONS

This document provides example calculations for determining surplus emission reductions and the maximum grant amounts for Carl Moyer Memorial Standards Attainment Program (Moyer Program) projects. The calculations draw on formulas and figures specified in Appendices C and D of the Moyer Program Guidelines (Guidelines) approved by the California Air Resources Board on April 27, 2017. The Board adopted new cost-effectiveness limits and other significant revisions to the Guidelines; these examples reflect those approved changes and are intended to highlight them. The examples address these and other scenarios:

- Advanced technology projects, applying the new \$100,000/ton cost-effectiveness limit for the incremental emission reductions beyond current emission standards;
- A co-funded project using Moyer Program funds, federal, and other State incentives to purchase a battery electric transit bus.
- Projects with split project lives;
- Two-for-one replacement projects;
- Projects with limited surplus due to upcoming regulatory compliance dates; and
- School bus projects, applying the unique school bus cost-effectiveness limit.

Note that most of the values in this document are rounded to four decimal places. Although ARB expects to incorporate this rounding convention in future updates to the Clean Air Reporting Log (CARL), the actual calculations currently made in CARL are not always similarly rounded. The Moyer Program Guidelines provide no specific guidance on rounding for cost-effectiveness and emission reduction calculations, except that the final maximum grant amount must not exceed the cost-effectiveness limit. Rounding should thus be done in a manner that does not risk exceeding that limit. Keeping emission reduction values in their full decimal form for intermediate steps in the calculations will usually generate results closer to those generated by CARL.

TABLE OF CONTENTS

I. On-Road Heavy-Duty Equipment	1
Example 1 – Replacement: New diesel heavy heavy-duty vehicle	1
Example 2 – Replacement: Used diesel medium heavy-duty vehicle	5
Example 3 – Replacement: New zero-emission transit bus (with co-funding)	9
Example 4 – Replacement: New optional low-NOx CNG school bus	13
Example 5 – Repower: Refuse truck optional low-NOx engine ***	17
Example 6 – Replacement: New optional low-NOx refuse truck ***	23
Example 7 – Replacement: New optional low-NOx CNG medium heavy-duty vehicle ***	30
Example 8 – Replacement: New emergency equipment on-road heavy-duty vehicle	38
II. Off-Road Equipment	42
Example 1 – Repower: Uncontrolled scraper engine with a Tier 4 Final engine	42
Example 2 – Retrofit: Tier 2 rubber tired loader engine with a Level 3 diesel particulate filter	46
Example 3 – Replacement: Uncontrolled agricultural tractor with Tier 4 Final tractor	49
Example 4 – Replacement: Tier 2 rubber tired loaders with one Tier 4 Final rubber tired loader	53
Example 5 – Replacement: Tier 3 narrow-body aircraft tug with Tier 4 Final narrow-body aircraft tug	58
Example 6 – Replacement: MY 2003 LSI with a new electric forklift ***	62
Example 7 – Replacement: Tier 1 diesel belt loader with a new electric belt loader ***	71
Example 8 – Replacement: Tier 3 to Tier 4 Portable Generator	79
Example 9 – Repower: Tier 3 portable pull-behind chipper with Tier 4 Final engine	83
Example 10–Repower: Tier 3 diesel stationary irrigation pump engine to electric motor ***	87
III. Locomotives	96
Example 1 – Switch Locomotive Engine Repower (Class 3 Railroad)	96
Example 2 – Multiple Engine Switcher Replacement (Class 1 Railroad)	99
Example 3 – Passenger Replacement with HEP (Class 3 Railroad)	102
IV. Marine Vessels	106
Example 1 – Repower: Fishing Vessel Propulsion Engine	106
Example 2 – Repower: Tow Boat Auxiliary Engine	109
Example 3 – Container Vessel (Ship Side) Shore Power	112
Example 4 – Installation of an EPA verified Hybrid System on a Tug Boat	114
V. Light-Duty Vehicles	118
Example 1 – Conventional VAVR Project	118
VI. Infrastructure	120
Example 1 – Natural Gas Fueling Station to support an On-Road Heavy Duty CNG Refuse Hauler	120
Example 2 – Battery Charging Station to support an Off-Road Electric Forklift	120
Example 3 – Stationary Agricultural Pump Electrification to support a Stationary Agricultural Pump	121
Example 4 – Battery Charging Station with Solar Power System to support a Light-Duty Vehicle	121

Select an example above to navigate throughout the document.
***** This project is eligible for a two-step cost-effectiveness calculation.**

I. On-Road Heavy-Duty Equipment

Example 1 – Replacement: New diesel heavy heavy-duty vehicle

A participant wants to replace a heavy heavy-duty (HHD) truck equipped with a 2005 model year engine with a new truck powered by a 2017 model year engine certified to the 0.20 g/bhp-hr NOx standard. The applicant operates a small fleet of three trucks 100 percent of the time in California. The fleet is subject to the Truck and Bus Regulation and is reported in TRUCRS under the Small Fleet Option. The truck is required to have a filter installed by January 1, 2018. There is no PM surplus. The truck has to meet the 2010 standard (0.20 g/bhp-hr NOx) by January 1, 2022; it has a 4-year surplus period. Surplus periods may change if the delivery date occurs later than the noted first year of operation.

Baseline Technology Information

- Baseline technology (application): EMY 2005 HHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-2):

	NOx	ROG	PM
EF	11.66 g/mi	0.49 g/mi	N/A
DR	0.049 g/mi-10,000 mi	0.018 g/mi-10,000 mi	N/A

- Activity (application): 40,000 mi/yr
- Discount rate is 1% and project life is 4 years; CRF (Table D-24): 0.256
- Percentage operation in California (application): 100%

Reduced Technology Information

- Reduced technology (application): EMY 2017 HHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-2):

	NOx	ROG	PM
EF	1.76 g/mi	0.13 g/mi	N/A
DR	0.039 g/mi-10,000 mi	0.001 g/mi-10,000 mi	N/A

- Cost of reduced technology: \$125,000
- Maximum eligible amount for a truck replacement (Table 4-3): 80%
- Maximum funding cap for HHD conventional diesel (Table 4-3): \$60,000
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions
- Expected first year of operation: 2017

(a) Determine deterioration calculations for a 2005 to 2017 0.20 NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + (project life / 2)

Deterioration life (baseline equipment) = 2017 – 2005 + (4 / 2) = 14 yrs

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 4 / 2 = 2 yrs

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

Total baseline equipment activity = 40,000 (mi/yr) * 14 (yrs) = 560,000 mi

Total reduced equipment activity = 40,000 (mi/yr) * 2 (yrs) = 80,000 mi

Calculate mile-based deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

NOx deterioration product = 0.049 (g/mi-10,000 mi) * 560,000 (mi) = 2.7440 g/mi

ROG deterioration product = 0.018 (g/mi-10,000 mi) * 560,000 (mi) = 1.0080 g/mi

Reduced equipment:

NOx deterioration product = 0.039 (g/mi-10,000 mi) * 80,000 (mi) = 0.3120 g/mi

ROG deterioration product = 0.001 (g/mi-10,000 mi) * 80,000 (mi) = 0.0080 g/mi

(b) Determine emission reductions calculations for a 2005 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

$(11.66 \text{ (g/mi)} + 2.7440 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$

= 0.6351 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)

$(1.76 \text{ (g/mi)} + 0.3120 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$

= 0.0914 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)

$(0.49 \text{ (g/mi)} + 1.0080 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$

= 0.0660 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)

$(0.13 \text{ (g/mi)} + 0.0080 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$

= 0.0061 tons/yr

(2) Calculate annual surplus emission reductions for each pollutant (tons/yr): Formula

C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

= 0.6351 (tons/yr) - 0.0914 (tons/yr) = 0.5437 tons/yr

Annual ROG surplus emission reductions (tons/yr)

= 0.0660 (tons/yr) - 0.0061 (tons/yr) = 0.0599 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

= 0.5437 (tons/yr NOx) + 0.0599 (tons/yr ROG)

= 0.6036 weighted tons/yr

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 30,000 \text{ (\$/ton)} * 0.6036 \text{ (tons/yr)} / 0.256 = \underline{\$70,734}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

$$\text{Potential grant amount} = \$125,000 * 80\% = \underline{\$100,000}$$

(3) Potential grant amount at the funding cap when applicable:

On-road conventional HHD vehicle (Table 4-3)

$$\text{Potential grant amount} = \underline{\$60,000}$$

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$60,000** in grant funds.

Example 2 – Replacement: Used diesel medium heavy-duty vehicle

A participant with a fleet of five vehicles wants to replace a 2010 medium heavy-duty (MHD) truck equipped with a 2009 engine model year (EMY) engine with a MHD truck equipped with a used 2013 engine certified to 0.20 g/bhp-hr NOx. Under the Truck and Bus Regulation, the reduced truck is required to meet 2010 standard (0.20 g/bhp-hr NOx) by 2023; it has a 5-year surplus period. Surplus periods may change if the delivery date occurs later than the noted first year of operation.

Baseline Technology Information

- Baseline technology (application): 2009 EMY MHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	3.99 g/mi	0.18 g/mi	0.014 g/mi
DR	0.090 g/mi-10,000 mi	0.007 g/mi-10,000 mi	0.0008 g/mi-10,000 mi

- Annual activity (application): 40,000 mi/yr
- Discount rate is 1% and project life is 5 years; CRF (Table D-24): 0.206
- Percentage operation in California (application): 80%

Reduced Technology Information

- Reduced technology (application): 2013 EMY MHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	1.03 g/mi	0.06 g/mi	0.002 g/mi
DR	0.045 g/mi-10,000 mi	0.001 g/mi-10,000 mi	0.0001 g/mi-10,000 mi

- Cost of reduced technology: \$65,000
- Maximum eligible amount for a truck replacement (Table 4-3): 80%
- Maximum funding cap for MHD used conventional diesel (Table 4-3): \$40,000
- Cost-effectiveness limit: \$30,000 per weighted ton
- Expected first year of operation: 2017

(a) Determine deterioration calculations for a 2009 to 2013 0.20 NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + (project life / 2)

Deterioration life (baseline equipment) = 2017 – 2009 + (5 / 2) = 10.5 yrs

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 5 / 2 = 2.5 yrs

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

Total baseline equipment activity = 40,000 (mi/yr) * 10.5 (yrs) = 420,000 mi

Total reduced equipment activity = 40,000 (mi/yr) * 2.5 (yrs) + 250,000 (mi) = 350,000 mi

The reduced equipment is used; the maximum mileage based on GVWR was added to the total reduced equipment activity. (Chapter 4 Section 5.C).

(4) Calculate mile-based deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

NOx deterioration product = 0.090 (g/mi-10,000 mi) * 420,000 (mi) = 3.780 g/mi

ROG deterioration product = 0.007 (g/mi-10,000 mi) * 420,000 (mi) = 0.2940 g/mi

PM deterioration product = 0.0008 (g/mi-10,000 mi) * 420,000 (mi) = 0.0336 g/mi

Reduced equipment:

NOx deterioration product = 0.045 (g/mi-10,000 mi) * 350,000 (mi) = 1.5750 g/mi

ROG deterioration product = 0.0010 (g/mi-10,000 mi) * 350,000 (mi) = 0.0350 g/mi

PM deterioration product = 0.0001 (g/mi-10,000 mi) * 350,000 (mi) = 0.0035 g/mi

Determine emission reductions calculations for a 2009 to 2013 0.20 NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

(3.99 (g/mi) + 3.78 (g/mi)) * 40,000 (mi/yr) * 80% / 907,200 (g/ton)

= 0.2741 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)

(1.03 (g/mi) + 1.575 (g/mi)) * 40,000 (mi/yr) * 80% / 907,200 (g/ton)

= 0.0919 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)

(0.18 (g/mi) + 0.294 (g/mi)) * 40,000 (mi/yr) * 80% / 907,200 (g/ton)

= 0.0167 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)

(0.06 (g/mi) + 0.035 (g/mi)) * 40,000 (mi/yr) * 80% / 907,200 (g/ton)

= 0.0034 tons/yr

Annual PM **baseline** technology emissions (tons/yr)
 $(0.14 \text{ (g/mi)} + 0.0336 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 80\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0061 \text{ tons/yr PM}}$
 Annual PM **reduced** technology emissions (tons/yr)
 $(0.002 \text{ (g/mi)} + 0.0035 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 80\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0002 \text{ tons/yr PM}}$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
 $= 0.2741 \text{ (tons/yr)} - 0.0919 \text{ (tons/yr)} = \underline{0.1822 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.0167 \text{ (tons/yr)} - 0.0034 \text{ (tons/yr)} = \underline{0.0133 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0.0061 \text{ (tons/yr)} - 0.0002 \text{ (tons/yr)} = \underline{0.0059 \text{ tons/yr}}$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
 $= 0.1822 \text{ (tons/yr NOx)} + 0.0133 \text{ (tons/yr ROG)} + (20 * 0.0059 \text{ (tons/yr PM)})$
 $= \underline{0.3135 \text{ weighted tons/yr}}$

(b) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 30,000 \text{ (\$/ton)} * 0.3135 \text{ (tons/yr)} / 0.206 = \underline{\$45,655}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

$$\text{Potential grant amount} = \$65,000 * 80\% = \underline{\$52,000}$$

(3) Potential grant amount at the funding cap when applicable:

On-road conventional MHD vehicle (Table 4-3)

$$\text{Potential grant amount} = \underline{\$40,000}$$

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$40,000** in grant funds.

Example 3 – Replacement: New zero-emission transit bus (with co-funding)

A public transit fleet of fleet size 50 is in compliance with the Fleet Rule for Transit Agencies (CCR, title 13, sections 1956.1, 2020, 2023, 2023.1 and 2023.4), and wants to replace a 2005 engine model year CNG transit bus with a 2017 EMY \$750K zero emission transit bus. The fleet operates 100 percent of the time in California. Annual usage is 40,000 miles. Cost-effectiveness calculations for transit bus projects can only include emission reductions from the 2007 engine model year when a project life of 12 years is used. Only NOx and ROG surplus emission reductions can be funded unless the replacement bus is zero emission in which case PM surplus emission reductions may also be funded. This transit bus project will include co-funding of Moyer program funds with Federal Transit Administration (FTA) funds and Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP) funds.

Baseline Technology Information

- Baseline technology: 2005 EMY CNG transit bus (note: use 2007+ EMY emission factors, as explained above)
- Emission factors (EF) and deterioration rates (DR) (Table D-4; note that transit fleets are well-maintained and have no deterioration (Chapter 4, Section C.2.(C)(5))):

	NOx	ROG	PM
EF	0.65 g/mi	0.04 g/mi	0.001 g/mi
DR	N/A	N/A	N/A

- Annual activity (application): 40,000 mi/yr
- Discount rate is 1% and project life is 12 years; CRF (Table D-24): 0.089
- Percentage operation in California (application): 100%

Reduced Technology Information

- Reduced technology: 2017 EMY zero emission transit bus
- Emission factors (EF) and deterioration rates (DR) (Table D-4; note that transit fleets are well-maintained and have no deterioration (Chapter 4, Section C.2.(C)(5))):

	NOx	ROG	PM
EF	0 g/mi	0 g/mi	0 g/mi
DR	N/A	N/A	N/A

- Cost of reduced technology: \$750,000
- Maximum eligible amount for a transit bus replacement (Table 4-6): \$80,000
- Maximum funding cap (Table 4-6): 50 percent (large fleets)
- Cost-effectiveness limit: \$100,000 per weighted ton of emission reductions
- Expected first year of operation: 2017

(a) Determine deterioration calculations for a 2007 CNG to zero-emission:

No deterioration for transit buses.

(b) Determine emission reductions calculations for a 2007 to zero-emission:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)
 $(0.65 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0287 \text{ tons/yr}}$

Annual NOx **reduced** technology emissions (tons/yr)
 $(0 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0 \text{ tons/yr}}$

Annual ROG **baseline** technology emissions (tons/yr)
 $(0.04 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0018 \text{ tons/yr}}$

Annual ROG **reduced** technology emissions (tons/yr)
 $(0 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0 \text{ tons/yr}}$

Annual PM **baseline** technology emissions (tons/yr)
 $(0.001 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0 \text{ tons/yr}}$

Annual PM **reduced** technology emissions (tons/yr)
 $(0 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 40,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0 \text{ tons/yr}}$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
 $= 0.0287 \text{ (tons/yr)} - 0 \text{ (tons/yr)} = \underline{0.0287 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.0018 \text{ (tons/yr)} - 0 \text{ (tons/yr)} = \underline{0.0018 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0 \text{ (tons/yr)} - 0 \text{ (tons/yr)} = \underline{0 \text{ tons/yr}}$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.0287 (tons/yr NOx) + 0.0018 (tons/yr ROG) + (20 * 0 (tons/yr PM))
= **0.0305 weighted tons/yr**

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$100,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 100,000 (\$/ton) * 0.0305 (tons/yr) / 0.089 = **\$34,269**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$750,000 * 50% = **\$375,000**

(3) Potential grant amount at the funding cap when applicable:

Zero-emission transit replacement (Table 4-6)
Potential grant amount = **\$80,000**

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$34,269** in grant funds.

.....Co-funding calculation.....

Listed below are a series of steps an air district or applicant should follow when considering a project for co-funding (Chapter 3, Section L).

(d) Categorize the funding source

FTA funding is a federal funding source while HVIP is a state funding source. Non-Moyer federal, state, local, penalty and other applied funds will be separately designated in CARL.

(e) Are these non-Moyer funds being used as match funds?

No, therefore they will not need to be included in the cost-effectiveness calculation (Chapter 3, Section L.4.).

(f) Calculate the applicant cost share and determine its applicability.

In this example the transit fleet is a public entity, and public entities are not subject to the applicant cost share provision (Chapter 3, Section L.5.).

Formula C-16: Applicant Cost Share (\$)

$$\text{Applicant Cost Share (\$)} \geq 15 \text{ percent} * \text{Moyer Eligible Costs (\$)}$$

Applicant Cost Share (\$) = zero in this example.

Moyer eligible and Moyer ineligible costs are defined in Appendix B and further specified in some source category chapters. When applicant cost share applies, the districts may choose a higher percentage of the Moyer eligible cost share to be paid by the applicant.

(g) Calculation for co-funding Moyer Funds with Other Sources

The Moyer grant is \$34,269 as determined above. The applicant received \$600,000 from FTA and \$45,731 from HVIP towards the purchase of this zero-emission transit bus in this example. The Moyer on-road heavy-duty source category chapter states that all state funding for transit bus project is capped at \$80,000 (Chapter 4, Table 4-6). The HVIP dollar amount in this example is then determined by subtracting the Moyer grant amount from the state cap.

Formula C-17: Project overpayment check (\$)

$$\text{Total Project Cost} \geq \text{Applicant Cost Share (\$)} + \sum \text{Grants Paid (\$)}$$

The total project cost for this transit bus:	\$ 750,000
Moyer Paid Project Cost:	\$ 34,269
FTA Paid Project Cost:	\$600,000
HVIP Paid Project Cost:	<u>\$ 45,731</u>
Grants Paid is:	\$680,000
Remaining Eligible Cost:	\$ 70,000

The total project cost (\$750,000) is greater than the all grants paid amount (\$680,000).

Example 4 – Replacement: New optional low-NOx CNG school bus

A school district wants to replace one of their older diesel school buses with a brand new school bus that costs \$230,000 and is equipped with a 2017 model year CNG engine certified to the 0.02 g/bhp-hr optional low-NOx standard. The baseline school bus has a 1999 model year engine, has been driven an average of 5,800 miles per year for the past two years, and it has already been retrofitted with a diesel particulate filter as per the requirements of the Truck and Bus Regulation. Most school bus engines fall under the medium heavy-duty intended service class, and the school bus in this example is no exception. The school bus is operated 100 percent of the time in California. Optional low-NOx school bus replacement projects have a funding cap of \$220,000 (as per Table 4-2), and since this is not a zero-emission school bus project no PM emissions may be claimed. The baseline school bus already meets the final requirements of the Truck and Bus Regulation, as it has been retrofitted, and so the maximum project life of 10 years (as per Table 4-8) may be used.

Baseline Technology Information

- Baseline technology (application): retrofitted 1999 EMY diesel school bus
- Emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	10.33 g/mi	0.28 g/mi	N/A
DR	0.072 g/mi-10,000 mi	0.036 g/mi-10,000 mi	N/A

- Activity (application): 5,800 mi/yr
- Discount rate is 1% and project life is 10 years; CRF (Table D-24): 0.106
- Percentage operation in California (application): 100%

Reduced Technology Information

- Reduced technology (application): 2017 EMY 0.02 g/bhp-hr optional low-NOx CNG school bus
- Emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	0.10 g/mi	0.06 g/mi	N/A
DR	0.005 g/mi-10,000 mi	0.001 g/mi-10,000 mi	N/A

- Eligible cost: \$230,000
- Maximum percentage of eligible cost: 100%
- Funding cap for optional low-NOx school bus replacement (Table 4-2): \$220,000
- Cost-effectiveness limit: \$276,230 per weighted ton
- Expected first year of operation: 2017

(a) Determine deterioration calculations for a 1999 to 2017 0.02NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + (project life / 2)

Deterioration life (baseline equipment) = 2017 – 1999 + (10 / 2) = 23 yrs

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 10 / 2 = 5 yrs

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

Total baseline equipment activity = 5,800 (mi/yr) * 23 (yrs) = 133,400 mi

Total reduced equipment activity = 5,800 (mi/yr) * 5 (yrs) = 29,000 mi

(4) Calculate mile-based deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

NOx deterioration product = 0.072 (g/mi-10,000 mi) * 133,400 (mi) = 0.9605 g/mi

ROG deterioration product = 0.036 (g/mi-10,000 mi) * 133,400 (mi) = 0.4802 g/mi

Reduced equipment:

NOx deterioration product = 0.005 (g/mi-10,000 mi) * 29,000 (mi) = 0.0145 g/mi

ROG deterioration product = 0.001 (g/mi-10,000 mi) * 29,000 (mi) = 0.0029 g/mi

(b) Determine emission reductions calculations for a 2005 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

$$(10.33 \text{ (g/mi)} + 0.9605 \text{ (g/mi)}) * 5,800 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0722 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions(tons/yr)

$$(0.10 \text{ (g/mi)} + 0.0145 \text{ (g/mi)}) * 5,800 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0007 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions (tons/yr)

$$(0.28 \text{ (g/mi)} + 0.4802 \text{ (g/mi)}) * 5,800 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0049 \text{ tons/yr}}$$

Annual ROG **reduced** technology emissions (tons/yr)

$$(0.06 \text{ (g/mi)} + 0.0029 \text{ (g/mi)}) * 5,800 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0004 \text{ tons/yr}}$$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr): Formula

C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.0722 \text{ (tons/yr)} - 0.0007 \text{ (tons/yr)} = \underline{0.0715 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0049 \text{ (tons/yr)} - 0.0004 \text{ (tons/yr)} = \underline{0.0045 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.0715 \text{ (tons/yr NOx)} + 0.0045 \text{ (tons/yr ROG)}$$

$$= \underline{0.0760 \text{ weighted tons/yr}}$$

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$276,230 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 276,230 \text{ (\$/ton)} * 0.0760 \text{ (tons/yr)} / 0.106 = \underline{\$198,052}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

$$\text{Potential grant amount} = \$230,000 * 100\% = \underline{\$230,000}$$

(3) Potential grant amount at the funding cap when applicable:

Optional low-NOx school bus replacement (Table 4-2)

Potential grant amount = \$220,000

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$198,052 in grant funds.

Example 5 – Repower: Refuse truck optional low-NOx engine ***

A refuse fleet owner wants to repower a heavy heavy-duty (HHD) refuse truck with a 2017 model year CNG engine certified to the optional low-NOx emissions standard of 0.02 g/bhp-hr. The existing truck has a GVWR of 34,000 lbs. and is equipped with a 2009 model year CNG engine. The fleet owner has provided conclusive documentation that for the last two years the refuse truck operated a minimum of 15,000 miles per year and operated 100 percent of the time in California. There is no PM surplus. The existing CNG engine is not subject to in-use fleet regulations and is eligible for a seven-year project life.

This project is eligible for a two-step cost-effectiveness calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 cost-effectiveness (CE) limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step cost-effectiveness calculation example consists of:

Step 1 – MY 2009 engine to MY 2017 0.20 g/bhp-hr NOx standard engine

Step 2 – MY 2017 engine to MY 2017 0.02 g/bhp-hr NOx standard engine

Baseline Technology Information – Step 1

- Baseline technology: EMY 2009 CNG HHD refuse truck
- Baseline emission factors (EF) and deterioration rates (DR) (Table D-6):

	NOx	ROG	PM
EF	18.80 g/mi	3.68 g/mi	N/A
DR	N/A	N/A	N/A

- Activity (application): 15,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 1

- Reduced technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-6):

	NOx	ROG	PM
EF	0.88 g/mi	0.14 g/mi	N/A
DR	N/A	N/A	N/A

- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions
- Maximum funding cap for refuse truck repower: N/A for Step 1
- Expected first year of operation: 2017

Baseline Technology Information – Step 2

- Baseline technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-6):

	NOx	ROG	PM
EF	0.88 g/mi	0.14 g/mi	N/A
DR	N/A	N/A	N/A

- Activity (application): 15,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 2

- Reduced emission factors (EF) and deterioration rates (DR) (Table D-6):

	NOx	ROG	PM
EF	0.09 g/mi	0.14 g/mi	N/A
DR	N/A	N/A	N/A

- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Cost of reduced technology: \$60,000
- Cost-effectiveness limit: \$100,000 per weighted ton of emission reductions
- Maximum funding cap for refuse truck repower (Table 4-5): \$40,000
- Expected first year of operation: 2017

..... *Step 1 – 2009 to 2017 0.20 g/bhp-hr NOx standard*.....

(a) Determine deterioration calculations for a 2009 to 2017 0.20 NOx:

No deterioration for refuse trucks.

(b) Determine emission reductions calculations for a 2009 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

$$(18.80 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.3108 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions (tons/yr)

$$(0.88 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0146 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions (tons/yr)

$$(3.68 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0608 \text{ tons/yr}}$$

Annual ROG **reduced** technology emissions (tons/yr)

$$(0.14 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0023 \text{ tons/yr}}$$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr): Formula

C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.3108 \text{ (tons/yr)} - 0.0146 \text{ (tons/yr)} = \underline{0.2962 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0608 \text{ (tons/yr)} - 0.0023 \text{ (tons/yr)} = \underline{0.0585 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.2962 \text{ (tons/yr NOx)} + 0.0585 \text{ (tons/yr ROG)}$$
$$= \underline{0.3547 \text{ weighted tons/yr}}$$

(c) Determine the maximum grant amount for Step 1:

Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 30,000 (\$/ton) * 0.3547 (tons/yr) / 0.149 = \$71,416

Maximum grant amount for Step 1: \$71,416

..... Step 2 – 2017 0.20 g/bhp-hr NOx standard to 2017 0.02 g/bhp-hr NOx.....

(d) Determine deterioration calculations for a 2017 0.20 NOx to 2017 0.02NOx:

No deterioration for refuse trucks.

(e) Determine emission reductions calculations for a 2017 0.20 NOx to 2017 0.02NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr):

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)
(0.88 (g/mi) + 0 (g/mi)) * 15,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0146 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)
(0.09 (g/mi) + 0 (g/mi)) * 15,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0015 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)
(0.14 (g/mi) + 0 (g/mi)) * 15,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0023 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)
(0.14 (g/mi) + 0 (g/mi)) * 15,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0023 tons/yr

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
= 0.0146 (tons/yr) - 0.0015 (tons/yr) = 0.0131 tons/yr
Annual ROG surplus emission reductions (tons/yr)
= 0.0023 (tons/yr) - 0.0023 (tons/yr) = 0 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.0131 (tons/yr NOx) + 0 (tons/yr ROG)
= 0.0131 weighted tons/yr

(f) Determine the potential maximum grant amount for Step 2:

Potential grant amount at the \$100,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 100,000 (\$/ton) * 0.0131 (tons/yr) / 0.149 = \$8,792

Maximum grant amount for Step 2: \$8,792

..... Maximum grant amount

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limit:

Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) + grant amount at the 100,000 cost-effectiveness limit (\$)

Potential grant amount = \$71,416 + \$8,792 = \$80,208

(2) Potential grant amount at the funding cap when applicable:

On-road optional low NOx repower (non-transit) (Table 4-5)
Potential grant amount = \$40,000

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$40,000 in grant funds.

..... Project's total estimated cost-effectiveness**

(h) Determine the project's overall cost-effectiveness

(1) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.3547 \text{ tons/yr.} * (7 / 7) + 0.0131 \text{ tons/yr.} * (7 / 7) = \underline{0.3678 \text{ tons/yr.}}$$

(2) Total estimated cost-effectiveness

Formula C-18: Cost-effectiveness of estimated surplus emission reductions (\$/tons)

*Cost-effectiveness (\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$40,000 * 0.149 / 0.3678 \text{ tons/yr} = \underline{\$16,204}$$

Project's estimated cost-effectiveness: \$16,204

***Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.*

Example 6 – Replacement: New optional low-NOx refuse truck ***

A refuse fleet owner wants to replace a heavy heavy-duty (HHD) refuse truck with a new refuse truck powered by a 2017 model year CNG engine certified to the optional low NOx standard emissions level of 0.02 g/bhp-hr. The existing truck has a GVWR of 36,500 lbs. and is equipped with a 2009 model year diesel engine. The fleet owner has provided conclusive documentation that for the last two years the refuse truck operated a minimum of 15,000 miles per year and operated 100 percent of the time in California. There is no PM surplus included. The fleet of 20 vehicles is subject to the Truck and Bus Regulation. The vehicle to be scrapped has a regulatory requirement to meet 2010 emission standards (0.20 g/bhp-hr NOx) by January 1, 2023, resulting in a 5-year surplus to meet 2010 standards. Surplus periods may change if the delivery date occurs later than the noted first year of operation. The overall project is eligible for a seven-year project life. A Moyer funded infrastructure project may be associated with this project. Please see Section VI (page 112), Example 1, for infrastructure project calculations.

This project is eligible for a two-step cost-effectiveness calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 cost-effectiveness (CE) limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step cost-effectiveness calculation example consists of:

Step 1 – MY 2009 engine to MY 2017 0.20 g/bhp-hr NOx standard engine

Step 2 – MY 2017 engine to MY 2017 0.02 g/bhp-hr NOx standard engine

Baseline Technology Information – Step 1

- Baseline technology: EMY 2009 diesel HHD refuse truck
- Baseline emission factors (EF) and deterioration rates (DR) (Table D-5):

	NOx	ROG	PM
EF	11.25 g/mi	0.14 g/mi	N/A
DR	N/A	N/A	N/A

- Activity (application): 15,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 1

- Reduced technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-5):

	NOx	ROG	PM
EF	1.09 g/mi	0.04 g/mi	N/A
DR	N/A	N/A	N/A

- Discount rate is 1% and project life is 5 years; CRF (Table D-24): 0.206
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions
- Funding cap for conventional HHD replacement (Table 4-3): \$60,000
- Expected first year of operation: 2017

Baseline Technology Information – Step 2

- Baseline technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-5):

	NOx	ROG	PM
EF	1.09 g/mi	0.04 g/mi	N/A
DR	N/A	N/A	N/A

- Activity (application): 15,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 2

- Reduced emission factors (EF) and deterioration rates (DR) (Table D-6):

	NOx	ROG	PM
EF	0.09 g/mi	0.14 g/mi	N/A
DR	N/A	N/A	N/A

- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Cost of reduced technology: \$265,000
- Cost-effectiveness limit: \$100,000 per weighted ton of emission reductions
- Maximum funding cap for HHD refuse truck replacement (Table 4-4): \$100,000
- Expected first year of operation: 2017

..... *Step 1 – 2009 to 2017 0.20 g/bhp-hr NOx standard*.....

(a) Determine deterioration calculations for a 2009 to 2017 0.20 NOx:

No deterioration for refuse trucks.

(b) Determine emission reductions calculations for a 2009 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

$$(11.25 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.1860 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions (tons/yr)

$$(1.09 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0180 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions (tons/yr)

$$(0.14 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0023 \text{ tons/yr}}$$

Annual ROG **reduced** technology emissions (tons/yr)

$$(0.04 \text{ (g/mi)} + 0 \text{ (g/mi)}) * 15,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)}$$
$$= \underline{0.0007 \text{ tons/yr}}$$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr): Formula

C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.1860 \text{ (tons/yr)} - 0.0180 \text{ (tons/yr)} = \underline{0.1680 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0023 \text{ (tons/yr)} - 0.0007 \text{ (tons/yr)} = \underline{0.0016 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.1680 \text{ (tons/yr NOx)} + 0.0016 \text{ (tons/yr ROG)}$$
$$= \underline{0.1696 \text{ weighted tons/yr}}$$

(c) Determine the maximum grant amount for Step 1:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 30,000 (\$/\text{ton}) * 0.1696 (\text{tons}/\text{yr}) / 0.206 = \underline{\$24,699}$$

(2) Potential grant amount at the funding cap when applicable (\$):

On-road alternative fuel 0.20 g/bhp-hr NOx MHD vehicle (Table 4-3)
Potential grant amount = \$60,000

The lower results of the two calculations above is the maximum grant amount at the \$30,000 cost-effectiveness:

Maximum grant amount for Step 1: \$24,699

..... Step 2 – 2017 0.20 NOx standard to 2017 0.02 g/bhp-hr NOx.....

(d) Determine deterioration calculations for a 2017 0.20 NOx to 2017 0.02NOx:

No deterioration for refuse trucks.

(e) Determine emission reductions calculations for a 2017 0.20 NOx to 2017 0.02NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr):
*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

$$\begin{aligned} &\text{Annual NOx **baseline** technology emissions (tons/yr)} \\ &(1.09 (\text{g}/\text{mi}) + 0 (\text{g}/\text{mi})) * 15,000 (\text{mi}/\text{yr}) * 100\% / 907,200 (\text{g}/\text{ton}) \\ &= \underline{0.0180 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} &\text{Annual NOx **reduced** technology emissions (tons/yr)} \\ &(0.09 (\text{g}/\text{mi}) + 0 (\text{g}/\text{mi})) * 15,000 (\text{mi}/\text{yr}) * 100\% / 907,200 (\text{g}/\text{ton}) \\ &= \underline{0.0015 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} &\text{Annual ROG **baseline** technology emissions (tons/yr)} \\ &(0.04 (\text{g}/\text{mi}) + 0 (\text{g}/\text{mi})) * 15,000 (\text{mi}/\text{yr}) * 100\% / 907,200 (\text{g}/\text{ton}) \\ &= \underline{0.0007 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} &\text{Annual ROG **reduced** technology emissions (tons/yr)} \\ &(0.14 (\text{g}/\text{mi}) + 0 (\text{g}/\text{mi})) * 15,000 (\text{mi}/\text{yr}) * 100\% / 907,200 (\text{g}/\text{ton}) \\ &= \underline{0.0023 \text{ tons/yr}} \end{aligned}$$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.0180 \text{ (tons/yr)} - 0.0015 \text{ (tons/yr)} = \underline{0.0165 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0007 \text{ (tons/yr)} - 0.0023 \text{ (tons/yr)} = \underline{-0.0016 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.0165 \text{ (tons/yr NOx)} - 0.0016 \text{ (tons/yr ROG)}$$

$$= \underline{0.0149 \text{ weighted tons/yr}}$$

(f) Determine the potential maximum grant amount for Step 2:

Potential grant amount at the \$100,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 100,000 \text{ (\$/ton)} * 0.0149 \text{ (tons/yr)} / 0.149 = \underline{\$10,000}$$

Maximum grant amount for Step 2: \$10,000

..... Maximum grant amount

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limit:

Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) + grant amount at the 100,000 cost-effectiveness limit (\$)

$$\text{Potential grant amount} = \$24,699 + \$10,000 = \underline{\$34,699}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$):

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

$$\text{Potential grant amount} = \$265,000 * 50\% = \underline{\$132,500}$$

(3) Potential grant amount at the funding cap when applicable:

On-road optional low NOx replacement (non-transit) (Table 4-4)

$$\text{Potential grant amount} = \underline{\$100,000}$$

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$34,699** in grant funds.

..... Project's total estimated cost-effectiveness **

(h) Determine the projects overall cost-effectiveness

(3) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.1696 \text{ tons/yr.} * (5 / 7) + 0.0149 \text{ tons/yr.} * (7 / 7) = \underline{0.1360 \text{ tons/yr.}}$$

(4) Total estimated cost-effectiveness

Formula C-18: Cost-effectiveness of estimated surplus emission reductions (\$/tons)

*Cost-effectiveness (\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$34,699 * 0.149 / 0.1360 \text{ tons/yr} = \underline{\$38,015}$$

Project's estimated cost-effectiveness: \$38,015

***Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.*

Example 7 – Replacement: New optional low-NOx CNG medium heavy-duty vehicle ***

A trucking company with a fleet of 13 trucks subject to the Truck and Bus Regulation wants to scrap a 2006 model year diesel engine powered, medium heavy-duty (MHD) truck with 32,000 lbs. GVWR and replace it with a new truck equipped with a 2017 model year CNG engine certified to a 0.02 g/bhp-hr NOx standard. The vehicle has a verified diesel emission control system (Level 3 diesel particulate filter (DPF)) installed that meets the filter requirements of the regulation. The participant has provided conclusive documentation that for the last two years the old truck operated a minimum of 30,000 miles per year and operated 100 percent of the time in California. The truck has to meet the 2010 standard (0.20 g/bhp-hr NOx) by January 1, 2022 resulting in a four-year surplus period. Surplus periods may change if the delivery date occurs later than the noted first year of operation. NOx and ROG emission reductions are eligible for a seven-year maximum project life, according to the On-Road chapter (Chapter 4).

This project is eligible for a two-step cost-effectiveness calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 cost-effectiveness (CE) limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step cost-effectiveness calculation example consists of:

- Step 1 – MY 2006 engine to MY 2017 0.20 g/bhp-hr NOx standard engine
- Step 2 – MY 2017 engine to MY 2017 0.02 g/bhp-hr NOx standard engine

Baseline Technology Information – Step 1

- Baseline technology: EMY 2006 MHD diesel truck with Level 3 DPF
- Baseline emission factors (EF) and deterioration rates (DR) (Table D-1); note that PM emissions have been reduced 85% to take into account the Level 3 DPF:

	NOx	ROG	PM
EF	6.84 g/mi	0.23 g/mi	0.026 g/mi
DR	0.071 g/mi-10,000 mi	0.021 g/mi-10,000 mi	0.0010 g/mi-10,000 mi

- Activity (application): 30,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 1

- Reduced technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	1.03 g/mi	0.06 g/mi	0.002 g/mi
DR	0.045 g/mi-10,000 mi	0.001 g/mi-10,000 mi	0.0001 g/mi-10,000 mi

- Discount rate is 1% and project life is 4 years; CRF (Table D-24): 0.256
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions
- Funding cap for MHD conventional diesel (Table 4-3): \$40,000
- Expected first year of operation: 2017

Baseline Technology Information – Step 2

- Baseline technology (current standard): EMY 2017 0.20 NOx diesel engine
- Current standard emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	1.03 g/mi	0.06 g/mi	0.002 g/mi
DR	0.045 g/mi-10,000 mi	0.001 g/mi-10,000 mi	0.0001 g/mi-10,000 mi

- Activity (application): 30,000 mi/yr
- Percentage operation in California (application): 100%

Reduced Technology Information – Step 2

- Reduced emission factors (EF) and deterioration rates (DR) (Table D-1):

	NOx	ROG	PM
EF	0.10 g/mi	0.06 g/mi	0.002 g/mi
DR	0.005 g/mi-10,000 mi	0.001 g/mi-10,000 mi	0.0001 g/mi-10,000 mi

- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Cost of reduced technology: \$150,000
- Cost-effectiveness limit: \$100,000 per weighted ton of emission reductions
- Maximum funding cap for MHD optional low NOx (Table 4-4): \$80,000
- Maximum funding percentage (Table 4-4): 50 percent
- Expected first year of operation: 2017

..... Step 1 – 2006 to 2017 0.20 g/bhp-hr NOx standard.....

(a) Determine deterioration calculations for a 2006 to 2017 0.20 NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + (project life / 2)

Deterioration life (baseline equipment) = 2017 – 2006 + (4 / 2) = 13 yrs

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 4 / 2 = 2 yrs

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

Total baseline equipment activity = 30,000 (mi/yr) * 13 (yrs) = 390,000 mi

Total reduced equipment activity = 30,000 (mi/yr) * 2 (yrs) = 60,000 mi

(4) Calculate mile-based deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

NOx deterioration product = 0.0710 (g/mi-10,000 mi) * 390,000 (mi) = 2.7690 g/mi

ROG deterioration product = 0.0210 (g/mi-10,000 mi) * 390,000 (mi) = 0.8190 g/mi

PM deterioration product = 0.0010 (g/mi-10,000 mi) * 390,000 (mi) = 0.0390 g/mi

Reduced equipment:

NOx deterioration product = 0.0450 (g/mi-10,000 mi) * 60,000 (mi) = 0.2700 g/mi

ROG deterioration product = 0.0010 (g/mi-10,000 mi) * 60,000 (mi) = 0.0060 g/mi

PM deterioration product = 0.0001 (g/mi-10,000 mi) * 60,000 (mi) = 0.0006 g/mi

(b) Determine emission reductions calculations for a 2006 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

(6.84 (g/mi) + 2.7690 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.3178 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)

(1.03 (g/mi) + 0.2700 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.0430 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)

(0.23 (g/mi) + 0.8190 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.0347 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)

(0.06 (g/mi) + 0.0060 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.0022 tons/yr

Annual PM **baseline** technology emissions (tons/yr)

(0.0263 (g/mi) + 0.0390 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.0022 tons/yr

Annual PM **reduced** technology emissions (tons/yr)

(0.002 (g/mi) + 0.0006 (g/mi)) * 30,000 (mi/yr) * 100% / 907,200 (g/ton)

= 0.0001 tons/yr

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.3178 \text{ (tons/yr)} - 0.0430 \text{ (tons/yr)} = \underline{0.2748 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0347 \text{ (tons/yr)} - 0.0022 \text{ (tons/yr)} = \underline{0.0325 \text{ tons/yr}}$$

Annual PM surplus emission reductions (tons/yr)

$$= 0.0022 \text{ (tons/yr)} - 0.0001 \text{ (tons/yr)} = \underline{0.0021 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.2748 \text{ (tons/yr NOx)} + 0.0325 \text{ (tons/yr ROG)} + (20 * 0.0021 \text{ (tons/yr PM)})$$

$$= \underline{0.3493 \text{ weighted tons/yr}}$$

(c) Determine the maximum grant amount for Step 1:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = 30,000 \text{ (\$/ton)} * 0.3493 \text{ (tons/yr)} / 0.256 = \underline{\$40,933}$$

(2) Potential grant amount at the funding cap when applicable (\$):

On-road alternative fuel 0.20 g/bhp-hr NOx MHD vehicle (Table 4-3)

$$\text{Potential grant amount} = \underline{\$40,000}$$

The lower result of the two calculations above is the maximum grant amount at the \$30,000 cost-effectiveness:

Maximum grant amount for Step 1: \$40,000

..... Step 2 – 2017 0.20 g/bhp-hr NOx standard to 2017 0.02 g/bhp-hr NOx.....

(d) Determine deterioration calculations for a 2017 0.20 NOx to 2017 0.02NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + (project life / 2)

Deterioration life (baseline equipment) = 2017 – 2017 + (7 / 2) = 3.5 yrs

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 7 / 2 = 3.5 yrs

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

Total baseline equipment activity = 30,000 (mi/yr) * 3.5 (yrs) = 105,000 mi

Total reduced equipment activity = 30,000 (mi/yr) * 3.5 (yrs) = 105,000 mi

(4) Calculate deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

NOx deterioration product = 0.045 (g/mi-10,000 mi) * 105,000 (mi) = 0.4725 g/mi

ROG deterioration product = 0.001 (g/mi-10,000 mi) * 105,000 (mi) = 0.0105 g/mi

Reduced equipment:

NOx deterioration product = 0.005 (g/mi-10,000 mi) * 105,000 (mi) = 0.0525 g/mi

ROG deterioration product = 0.001 (g/mi-10,000 mi) * 105,000 (mi) = 0.0105 g/mi

(e) Determine emission reductions calculations for a 2017 0.20 NOx to 2017 0.02NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr):

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)

$$(1.03 \text{ (g/mi)} + 0.4725 \text{ (g/mi)}) * 30,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)} \\ = \underline{0.0497 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions (tons/yr)

$$(0.10 \text{ (g/mi)} + 0.0525 \text{ (g/mi)}) * 30,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)} \\ = \underline{0.0050 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions (tons/yr)

$$(0.06 \text{ (g/mi)} + 0.0105 \text{ (g/mi)}) * 30,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)} \\ = \underline{0.0023 \text{ tons/yr}}$$

Annual ROG **reduced** technology emissions (tons/yr)

$$(0.06 \text{ (g/mi)} + 0.0105 \text{ (g/mi)}) * 30,000 \text{ (mi/yr)} * 100\% / 907,200 \text{ (g/ton)} \\ = \underline{0.0023 \text{ tons/yr}}$$

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr): Formula

C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)

$$= 0.0497 \text{ (tons/yr)} - 0.0050 \text{ (tons/yr)} = \underline{0.0447 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$= 0.0023 \text{ (tons/yr)} - 0.0023 \text{ (tons/yr)} = \underline{0 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.0447 \text{ (tons/yr NOx)} + 0 \text{ (tons/yr ROG)}$$

$$= \underline{0.0447 \text{ weighted tons/yr}}$$

(f) Determine the potential maximum grant amount for Step 2:

Potential grant amount at the \$100,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 100,000 (\$/ton) * 0.0447 (tons/yr) / 0.149 = \$30,000

Maximum grant amount for Step 2: \$30,000

..... Maximum grant amount

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limit:

Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) + grant amount at the 100,000 cost-effectiveness limit (\$)

Potential grant amount = \$40,000 + \$30,000 = \$70,000

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$150,000 * 50% = \$75,000

(3) Potential grant amount at the funding cap when applicable:

On-road optional low NOx MHD vehicle (Table 4-4)

Potential grant amount = \$80,000

The lowest result of the three calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$70,000 in grant funds.

..... Project's total estimated cost-effectiveness**

(h) Determine the projects overall cost-effectiveness

(5) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.3493 \text{ tons/yr.} * (4 / 7) + 0.0447 \text{ tons/yr.} * (7 / 7) = \underline{0.2443 \text{ tons/yr.}}$$

(6) Total estimated cost-effectiveness

Formula C-18: Cost-effectiveness of estimated surplus emission reductions (\$/tons)

*Cost-effectiveness(\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$70,000 * 0.149 / 0.2443 \text{ tons/yr} = \underline{\$42,693}$$

Project's estimated cost-effectiveness: \$42,693

***Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.*

Example 8 – Replacement: New emergency equipment on-road heavy-duty vehicle

A participant wants to replace a heavy heavy-duty (HHD) ladder fire apparatus equipped with a 2000 model year engine with a new apparatus equipped with a model year 2017 engine. The replacement engine is certified to a particulate matter emission standard of 0.01 g/bhp-hr and a NOx emission standard of 0.20 g/bhp-hr. The applicant operates 100 percent of the time in California and the emergency equipment is not subject to any in-use regulations. There are NOx, ROG, and PM surplus emission reductions eligible for funding. The expected first year of operation is 2017.

Baseline Technology Information

- Baseline technology (application): EMY 2000 EMY HHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-2):

	NOx	ROG	PM
EF	17.61 g/mi	0.60 g/mi	0.415 g/mi
DR	0.049 g/mi-10,000 mi	0.031 g/mi-10,000 mi	0.0073 g/mi-10,000 mi

- Activity (application): 10,000 mi/yr
- Discount rate is 1% and project life is 14 years; CRF (Table D-24): 0.077
- Percentage operation in California (application): 100%

Reduced Technology Information

- Reduced technology (application): EMY 2017 HHD diesel truck
- Emission factors (EF) and deterioration rates (DR) (Table D-2):

	NOx	ROG	PM
EF	1.76 g/mi	0.13 g/mi	0.004 g/mi
DR	0.039 g/mi-10,000 mi	0.001 g/mi-10,000 mi	0.0001 g/mi-10,000 mi

- Cost of reduced technology: \$400,000
- Maximum eligible amount for an emergency vehicle replacement (Table 4-3): 80%
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions
- Expected first year of operation: 2017

(a) Determine deterioration calculations for a 2005 to 2017 0.20NOx:

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = (\text{emission factor (g/mi)} + \text{deterioration product (g/mi)}) * \text{annual activity (mi/yr)} * \text{percentage operation in California} / 907,200 \text{ (g/ton)}$$

(1) Calculate deterioration life (baseline equipment)(yrs):

$$\text{Deterioration life (baseline equipment) (yrs)} = \text{expected first year of operation} - + (\text{project life} / 2)$$

$$\text{Deterioration life (baseline equipment)} = 2017 - 2000 + (14 / 2) = \underline{24 \text{ yrs}}$$

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

$$\text{Deterioration life (reduced equipment)} = 14 / 2 = \underline{7 \text{ yrs}}$$

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable (mi):

*Total equipment activity (mi) = annual activity (mi/yr) * deterioration life (yrs)*

$$\text{Total baseline equipment activity} = 10,000 \text{ (mi/yr)} * 24 \text{ (yrs)} = \underline{240,000 \text{ mi}}$$

$$\text{Total reduced equipment activity} = 10,000 \text{ (mi/yr)} * 7 \text{ (yrs)} = \underline{70,000 \text{ mi}}$$

(4) Calculate mile-based deterioration product for baseline and reduced equipment, for each pollutant (g/mi):

*Mile-based deterioration product (g/mi) = deterioration rate (g/mi-10,000 mi) * total equipment activity (mi)*

Baseline equipment:

$$\text{NOx deterioration product} = 0.0490 \text{ (g/mi-10,000 mi)} * 240,000 \text{ (mi)} = \underline{1.1760 \text{ g/mi}}$$

$$\text{ROG deterioration product} = 0.0310 \text{ (g/mi-10,000 mi)} * 240,000 \text{ (mi)} = \underline{0.7440 \text{ g/mi}}$$

$$\text{PM deterioration product} = 0.0073 \text{ (g/mi-10,000 mi)} * 240,000 \text{ (mi)} = \underline{0.1752 \text{ g/mi}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.0390 \text{ (g/mi-10,000 mi)} * 70,000 \text{ (mi)} = \underline{0.2730 \text{ g/mi}}$$

$$\text{ROG deterioration product} = 0.0010 \text{ (g/mi-10,000 mi)} * 70,000 \text{ (mi)} = \underline{0.0070 \text{ g/mi}}$$

$$\text{PM deterioration product} = 0.0001 \text{ (g/mi-10,000 mi)} * 70,000 \text{ (mi)} = \underline{0.0007 \text{ g/mi}}$$

(b) Determine emission reductions calculations for a 2005 to 2017 0.20NOx:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-5: Estimated annual emissions based on mileage (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/mi) + deterioration product (g/mi)) * annual activity (mi/yr) * percentage operation in California / 907,200 (g/ton)*

Annual NOx **baseline** technology emissions (tons/yr)
(17.61 (g/mi) + 1.1760 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.2071 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)
(1.76 (g/mi) + 0.273 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0224 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)
(0.60 (g/mi) + 0.744 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0148 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)
(0.13 (g/mi) + 0.007 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0015 tons/yr

Annual PM **baseline** technology emissions (tons/yr)
(0.415 (g/mi) + 0.1752 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0065 tons/yr

Annual PM **reduced** technology emissions (tons/yr)
(0.004 (g/mi) + 0.0007 (g/mi)) * 10,000 (mi/yr) * 100% / 907,200 (g/ton)
= 0.0001 tons/yr

(2) Calculate annual surplus emission reductions for each pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
= 0.2071 (tons/yr) - 0.0224 (tons/yr) = 0.1847 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= 0.0148 (tons/yr) - 0.0015 (tons/yr) = 0.0133 tons/yr

Annual PM surplus emission reductions (tons/yr)
= 0.0065 (tons/yr) - 0.0001 (tons/yr) = 0.0064 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.1847 (tons/yr NOx) + 0.0133 (tons/yr ROG) + (20 * 0.0064 (tons/yr PM))
= **0.3260 weighted tons/yr**

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 30,000 (\$/ton) * 0.3260 (tons/yr) / 0.077 = **\$127,013**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$400,000 * 80% = **\$320,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$127,013** in grant funds.

II. Off-Road Equipment

Example 1 – Repower: Uncontrolled scraper engine with a Tier 4 Final engine

A construction company meeting the definition of a large fleet in the Off-Road Regulation wants to repower a scraper with a Tier 4 Final engine. The baseline technology is a model year 1988, 300 hp uncontrolled engine that operates for 1,500 hours per year. The applicant is proposing to install a model year 2017, 300 hp Tier 4 Final engine that costs \$700,000. This equipment operates 100 percent of the time in California. This project will be installed and in operation prior to January 1, 2018; thus the applicant is potentially eligible for funding of up to 41.2 percent of the fleet's horsepower. The project is eligible for a project life of three years. In the future, this fleet will only be eligible for zero-emission projects.

Baseline Technology Information

- Engine (application): MY 1988 (Uncontrolled)
- Engine horsepower (application): 300 hp
- Activity (application): 1,500 hrs/yr
- Percentage of operation in California (application): 100%
- Load factor (Table D-7): 0.48
- MY 1988 emission factors (EF) and deterioration rates (DR) (Table D-8)

	NOx	ROG	PM
EF	7.6 (g/bhp-hr)	0.62 (g/bhp-hr)	0.274 (g/bhp-hr)
DR	0.00018 (g/bhp-hr-hr)	0.000029 (g/bhp-hr-hr)	0.0000199 (g/bhp-hr-hr)

- Discount rate is 1% and project life is 3 years; CRF (Table D-24): 0.34

Reduced Technology Information

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- Engine horsepower (application): 300 hp
- Cost of new engine (application): \$700,000
- Maximum eligible percentage (Table 5-4): 85 percent
- Load factor (Table D-7): 0.48
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000036 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000003 (g/bhp-hr-hr)

- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for an uncontrolled to a Tier 4 Final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = [\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/bhp-hr)}] * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g}$$

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation - + project life / 2

$$\text{Deterioration life (baseline equipment)} = 2017 - 1988 + (3 / 2) = \underline{30.5 \text{ years}}$$

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

$$\text{Deterioration life (reduced equipment)} = 3 / 2 = \underline{1.5 \text{ years}}$$

(3) Calculate total equipment activity (hrs) and cap the baseline equipment activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

$$\text{Total baseline equipment activity} = 1,500 \text{ (hrs/yr)} * 30.5 \text{ (yrs)} = \underline{45,750 \text{ hours}}$$

$$\text{Total reduced equipment activity} = 1,500 \text{ (hrs/yr)} * 1.5 \text{ (yrs)} = \underline{2,250 \text{ hours}}$$

(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 baseline and reduced equipment, for each pollutant (g/bhp-hr):

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

$$\text{NOx deterioration product} = 0.0001800 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{2.1600 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.0000290 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.3480 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000199 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.2388 \text{ g/bhp-hr}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.0000036 \text{ (g/bhp-hr-hr)} * 2,250 \text{ hrs} = \underline{0.0081 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.0000110 \text{ (g/bhp-hr-hr)} * 2,250 \text{ hrs} = \underline{0.0248 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000003 \text{ (g/bhp-hr-hr)} * 2,250 \text{ hrs} = \underline{0.0007 \text{ g/bhp-hr}}$$

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

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions (tons/yr)
= $[(7.6 \text{ g/bhp-hr} + 2.1600 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 2.3238 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)
= $[(0.26 \text{ g/bhp-hr} + 0.0081 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0638 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)
= $[(0.62 \text{ g/bhp-hr} + 0.3480 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.2305 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)
= $[(0.05 \text{ g/bhp-hr} + 0.0248 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0178 tons/yr

Annual PM **baseline** technology emissions (tons/yr)
= $[(0.274 \text{ g/bhp-hr} + 0.2388 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.1221 tons/yr

Annual PM **reduced** technology emissions (tons/yr)
= $[(0.009 \text{ g/bhp-hr} + 0.0007 \text{ g/bhp-hr}) * 300 \text{ hp} * 0.48 * 1500 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0023 tons/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emissions reductions (tons/yr)
Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
= 2.3238 tons/yr - 0.0638 tons/yr = 2.2600 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= 0.2305 tons/yr - 0.0178 tons/yr = 0.2127 tons/yr

Annual PM surplus emission reductions (tons/yr)
= 0.1221 tons/yr - 0.0023 tons/yr = 0.1198 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 2.2600 (tons/yr NOx) + 0.2127 (tons/yr ROG) + (20 * 0.1198 (tons/yr PM))
= **4.8687 weighted tons/yr**

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000/ton * 4.8687 tons/yr) / 0.34 = **\$429,591**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount = \$700,000 * 85% = **\$595,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$429,591** in grant funds.

Example 2 – Retrofit: Tier 2 rubber tired loader engine with a Level 3 diesel particulate filter

A local municipality proposes to install a Level 3 diesel particulate filter (DPF) on a rubber-tired loader with a model year 2004, Tier 2, 160 hp engine. The cost of the retrofit is \$20,000; the DPF is verified for 85 percent reductions of PM. The rubber-tired loader operates 850 hours per year, 100 percent of the time in California with a total fleet horsepower of 2,100 hp. The local municipality meets the definition of a small fleet under the Off-Road Regulation. This project will be installed and in operation prior to January 1, 2018. The municipality requested a project life of five years for this project. No more than 60 percent of the municipality’s total fleet horsepower is eligible for funding with a project life of five years. Since the horsepower of the loader is less than 60 percent of the total fleet’s horsepower, the loader is eligible for the requested five-year project life.

Baseline Technology Information

- Engine (application): MY 2004 (Tier 2)
- Engine horsepower (application): 160 hp
- Activity (application): 850 hrs/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.36
- MY 2004 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	N/A	N/A	0.128 (g/bhp-hr)
DR	N/A	N/A	0.0000094 (g/bhp-hr-hr)

- Discount rate is 1% and project life is 5 years; CRF (Table D-24): 0.206

Reduced Technology Information

- Level 3 verified reductions: 85% PM
- Cost of filter (application): \$20,000
- Maximum eligible percentage (Table 5-4): 100%
- Emission factors (Table D-9): 0.128 g/bhp-hr PM
- Deterioration rates (Table D-9): 0.0000094 g/bhp-hr-hr PM
- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for a Tier 2 engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = [\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/bhp-hr)}] * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g}$$

(1) Calculate deterioration life (baseline equipment)(yrs):

$$\text{Deterioration life (baseline equipment) (yrs)} = \text{expected first year of operation} - \text{baseline engine model year} + \text{project life} / 2$$

$$\text{Deterioration life (baseline equipment)} = 2017 - 2004 + (5 / 2) = \underline{15.5 \text{ years}}$$

(2) Calculate total equipment activity (hrs) and cap the baseline equipment activity when applicable:

$$\text{Total equipment activity (hrs)} = \text{activity (hrs/yr)} * \text{deterioration life (yrs)}$$

$$\text{Total baseline equipment activity} = 850 \text{ (hrs/yr)} * 15.5 \text{ (yrs)} = \underline{13,175 \text{ hours}}$$

(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

(3) Calculate hour-based deterioration rate for baseline and reduced equipment, for each pollutant (g/bhp-hr):

$$\text{Hour-based deterioration product (g/bhp-hr)} = \text{deterioration rate (g/bhp-hr-hr)} * \text{total equipment activity (hrs)}$$

Baseline equipment:

$$\text{PM deterioration product} = 0.0000094 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.1128 \text{ g/bhp-hr}}$$

(b) Determine emission reductions calculations for a retrofit of a Tier 2 engine with a Level 3 DPF:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = [\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/bhp-hr)}] * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g}$$

Annual PM **baseline** technology emissions (tons/yr)

$$= [(0.128 \text{ g/bhp-hr} + 0.1128 \text{ g/bhp-hr}) * 160 \text{ hp} * 0.36 * 850 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$$
$$= \underline{0.0130 \text{ tons/yr PM}}$$

(2) Calculate annual surplus emission reductions by pollutant (tons/yr) for retrofits:

Formula C-9: Annual surplus emissions reductions (tons/yr)

$$\text{Annual surplus emission reductions by pollutant (tons/yr)} = \text{annual emissions for the baseline technology (tons/yr)} * \text{reduced technology verification percentage (\%)}$$

Annual PM surplus emission reductions (tons/yr)

$$= 0.0130 \text{ tons/yr} * 0.85 = \underline{0.0111 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Annual weighted surplus emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 20 * 0.0111 (tons/yr PM)
= **0.2220 weighted tons/yr**

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000/ton * 0.2220 tons/yr) / 0.206 = **\$32,330**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount = \$20,000 * 100% = **\$20,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$20,000** in grant funds.

Example 3 – Replacement: Uncontrolled agricultural tractor with Tier 4 Final tractor

A farmer proposes to replace an uncontrolled model year 1985, 170 hp agricultural tractor with a new model year 2018, 340 hp, Tier 4 Final agricultural tractor. The new 340 hp equipment will cost \$175,000 and will be in operation in April 2018. This 340 hp tractor is greater than 125 percent of the baseline 170 hp. Although a similar Tier 4 final tractor at 170 hp is available for \$125,000, the applicant wishes to purchase the 340 hp version and pay the difference. Per guideline criteria, the emission reduction calculations and grant amount are based on the 340 hp tractor and the cost of purchasing the 170 hp tractor. This equipment operates 1,000 hours annually, 100 percent of the time in California. The project is eligible for up to 80 percent of the new equipment cost. This equipment is eligible for a project life of ten years.

Baseline Technology Information

- Engine (application): MY 1985 (Uncontrolled)
- Engine horsepower (application): 170 hp
- Activity (application): 1,000 hrs/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.70
- MY 1985 emission factors (EF) and deterioration rates (DR) (Table D-8)

	NOx	ROG	PM
EF	10.23 (g/bhp-hr)	0.8 (g/bhp-hr)	0.396 (g/bhp-hr)
DR	0.00024 (g/bhp-hr-hr)	0.000037 (g/bhp-hr-hr)	0.0000288 (g/bhp-hr-hr)

- Discount rate is 1% and project life is 10 years; CRF (Table D-24): 0.106

Reduced Technology Information

- Engine (ARB executive order): MY 2018 (Tier 4 Final)
- Engine horsepower (application): 340 hp
- Activity (application): 1000 hrs/yr
- Cost of new 170 hp equipment (application): \$125,000
- Maximum eligible percentage (Table 5-4): 80percent
- MY 2018 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000036 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000003 (g/bhp-hr-hr)

- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for an uncontrolled to Tier 4 Final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation - baseline engine model year + project life / 2

Deterioration life (baseline equipment) = 2018 – 1985 + (10 / 2) = 38 years

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 10 / 2 = 5 years

(3) Calculate total equipment activity (hrs) and cap the baseline equipment activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Total baseline equipment activity = 1000 (hrs/yr) * 38 (yrs) = 38,000 hours

Total reduced equipment activity = 1000 (hrs/yr) * 5 (yrs) = 5,000 hours

(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 baseline and reduced equipment, for each pollutant (g/bhp-hr):

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

NOx deterioration product = 0.00024 (g/bhp-hr-hr) * 12,000 hrs = 2.8800 g/bhp-hr

ROG deterioration product = 0.000037 (g/bhp-hr-hr) * 12,000 hrs = 0.4440 g/bhp-hr

PM deterioration product = 0.0000288 (g/bhp-hr-hr) * 12,000 hrs = 0.3456 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0.0000036 (g/bhp-hr-hr) * 5,000 hrs = 0.0180 g/bhp-hr

ROG deterioration product 0.000011 (g/bhp-hr-hr) * 5,000 hrs = 0.0550 g/bhp-hr

PM deterioration product = 0.0000003 (g/bhp-hr-hr) * 5,000 hrs = 0.0015 g/bhp-hr

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

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions (tons/yr)
= $[(10.23 \text{ g/bhp-hr} + 2.8800 \text{ g/bhp-hr}) * 170 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%]$ * ton/907,200g
= 1.7197 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)
= $[(0.26 \text{ g/bhp-hr} + 0.0180 \text{ g/bhp-hr}) * 340 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0729 tons/yr

$$\begin{aligned} & \text{Annual ROG } \textit{baseline} \text{ technology emissions (tons/yr)} \\ & = [(0.8 \text{ g/bhp-hr} + 0.4440 \text{ g/bhp-hr}) * 170 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g)} \\ & = \underline{0.1632 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} & \text{Annual ROG } \textit{reduced} \text{ technology emissions (tons/yr)} \\ & = [(0.05 \text{ g/bhp-hr} + 0.0550 \text{ g/bhp-hr}) * 340 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g)} \\ & = \underline{0.0275 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} & \text{Annual PM } \textit{baseline} \text{ technology emissions (tons/yr)} \\ & = [(0.396 \text{ g/bhp-hr} + 0.3456 \text{ g/bhp-hr}) * 170 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%] * \\ & \text{ton}/907,200\text{g)} \\ & = \underline{0.0973 \text{ tons/yr}} \end{aligned}$$

$$\begin{aligned} & \text{Annual PM } \textit{reduced} \text{ technology emissions (tons/yr)} \\ & = [(0.009 \text{ g/bhp-hr} + 0.0015 \text{ g/bhp-hr}) * 340 \text{ hp} * 0.70 * 1000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g)} \\ & = \underline{0.0028 \text{ tons/yr}} \end{aligned}$$

(2) Calculate the annual surplus emission reductions by pollutant (tons/yr):

Formula C-9: Annual surplus emissions reductions (tons/yr)

*Annual surplus emission reductions by pollutant (tons/yr) =
annual emissions for the baseline technology (tons/yr) – annual emissions for the
reduced technology (tons/yr)*

Annual NOx surplus emission reductions (tons/yr)

$$1.7197 \text{ tons/yr} - 0.0729 \text{ tons/yr} = \underline{1.6468 \text{ tons/yr}}$$

Annual ROG surplus emission reductions (tons/yr)

$$0.1632 \text{ tons/yr} - 0.0275 \text{ tons/yr} = \underline{0.1357 \text{ tons/yr}}$$

Annual PM surplus emission reductions (tons/yr)

$$0.0973 \text{ tons/yr} - 0.0028 \text{ tons/yr} = \underline{0.0945 \text{ tons/yr}}$$

(3) Calculate the annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Annual weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) +
ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 1.6468 \text{ (tons/yr NOx)} + 0.1357 \text{ (tons/yr ROG)} + (20 * 0.0945 \text{ (tons/yr)})$$

$$= \underline{3.6725 \text{ weighted tons/yr}}$$

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$30,000/\text{ton} * 3.6725 \text{ tons/yr}) / 0.106 = \underline{\$1,039,387}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

$$\text{Potential grant amount} = \$125,000 * 80\% = \underline{\$100,000}$$

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$100,000** in grant funds.

Example 4 – Replacement: Tier 2 rubber tired loaders with one Tier 4 Final rubber tired loader

A construction company with a total fleet horsepower of 3506, thereby meeting the definition of a medium fleet in the Off-Road Regulation, wants to replace two rubber tired loaders with one Tier 4 Final rubber tired loader. The baseline technologies are: 1) a model year 2005, 240 hp Tier 2 engine that operates for 750 hours per year and 2) a model year 2004, 180 hp Tier 2 engine that operates for 350 hours per year. The horsepower rating for the replacement equipment must not be greater than 125 percent of the lowest hp of the baseline engine (i.e., 180hp).

The applicant is proposing to purchase a model year 2017, 210 hp Tier 4 Final rubber tired loader. The new equipment costs \$280,000. This equipment operates 100 percent of the time in California. The applicant is eligible for up to 80 percent of the new equipment cost. This project will be in operation prior to January 1, 2018, thus the applicant is potentially eligible for funding up to 62 percent of the fleet’s horsepower with a three-year project life. Since the horsepower of the loader is less than 62 percent of the total fleet horsepower, the loader is eligible for up to the requested three-year project life.

Baseline Technology Information, Equipment 1

- Engines (application): MY 2005 (Tier 2)
- Engine horsepower (application): 240 hp
- Activity (application): 750 hrs/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.36
- MY 2005 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	4.15 (g/bhp-hr)	0.11 (g/bhp-hr)	0.088 (g/bhp-hr)
DR	0.000060 (g/bhp-hr-hr)	0.000022 (g/bhp-hr-hr)	0.0000046 (g/bhp-hr-hr)

- Discount rate is 1% and project life is 3 years; CRF (Table D-24): 0.34

Baseline Technology Information, Equipment 2

- Engine (application): MY 2004 (Tier 2)
- Engine horsepower (application): 180 hp
- Activity (application): 350 hrs/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.36
- MY 2004 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	4.15 (g/bhp-hr)	0.11 (g/bhp-hr)	0.088 (g/bhp-hr)
DR	0.000060 (g/bhp-hr-hr)	0.000022 (g/bhp-hr-hr)	0.0000046 (g/bhp-hr-hr)

Reduced Technology Information

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- Engine Horsepower (application): 210 hp
- Activity (application): 1,100 hrs/yr
- Cost of new equipment (application): \$280,000
- Maximum eligible percentage (Table 5-4): 80%
- Load factor (Table D-7): 0.36
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000036 (g/bhp-hr-hr)	0.000011(g/bhp-hr-hr)	0.0000003 (g/bhp-hr-hr)

- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for two Tier 2 engines to one Tier 4 Final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation - baseline engine model year + project life/2

Deterioration life (baseline equipment 1) = 2017 – 2005 + (3 / 2) = 13.5 years

Deterioration life (baseline equipment 2) = 2017 – 2004 + (3 / 2) = 14.5 years

(2) Deterioration Life (Reduced Equipment)(yrs):

Deterioration life (reduced equipment) (yrs) = project life/2

Deterioration life (reduced equipment) = 3 / 2 = 1.5 years

(3) Calculate total equipment activity (hrs) and cap the baseline equipment activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Baseline equipment:

Total equipment activity (equipment 1) = 750 (hrs/yr) * 13.5 (yrs) = 10,125 hours

Total equipment activity (equipment 2) = 350 (hrs/yr) * 14.5 (yrs) = 5,075 hours

Total equipment activity (reduced) = 1100 (hrs/yr) * 1.5 (yrs) = 1,650 hours

(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 baseline and reduced equipment, for each pollutant (g/bhp-hr):

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment 1:

NOx deterioration product = 0.000060 (g/bhp-hr-hr) * 10,125 hrs = 0.6075 g/bhp-hr

ROG deterioration product = 0.000022 (g/bhp-hr-hr) * 10,125 hrs = 0.2228 g/bhp-hr

PM deterioration product = 0.0000046 (g/bhp-hr-hr) * 10,125 hrs = 0.0466 g/bhp-hr

Baseline equipment 2:

NOx deterioration product = 0.000060 (g/bhp-hr-hr) * 5,075 hrs = 0.3045 g/bhp-hr

ROG deterioration product = 0.000022 (g/bhp-hr-hr) * 5,075 hrs = 0.1117 g/bhp-hr

PM deterioration product = 0.0000046 (g/bhp-hr-hr) * 5,075 hrs = 0.0233 g/bhp-hr

Reduced Equipment:

NOx deterioration product = 0.0000036 (g/bhp-hr-hr) * 1,650 hrs = 0.0059 g/bhp-hr

ROG deterioration product = 0.000011 (g/bhp-hr-hr) * 1,650 hrs = 0.0182 g/bhp-hr

PM deterioration product = 0.0000003 (g/bhp-hr-hr) * 1,650 hrs = 0.0005 g/bhp-hr

(b) Determine emission reductions calculations for two Tier 2 engines to one Tier 4 Final engine:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

Baseline equipment 1:

Annual NOx **baseline** technology emissions (tons/yr)

= [(4.15 g/bhp-hr + 0.6075 g/bhp-hr) * 240 hp * 0.36 * 750 hrs * 100%] * ton/907,200g)

= 0.3398 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)

= [(0.11 g/bhp-hr + 0.2228 g/bhp-hr) * 240 hp * 0.36 * 750 hrs * 100%] * ton/907,200g)

= 0.0238 tons/yr

Annual PM **baseline** technology emissions (tons/yr)

= [(0.088 g/bhp-hr + 0.0466 g/bhp-hr) * 240 hp * 0.36 * 750 hrs * 100%] * ton/907,200g)

= 0.0096 tons/yr

Baseline equipment 2:

Annual NOx **baseline** technology emissions (tons/yr)
= $[(4.15 \text{ g/bhp-hr} + 0.3045 \text{ g/bhp-hr}) * 180 \text{ hp} * 0.36 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.1114 tons/yr NOx

Annual ROG **baseline** technology emissions (tons/yr)
= $[(0.11 \text{ g/bhp-hr} + 0.1117 \text{ g/bhp-hr}) * 180 \text{ hp} * 0.36 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0055 tons/yr ROG

Annual PM **baseline** technology emissions (tons/yr)
= $[(0.088 \text{ g/bhp-hr} + 0.0233 \text{ g/bhp-hr}) * 180 \text{ hp} * 0.36 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0028 tons/yr PM

Annual NOx **reduced** technology emissions (tons/yr)
= $[(0.26 \text{ g/bhp-hr} + 0.0059 \text{ g/bhp-hr}) * 210 \text{ hp} * 0.36 * 1100 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0244 tons/yr NOx

Annual ROG **reduced** technology emissions (tons/yr)
= $[(0.05 \text{ g/bhp-hr} + 0.0182 \text{ g/bhp-hr}) * 210 \text{ hp} * 0.36 * 1100 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0063 tons/yr ROG

Annual PM **reduced** technology emissions (tons/yr)
= $[(0.009 \text{ g/bhp-hr} + 0.0005 \text{ g/bhp-hr}) * 210 \text{ hp} * 0.36 * 1100 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0009 tons/yr PM

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emissions reductions (tons/yr)

*Annual surplus emission reductions by pollutant (tons/yr) =
annual emissions for the baseline technology (tons/yr) – annual emissions for the
reduced technology (tons/yr)*

Annual NOx surplus emission reductions (tons/yr)
= $(0.3398 \text{ tons/yr} + 0.1114 \text{ tons/yr}) - 0.0244 \text{ tons/yr} = \underline{0.4268 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
= $(0.0238 \text{ tons/yr} + 0.0055 \text{ tons/yr}) - 0.0063 \text{ tons/yr} = \underline{0.0230 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
= $(0.0096 \text{ tons/yr} + 0.0028 \text{ tons/yr}) - 0.0009 \text{ tons/yr} = \underline{0.0115 \text{ tons/yr}}$

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Annual weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) +
ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= $0.4268 \text{ (tons/yr NOx)} + 0.0230 \text{ (tons/yr ROG)} + (20 * 0.0115 \text{ (tons/yr PM)})$
= 0.6798 tons/yr

(c) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$30,000/\text{ton} * 0.6798 \text{ tons/yr})/0.34 = \underline{\$59,982}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

$$\text{Potential grant amount} = \$280,000 * 80 \text{ percent} = \underline{\$224,000}$$

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$59,982** in grant funds.

Example 5 – Replacement: Tier 3 narrow-body aircraft tug with Tier 4 Final narrow-body aircraft tug

An airport ground handling company would like to replace a model year 2006, Tier 3 aircraft tug with a model year 2017, Tier 4 Final aircraft tug. The company has a total fleet horsepower of 6,551 and meets the definition of a large fleet in the Off-Road Regulation. The baseline equipment has a model year 2006, 310 horsepower Tier 3 engine that operates 350 hours per year. The applicant is proposing to replace it with a 350 horsepower narrow-body aircraft tug with a Tier 4 Final engine that costs \$250,000. The equipment operates 100 percent of the time in California. The equipment will be in operation before January 1, 2018; thus the project is eligible for a maximum project life of five years. No more than 21.2 percent of the ground handling company’s total fleet horsepower is eligible for funding. Since the replacement aircraft tug engine is less than 21.2 percent of the total fleet’s horsepower, the tug is eligible for up to the requested five-year project life. In the future, this fleet will only be eligible for zero-emission projects.

Baseline Technology Information

- Engine (application): MY 2006 (Tier 3)
- Engine horsepower (application): 310 hp
- Activity (application): 350 hrs/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.54
- MY 2006 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.32 (g/bhp-hr)	0.09 (g/bhp-hr)	0.088 (g/bhp-hr)
DR	0.000030 (g/bhp-hr-hr)	0.000023 (g/bhp-hr-hr)	0.0000044 (g/bhp-hr-hr)

- Discount rate is 1 % and project life is 5 years; CRF (Table D-24): 0.206

Reduced Technology Information

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- Engine horsepower (application): 350 hp
- Activity (application): 350 hrs/yr
- Cost of new equipment (application): \$250,000
- Maximum eligible percentage: 100%
- Load factor (Table D-7): 0.54
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000036 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000003 (g/bhp-hr-hr)

- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for a Tier 3 to Tier 4 Final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = [\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/bhp-hr)}] * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g}$$

(1) Calculate deterioration life (baseline equipment):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + project life/2

$$\text{Deterioration life (baseline equipment)} = 2017 - 2006 + (5 / 2) = \underline{13.5 \text{ years}}$$

(2) Calculate deterioration life (reduced equipment):

Deterioration life (reduced equipment) (yrs) = project life/2

$$\text{Deterioration life (reduced equipment)} = 5 / 2 = \underline{2.5 \text{ years}}$$

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable:

*Total equipment activity (hours) = activity (hrs/yr) * deterioration life (yrs)*

$$\text{Total equipment activity (baseline)} = 350 \text{ (hrs/yr)} * 13.5 \text{ (yrs)} = \underline{4,725 \text{ hours}}$$

$$\text{Total equipment activity (reduced)} = 350 \text{ (hrs/yr)} * 2.5 \text{ (yrs)} = \underline{875 \text{ hours}}$$

(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 deterioration rate for baseline and reduced equipment, for each pollutant:

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

$$\text{NOx deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 4,725 \text{ hrs} = \underline{0.1418 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000023 \text{ (g/bhp-hr-hr)} * 4,725 \text{ hrs} = \underline{0.1087 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000044 \text{ (g/bhp-hr-hr)} * 4,725 \text{ hrs} = \underline{0.0208 \text{ g/bhp-hr}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.0000036 \text{ (g/bhp-hr-hr)} * 875 \text{ hrs} = \underline{0.0032 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000011 \text{ (g/bhp-hr-hr)} * 875 \text{ hrs} = \underline{0.0096 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000003 \text{ (g/bhp-hr-hr)} * 875 \text{ hrs} = \underline{0.0003 \text{ g/bhp-hr}}$$

(b) Determine emission reductions calculations for a Tier 3 to Tier 4 Final Engine:

(1) Calculate the estimated annual emissions for baseline and reduced for each equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)) * horsepower (hp) * load factor * activity (hrs/yr) * percent operation in CA * ton / 907,200 g*

Annual NOx **baseline** technology emissions
= $[(2.32 \text{ g/bhp-hr} + 0.1418 \text{ g/bhp-hr}) * 310 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.1590 tons/yr

Annual NOx **reduced** technology emissions
= $[(0.26 \text{ g/bhp-hr} + 0.0032 \text{ g/bhp-hr}) * 350 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0192 tons/yr

Annual ROG **baseline** technology emissions
= $[(0.09 \text{ g/bhp-hr} + 0.1087 \text{ g/bhp-hr}) * 310 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0128 tons/yr

Annual ROG **reduced** technology emissions
= $[(0.05 \text{ g/bhp-hr} + 0.0096 \text{ g/bhp-hr}) * 350 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0043 tons/yr

Annual PM **baseline** technology emissions
= $[(0.088 \text{ g/bhp-hr} + 0.0208 \text{ g/bhp-hr}) * 310 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0070 tons/yr

Annual PM **reduced** technology emissions
= $[(0.009 \text{ g/bhp-hr} + 0.0003 \text{ g/bhp-hr}) * 350 \text{ hp} * 0.54 * 350 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0007 tons/yr

(2) Calculate the annual surplus emission reductions by pollutant(tons/yr)

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions (tons/yr)
= $0.1590 \text{ tons/yr} - 0.0192 \text{ tons/yr} = \underline{0.1398 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
= $0.0128 \text{ tons/yr} - 0.0043 \text{ tons/yr} = \underline{0.0085 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
= $0.0070 \text{ tons/yr} - 0.0007 \text{ tons/yr} = \underline{0.0063 \text{ tons/yr}}$

(3) Calculate annual weighted surplus emission reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
Annual weighted emission reductions (weighted tons/yr) =
*NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr):
= 0.1398 (tons/yr NOx) + 0.0085 (tons/yr ROG) + (20 * 0.0063 (tons/yr PM))
= **0.2743 weighted tons/yr**

(c) Determine the potential maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission*
reductions (weighted tons/yr) / CRF

Potential grant amount = (\$30,000/ton * 0.2743 tons/yr) / 0.206 = **\$39,947**

(2) Potential grant amount based on maximum percentage of eligible cost (\$)

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
Potential grant amount based on maximum percentage of eligible cost (\$)
*= cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount = \$250,000 * 80% = **\$200,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$39,947** in grant funds.

Example 6 – Replacement: MY 2003 LSI with a new electric forklift ***

An applicant proposes to replace a MY 2003, 91 hp LPG forklift with a new MY 2018 electric forklift. The new equipment will be in operation in 2018 and cost \$70,600. The existing equipment operates 750 hours per year, 100 percent of the time in California. This equipment belongs to a small fleet and is exempt from the LSI fleet regulation, and thus is eligible for a maximum total project life of 10 years. In addition, the project includes a three-year project life to account for the remaining life of the existing LSI equipment. When calculating emission benefits for off-road equipment replacement projects with zero-emission equipment, SB 467 requires two-step calculations for the emission reductions. A Moyer-funded infrastructure project may be associated with this project. Please see Section VI (page 112), Example 2 for infrastructure project calculations.

This project is eligible for a two-step cost-effectiveness (CE) calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 CE limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step CE calculation example consists of:

- Step 1 – MY 2003 to MY 2018 LPG forklift
- Step 2 – MY 2018 LPG to MY 2018 electric forklift

Baseline Technology Information – Step 1

- Baseline engine (application): MY 2003 LPG uncontrolled
- MY 2003 emission factors (EF) and deterioration rates (DR) (Table D-11b)

	NOx	ROG	PM
EF	10.53 (g/bhp-hr)	1.55 (g/bhp-hr)	0.060 (g/bhp-hr)
DR	0.0000533 (g/bhp-hr-hr)	0.000169 (g/bhp-hr-hr)	0.000 (g/bhp-hr-hr)

- Activity (application): 750 hrs/yr
- Engine horsepower (application): 91 hp
- Load factor (Table D-10): 0.30
- Percentage of operation in California (application): 100%

Reduced Technology Information – Step 1

- Reduced engine (ARB executive order): MY 2018 LPG
- MY 2018 emission factors (EF) and deterioration rates (DR) (Table D-11b)

	NOx	ROG	PM
EF	0.31 (g/bhp-hr)	0.03 (g/bhp-hr)	0.060 (g/bhp-hr)
DR	0.0000380 (g/bhp-hr-hr)	0.000014 (g/bhp-hr-hr)	0.000 (g/bhp-hr-hr)

- Activity (application): 750 hrs/yr
- Engine horsepower (application): 91 hp
- Load factor (Table D-10): 0.30
- Percentage of operation in California (application): 100%
- Discount rate is 1% and project life is 3 years; CRF (Table D-24): 0.34
- Cost-effectiveness limit: \$30,000/weighted ton

Baseline Technology Information – Step 2

- Baseline engine (application): MY 2018 LPG
- MY 2018 emission factors (EF) and deterioration rates (DR) (Table D-11b)

	NOx	ROG	PM
EF	0.31 (g/bhp-hr)	0.03 (g/bhp-hr)	0.060 (g/bhp-hr)
DR	0.0000380 (g/bhp-hr-hr)	0.000014 (g/bhp-hr-hr)	0.000 (g/bhp-hr-hr)

- Activity (application): 750 hrs/yr
- Engine horsepower (application): 91 hp
- Load factor (Table D-10): 0.30

Reduced Technology Information – Step 2

- Reduced engine (application): Electric
- MY 2018 emission factors (EF) and deterioration rates (DR)

	NOx	ROG	PM
EF	0 (g/bhp-hr)	0 (g/bhp-hr)	0 (g/bhp-hr)
DR	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)

- Activity (application): 750 hrs/yr
- Engine horsepower (application): 70 hp
- Load factor (Table D-10): 0.30
- Cost of new equipment (application): \$70,600
- Maximum eligible percentage (Table 5-4): 80%
- Discount rate is 1% and project life is 10 years; CRF (Table D-24): 0.106
- Cost-effectiveness limit: \$100,000/weighted ton

..... Step 1 – MY 2003 to MY 2018 LPG forklift

(a) Determine deterioration calculations for a 2003 to 2018 LPG forklift:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment)(yrs) = expected first year of operation – + project life / 2

Deterioration life (baseline equipment) = 2018 – 2003 + 3 / 2 = 16.5 years

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment)(yrs) = project life / 2

Deterioration life (reduced equipment) = 3 / 2 = 1.5 years

(3) Calculate total equipment activity, and cap the activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Total baseline equipment activity = 750 (hrs/yr) * 16.5 (yrs) = 12,375 hours

Total reduced equipment activity = 750 (hrs/yr) * 1.5 (yrs) = 1,125 hours

(Appendix C, page C-7, Footnote (c))

Total equipment activity used for deterioration rate is capped at 3,500 hours for MY 2006 and older LSI engines

(4) Calculate deterioration product for baseline and reduced equipment, for each pollutant:

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

NOx deterioration product = 0.0000533 (g/bhp-hr-hr) * 3,500 (hrs) = 0.1866 g/bhp-hr

ROG deterioration product = 0.000169 (g/bhp-hr-hr) * 3,500 (hrs) = 0.5915 g/bhp-hr

PM deterioration product = 0.000 (g/bhp-hr-hr) * 3,500 (hrs) = 0.0000 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0.0000380 (g/bhp-hr-hr) * 1,125 (hrs) = 0.0428 g/bhp-hr

ROG deterioration product = 0.000014 (g/bhp-hr-hr) * 1,125 (hrs) = 0.0158 g/bhp-hr

PM deterioration product = 0.000 (g/bhp-hr-hr) * 1,125 (hrs) = 0.0000 g/bhp-hr

(b) Determine emission reductions calculations for a MY 2003 to MY 2018 LPG forklift:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)) * horsepower (hp) * load factor * activity (hrs/yr) * percent operation in CA * ton / 907,200 g*

Annual NOx **baseline** technology emissions

$$([(10.53 \text{ g/bhp-hr} + 0.1866 \text{ g/bhp-hr}) * 91 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%]) * \text{on}/907,200\text{g}$$
$$= \underline{0.2419 \text{ tons/yr NOx}}$$

Annual NOx **reduced** technology emissions

$$([(0.31 \text{ g/bhp-hr} + 0.0428 \text{ g/bhp-hr}) * 91 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%]) * \text{ton}/907,200\text{g}$$
$$= \underline{0.0080 \text{ tons/yr NOx}}$$

Annual ROG **baseline** technology emissions
(((1.55 g/bhp-hr + 0.5915 g/bhp-hr) * 91 hp * 0.30 * 750 hrs * 100%) * ton/907,200g)
= 0.0483 tons/yr ROG

Annual ROG **reduced** technology emissions
(0.03 g/bhp-hr + 0.0158 g/bhp-hr) * 91 hp * 0.30 * 750 hrs * 100%] * ton/907,200g)
= 0.0010 tons/yr ROG

Annual PM **baseline** technology emissions
(0.060 g/bhp-hr + 0.0000 g/bhp-hr) * 91 hp * 0.30 * 750 hrs * 100%] * ton/907,200g)
= 0.0014 tons/yr PM

Annual PM **reduced** technology emissions
(0.060 g/bhp-hr + 0.0000 g/bhp-hr) * 91 hp * 0.30 * 750 hrs * 100%] * ton/907,200g)
= 0.0014 tons/yr PM

(2) Calculate the annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual surplus NOx emission reductions
= 0.2419 tons/yr - 0.0080 tons/yr = 0.2339 tons/yr

Annual surplus ROG emission reductions
= 0.0483 tons/yr - 0.0010 tons/yr = 0.0473 tons/yr

Annual surplus PM emission reductions
= 0.0014 tons/yr - 0.0014 tons/yr = 0.0000 tons/yr

(3) Calculate Annual Weighted Surplus Emission Reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.2339 (tons/yr NOx) + 0.0473 (tons/yr ROG) + (20 * 0.0000 (tons/yr PM))
= 0.2812 weighted tons /yr

(c) Determine the potential maximum grant amount (Step 1):

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: *Potential Grant amount at the cost-effectiveness limit (\$) Grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$30,000/\text{ton} * 0.2812 \text{ tons/yr}) / 0.34 = \underline{\$24,812}$$

Maximum grant amount for step 1: \$ 24,812

..... Step 2 – MY 2018 LPG to MY 2018 electric forklift

(d) Determine deterioration calculations for a MY 2018 LPG to MY 2018 electric forklift:

Formula C-6: *Estimated annual emissions based on hours of operation (tons/yr) 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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment)(yrs) = expected first year of operation – + project life / 2

$$\text{Deterioration life (baseline equipment)} = 2018 - 2018 + (10 / 2) = \underline{5 \text{ years}}$$

(2) Calculate deterioration life (reduced equipment):

Deterioration life (reduced equipment) (yrs) = project life / 2

$$\text{Deterioration life (reduced equipment)} = 10 / 2 = \underline{5 \text{ years}}$$

(3) Calculate total equipment activity, and cap the activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

$$\text{Total baseline equipment activity} = 750 \text{ (hrs/yr)} * 5 \text{ (yrs)} = \underline{3,750}$$

$$\text{Total reduced equipment activity} = 750 \text{ (hrs/yr)} * 5 \text{ (yrs)} = \underline{3,750 \text{ hours}}$$

(4) Calculate deterioration rate for baseline and reduced equipment, for each pollutant:

*Hours-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

NOx deterioration product = 0.0000380 (g/bhp-hr-hr) * 3,750 (hrs) = 0.1425 g/bhp-hr

ROG deterioration product = 0.000014 (g/bhp-hr-hr) * 3,750 (hrs) = 0.0525 g/bhp-hr

PM deterioration product = 0.000 (g/bhp-hr-hr) * 3,750 (hrs) = 0.0000 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0.0000 (g/bhp-hr-hr) * 3,750 (hrs) = 0.0000 g/bhp-hr

ROG deterioration product = 0.0000 (g/bhp-hr-hr) * 3,750 (hrs) = 0.0000 g/bhp-hr

PM deterioration product = 0.0000 (g/bhp-hr-hr) * 3,750 (hrs) = 0.0000 g/bhp-hr

(e) Determine emission reductions calculations for a MY 2018 LPG to MY 2018 electric forklift:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions

$[(0.31 \text{ g/bhp-hr} + 0.1425 \text{ g/bhp-hr}) * 91 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0102 tons/yr NOx

Annual NOx **reduced** technology emissions

$[(0.0000 \text{ g/bhp-hr} + 0.0000 \text{ g/bhp-hr}) * 70 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0000 tons/yr NOx

Annual ROG **baseline** technology emissions

$[(0.03 \text{ g/bhp-hr} + 0.0525 \text{ g/bhp-hr}) * 91 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0019 tons/yr ROG

Annual ROG **reduced** technology emissions

$[(0.0000 \text{ g/bhp-hr} + 0.00 \text{ g/bhp-hr}) * 70 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0000 tons/yr ROG

Annual PM **baseline** technology emissions

$[(0.060 \text{ g/bhp-hr} + 0.0000 \text{ g/bhp-hr}) * 91 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0014 tons/yr PM

Annual PM **reduced** technology emissions

$[(0.000 \text{ g/bhp-hr} + 0.0000 \text{ g/bhp-hr}) * 70 \text{ hp} * 0.30 * 750 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
= 0.0000 tons/yr PM

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual surplus NOx emission reductions

$$= 0.0102 \text{ tons/yr} - 0.0000 \text{ tons/yr} = \underline{0.0102 \text{ tons/yr}}$$

Annual surplus ROG emission reductions

$$= 0.0019 \text{ tons/yr} - 0.0000 \text{ tons/yr} = \underline{0.0019 \text{ tons/yr}}$$

Annual surplus PM emission reductions

$$= 0.0014 \text{ tons/yr} - 0.0000 \text{ tons/yr} = \underline{0.0014 \text{ tons/yr}}$$

(3) Calculate annual weighted surplus emission reductions(tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.0102 \text{ (tons/yr NOx)} + 0.0019 \text{ (tons/yr ROG)} + (20 * 0.0014 \text{ (tons/yr PM)})$$

$$= \underline{0.0401 \text{ weighted tons /yr}}$$

(f) Determine the potential maximum grant amount (Step 2):

(1) Potential grant amount at the \$100,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$100,000/\text{ton} * 0.0401 \text{ tons/yr}) / 0.106 = \underline{\$37,830 \text{ Maximum}}$$

grant amount for Step 2: \$37,830

..... Maximum grant amount.....

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limit:

*Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) +
grant amount at the 100,000 cost-effectiveness limit (\$)*

$$\text{Potential grant amount} = \$24,812 + \$37,830 = \underline{\$62,642}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost
(\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of
eligible cost (Table 4-3)*

$$\text{Potential grant amount} = \$70,600 * 80\% = \underline{\$56,480}$$

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$56,480** in grant funds.

..... Project's total estimated cost-effectiveness**

(h) Determine the projects overall cost-effectiveness

(1) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.2812 \text{ tons/yr} * (3 / 10) + 0.0401 \text{ tons/yr} * (10 / 10) = \underline{0.1245 \text{ tons/yr}}$$

(2) Total estimated cost-effectiveness Formula C-18: Cost-effectiveness of weighted surplus emission reductions (\$/tons)

*Cost-effectiveness(\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$56,480 * 0.106 / 0.1245 \text{ tons/yr} = \underline{\$48,087}$$

Project's estimated cost-effectiveness: \$48,087

***Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.*

Example 7 – Replacement: Tier 1 diesel belt loader with a new electric belt loader ***

An airline proposes to replace a MY 1998, 59 hp Tier 1 belt loader with a new MY 2018 electric belt loader. The new equipment will be in operation in 2018 and cost \$61,000. The existing equipment operates 700 hours per year, 100 percent of the time in California.

This equipment belongs to a large fleet subject to the Off-Road Regulation, which received funding in 2017 for a diesel-to-diesel replacement project. Large fleets are eligible for funding a second time to repower or replace with zero-emission equipment after January 1, 2017. Based on the total horsepower of the fleet, the amount of horsepower funded in 2017 and the electric replacement project in 2018, the fleet is eligible for a four-year project life due to regulatory requirements. Therefore, step one is limited to a four-year project life. Step two is eligible for a maximum ten-year project life allowed for zero-emission replacement projects. Since funded equipment cannot count towards a fleet's regulatory compliance for the duration of the project contract, the applicant has chosen a four-year project life for step two. At the end of the contract term, the fleet may include the electric equipment towards their regulatory requirements.

This project is eligible for a two-step cost-effectiveness (CE) calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 CE limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step CE calculation example consists of:

- Step 1 – MY 1998 Tier 1 to MY 2018 Tier 4 Final belt loader
- Step 2 – MY 2018 Tier 4 Final to MY 2018 electric belt loader

Baseline Technology Information – Step 1

- Baseline engine (application): MY 1998 Tier 1 diesel
- MY 1998 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	6.54 (g/bhp-hr)	0.90 (g/bhp-hr)	0.552 (g/bhp-hr)
DR	0.0001500 (g/bhp-hr-hr)	0.000042 (g/bhp-hr-hr)	0.0000402 (g/bhp-hr-hr)

- Activity (application): 700 hrs/yr
- Engine horsepower (application): 59 hp
- Load factor (Table D-7): 0.34
- Percentage of operation in California (application): 100%

Reduced Technology Information – Step 1

- Reduced engine (ARB executive order): MY 2018 Tier 4 Final
- MY 2018 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.74 (g/bhp-hr)	0.09 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000360 (g/bhp-hr-hr)	0.000023 (g/bhp-hr-hr)	0.0000009 (g/bhp-hr-hr)

- Activity (application): 700 hrs/yr
- Engine horsepower (application): 59 hp
- Load factor (Table D-7): 0.34
- Percentage of operation in California (application): 100%
- Capital recovery factor (Table D-24): 0.256 (1% discount rate; 4-year project life)
- Cost-effectiveness limit: \$30,000/weighted ton

Baseline Technology Information – Step 2

- Baseline engine (application): MY 2018 Tier 4 Final
- MY 2018 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.74 (g/bhp-hr)	0.09 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000360 (g/bhp-hr-hr)	0.000023 (g/bhp-hr-hr)	0.0000009 (g/bhp-hr-hr)

- Activity (application): 700 hrs/yr
- Engine horsepower (application): 59 hp
- Load factor (Table D-7): 0.34

Reduced Technology Information – Step 2

- Reduced engine (application): Electric
- MY 2018 emission factors (EF) and deterioration rates (DR)

	NOx	ROG	PM
EF	0 (g/bhp-hr)	0 (g/bhp-hr)	0 (g/bhp-hr)
DR	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)

- Activity (application): 700 hrs/yr
- Engine horsepower (application): 40 hp
- Load factor (Table D-11b): 0.34
- Cost of new equipment (application): \$61,000
- Maximum eligible percentage (Table 5-4): 80%
- Capital recovery factor (Table D-24): 0.256 (1% discount rate; 4-year project life)
- Cost-effectiveness limit: \$100,000/weighted ton

.....Step 1 – Tier 1 to Tier 4 Final engine.....

(a) Determine deterioration calculations for a Tier 1 to Tier 4 Final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment)(yrs) = expected first year of operation – + project life / 2

Deterioration life (baseline equipment) = 2018 – 1998 + 4 / 2 = 22 years

(2) Calculate deterioration life (reduced equipment)(yrs):

Deterioration life (reduced equipment)(yrs) = project life / 2

Deterioration life (reduced equipment) = 4 / 2 = 2 years

(3) Calculate total equipment activity, and cap the activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Total baseline equipment activity = 700 (hrs/yr) * 22 (yrs) = 15,400 hours

Total reduced equipment activity = 700 (hrs/yr) * 2 (yrs) = 1,400 hours

(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 deterioration product for baseline and reduced equipment, for each pollutant:

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

NOx deterioration product = 0.0001500 (g/bhp-hr-hr) * 12,000 (hrs) = 1.8000 g/bhp-hr

ROG deterioration product = 0.000042 (g/bhp-hr-hr) * 12,000 (hrs) = 0.5040 g/bhp-hr

PM deterioration product = 0.0000402 (g/bhp-hr-hr) * 12,000 (hrs) = 0.4824 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0.0000360 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0504 g/bhp-hr

ROG deterioration product = 0.000023 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0322 g/bhp-hr

PM deterioration product = 0.0000009 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0013 g/bhp-hr

(b) Determine emission reductions calculations for a Tier 1 to Tier 4 Final engine:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*Annual emissions by pollutant (tons/yr) = (emission factor (g/bhp-hr) + deterioration product (g/bhp-hr)) * horsepower (hp) * load factor * activity (hrs/yr) * percent operation in CA * ton / 907,200 g*

Annual NOx **baseline** technology emissions

$$[(6.54 \text{ g/bhp-hr} + 1.8000 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.1291 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions

$$[(2.74 \text{ g/bhp-hr} + 0.0504 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.0432 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions

$$[(0.90 \text{ g/bhp-hr} + 0.5040 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.0217 \text{ tons/yr}}$$

Annual ROG **reduced** technology emissions

$$(0.09 \text{ g/bhp-hr} + 0.0322 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.0019 \text{ tons/yr}}$$

Annual PM **baseline** technology emissions

$$(0.552 \text{ g/bhp-hr} + 0.4824 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.0160 \text{ tons/yr}}$$

Annual PM **reduced** technology emissions

$$(0.009 \text{ g/bhp-hr} + 0.0013 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
$$= \underline{0.0002 \text{ tons/yr}}$$

(2) Calculate the annual surplus emission reductions by pollutant (tons/yr):

Formula C-9: Annual surplus emission reductions by pollutant (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual surplus NOx emission reductions

$$= 0.1291 \text{ tons/yr} - 0.0432 \text{ tons/yr} = \underline{0.0859 \text{ tons/yr}}$$

Annual surplus ROG emission reductions

$$= 0.0217 \text{ tons/yr} - 0.0019 \text{ tons/yr} = \underline{0.0198 \text{ tons/yr}}$$

Annual surplus PM emission reductions

$$= 0.0160 \text{ tons/yr} - 0.0002 \text{ tons/yr} = \underline{0.0158 \text{ tons/yr}}$$

(3) Calculate Annual Weighted Surplus Emission Reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * (PM reductions (tons/yr)))*

Annual weighted emission reductions (weighted tons/yr)

$$= 0.0859 \text{ (tons/yr NOx)} + 0.0198 \text{ (tons/yr ROG)} + (20 * (0.0158 \text{ tons/yr PM}))$$

$$= \underline{0.4217 \text{ weighted tons /yr}}$$

(c) Determine the potential maximum grant amount (Step 1):

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: *Potential grant amount at the cost-effectiveness limit (\$) Grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$30,000/\text{ton} * 0.4217 \text{ tons/yr}) / 0.256 = \underline{\$49,418}$$

Maximum grant amount for step 1: \$ 49,418

(d) Determine deterioration calculations for a Tier 4 Final to 2018 electric beltloader:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment)(yrs) = expected first year of operation – + project life / 2

Deterioration life (baseline equipment) = 2018 – 2018 + (4 / 2) = 2 years

(2) Calculate deterioration life (reduced equipment):

Deterioration life (reduced equipment) (yrs) = project life / 2

Deterioration life (reduced equipment) = 4 / 2 = 2 years

(3) Calculate total equipment activity, and cap the activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Total baseline equipment activity 700 (hrs/yr) * 2 (yrs) = 1,400 hours

Total reduced equipment activity = 700 (hrs/yr) * 2 (yrs) = 1,400 hours

(4) Calculate deterioration rate for baseline and reduced equipment, for each pollutant:

*Hours-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

NOx deterioration product = 0.0000360 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0504 g/bhp-hr

ROG deterioration product = 0.000023 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0322 g/bhp-hr

PM deterioration product = 0.0000009 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0013 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0.0000 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0000 g/bhp-hr

ROG deterioration product = 0.0000 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0000 g/bhp-hr

PM deterioration product = 0.0000 (g/bhp-hr-hr) * 1,400 (hrs) = 0.0000 g/bhp-hr

(e) Determine emission reductions calculations for a Tier 4 Final to 2018 electric belt loader:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions

$$[(2.74 \text{ g/bhp-hr} + 0.0504 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g} =$$
0.0432 tons/yr

Annual NOx **reduced** technology emissions

$$[(0.0000 \text{ g/bhp-hr} + 0.0000 \text{ g/bhp-hr}) * 40 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
= 0.0000 tons/yr

Annual ROG **baseline** technology emissions

$$[(0.09 \text{ g/bhp-hr} + 0.0322 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g} =$$
0.0019 tons/yr

Annual ROG **reduced** technology emissions

$$[(0.0000 \text{ g/bhp-hr} + 0.00 \text{ g/bhp-hr}) * 40 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g} =$$
0.0000 tons/yr

Annual PM **baseline** technology emissions

$$[(0.009 \text{ g/bhp-hr} + 0.0013 \text{ g/bhp-hr}) * 59 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g} =$$
0.0002 tons/yr

Annual PM **reduced** technology emissions

$$[(0.000 \text{ g/bhp-hr} + 0.0000 \text{ g/bhp-hr}) * 40 \text{ hp} * 0.34 * 700 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$$
= 0.0000 tons/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (by pollutant)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions
= 0.0432 tons/yr - 0.0000 tons/yr = 0.0432 tons/yr

Annual ROG surplus emission reductions
= 0.0019 tons/yr - 0.0000 tons/yr = 0.0019 tons/yr

Annual PM surplus emission reductions
= 0.0002 tons/yr - 0.0000 tons/yr = 0.0002 tons/yr

(3) Calculate annual weighted surplus emission reductions(tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.0432 (tons/yr NOx) + 0.0019 (tons/yr ROG) + (20 * 0.0002 (tons/yr PM))
= 0.0491 weighted tons /yr

(f) Determine the potential maximum grant amount (Step 2):

(1) Potential grant amount at the \$100,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$100,000/ton * 0.0491 tons/yr) / 0.256 = **\$19,180 Maximum grant amount for Step 2: \$19,180**

..... Maximum grant amount.....

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limit:

Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) + grant amount at the 100,000 cost-effectiveness limit (\$)

Potential grant amount = \$49,418 + \$19,180 = **\$68,598**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (Table 4-3)*

Potential grant amount = \$61,000 * 80% = **\$48,800**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$48,800** in grant funds.

..... Project's total estimated cost-effectiveness**

(h) Determine the projects overall cost-effectiveness

(1) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.4217 \text{ tons/yr} * (4 / 4) + 0.0491 \text{ tons/yr} * (4 / 4) = \underline{0.4708 \text{ tons/yr}}$$

(2) Total estimated cost-effectiveness

Formula C-18: Cost-effectiveness of weighted surplus emission reductions (\$/tons)

*Cost-effectiveness(\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$48,800 * 0.256 / 0.4708 \text{ tons/yr} = \underline{\$26,535/\text{ton}}$$

estimated cost-effectiveness: \$26,535/ton

****Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.**

Example 8 – Replacement: Tier 3 to Tier 4 Portable Generator

An applicant proposes to replace an existing MY 2006 Tier 3, 150 hp portable diesel generator with a new Tier 4 Final, 150 hp diesel generator to be placed in operation in 2017. This portable generator is owned by a rental company, is subject to the Portable Engine ATCM, and operates 100 percent in California. The fleet has met the final compliance requirements of the applicable Air Toxics Control Measure. The generator will operate 500 hours per year with a 5-year project life. Cost of the new generator is \$30,000.

Baseline Technology Information

- Baseline technology (application): MY 2006 (Tier 3)
- Engine horsepower (application): 150 hp
- MY 2006 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.32 (g/bhp-hr)	0.09 (g/bhp-hr)	0.112 (g/bhp-hr)
DR	0.0000300 (g/bhp-hr-hr)	0.0000300 (g/bhp-hr-hr)	0.0000080 (g/bhp-hr-hr)

- Activity (application): 500 hrs/yr
- Load factor (Table D-7): 0.74
- Percentage of operation in California: 100%
- Discount rate is 1% and project life is 5 years; CRF (Table D-24): 0.206

Reduced Technology Information

- Reduced technology (application): MY 2017 (Tier 4 Final)
- Engine horsepower (application): 150 hp
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9):

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000040 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000004 (g/bhp-hr-hr)

- Activity (application): 500 hr/yr
- Load factor (Table D-10): 0.74
- Cost of new equipment (quote provided with application): \$30,000
- Maximum eligible percentage (Table 5-4): 80%
- Cost-effectiveness limit: \$30,000/weighted ton

(a) Determine deterioration calculations for a Tier 3 to Tier 4 Final Engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

(1) Calculate deterioration product(baseline equipment):

Deterioration life (baseline equipment) (yrs) = expected first year of operation - baseline engine model year + project life/2

Deterioration life (baseline equipment) = 2017 – 2006 + (5 / 2) = 13.5 years

(2) Calculate deterioration product(baseline equipment):

$$\text{Deterioration life (reduced equipment) (yrs)} = \text{project life}/2$$

$$\text{Deterioration life (reduced equipment)} = (5 / 2) = \underline{2.5 \text{ years}}$$

(3) Calculate total equipment activity and cap the baseline and reduced activity when applicable:

$$\text{Total equipment activity (mi)} = \text{annual activity (mi/yr)} * \text{deterioration life (yrs)}$$

$$\text{Total equipment activity (baseline)} = 500 \text{ (hrs/yr)} * 13.5 \text{ (yrs)} = \underline{6,750 \text{ hours}}$$

$$\text{Total equipment activity (reduced)} = 500 \text{ (hrs/yr)} * 2.5 \text{ (yrs)} = \underline{1,250 \text{ hours}}$$

(Appendix C, page C-7, Footnote (c))

Total equipment activity used for deterioration rate is capped at 12,000 for off-road diesel engines

(4) Calculate hour-based deterioration product for baseline and reduced equipment, for each pollutant:

$$\text{Hours-based deterioration product (g/bhp-hr)} = \text{deterioration rate (g/bhp-hr-hr)} * \text{total equipment activity (hrs/yr)}$$

Baseline equipment:

$$\text{NOx deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 6,750 \text{ (hrs)} = \underline{0.2025 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 6,750 \text{ (hrs)} = \underline{0.2025 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000080 \text{ (g/bhp-hr-hr)} * 6,750 \text{ (hrs)} = \underline{0.0540 \text{ g/bhp-hr}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.000004 \text{ (g/bhp-hr-hr)} * 1,250 \text{ (hrs)} = \underline{0.0050 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000011 \text{ (g/bhp-hr-hr)} * 1,250 \text{ (hrs)} = \underline{0.0138 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000004 \text{ (g/bhp-hr-hr)} * 1,250 \text{ (hrs)} = \underline{0.0005 \text{ g/bhp-hr}}$$

(b) Determine emission reductions calculations for a Tier 3 to Tier 4 Final engine:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions
= $[(2.32 \text{ g/bhp-hr} + 0.2025 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.1543 tons/yr

Annual NOx **reduced** technology emissions
 $[(0.26 \text{ g/bhp-hr} + 0.0050 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.0162 tons/yr

Annual ROG **baseline** technology emissions
= $[(0.09 \text{ g/bhp-hr} + 0.2025 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.0179 tons/yr

Annual ROG **reduced** technology emissions
= $[(0.05 \text{ g/bhp-hr} + 0.0138 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.0039 tons/yr

Annual PM **baseline** technology emissions
= $[(0.112 \text{ g/bhp-hr} + 0.0540 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.0102 tons/yr

Annual PM **reduced** technology emissions
= $[(0.009 \text{ g/bhp-hr} + 0.0007 \text{ g/bhp-hr}) * 150 \text{ hp} * 0.74 * 500 \text{ hrs} * 100\%] * \text{ton} / 907,200\text{g}$
= 0.0006 tons/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emissions reductions (tons/yr)
Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions (tons/yr)
= 0.1543 tons/yr - 0.0162 tons/yr = 0.1381 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= 0.0179 tons/yr - 0.0039 tons/yr = 0.0140 tons/yr

Annual PM surplus emission reductions (tons/yr)
= 0.0102 g/bhp-hr - 0.0006 g/bhp-hr = 0.0096 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.1381 (tons/yr NOx) + 0.0140 (tons/yr ROG) + (20 * 0.0096 (tons/yr))
= **0.3441 weighted tons/yr**

(c) Determine maximum grant amount

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 (\$/ton) * 0.3441 tons/yr) / 0.206 = **\$50,111**

(2) Potential grant amount based on maximum percentage of eligible cost (\$)

Formula C-14: *Potential grant amount based on maximum percentage of eligible cost (\$)*

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount = \$30,000 * 80% = **\$24,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$24,000** in grant funds.

Example 9 – Repower: Tier 3 portable pull-behind chipper with Tier 4 Final engine

An applicant proposes to replace an existing diesel Tier 3, 503 hp engine in a pull-behind chipper with a new diesel Tier 4 Final, 500 hp engine in 2017. The cost of the repower is \$92,000. This portable equipment is operated exclusively at an agricultural source in California and is subject to the agricultural provisions of the Stationary Engine ATCM. This equipment is also subject to SBx2 3 and may be eligible for funding up to the compliance date of an applicable in-use rule. In order to be eligible, portable farm equipment projects must be under fully executed contract, and must be installed in the equipment and in operation prior to the applicable compliance date.

Per SBX2 3, the district offered the applicant a ten-year project life for this portable farm equipment; however, the applicant requested a five-year project life.

Baseline Technology Information

- Engine (application): MY 2006 (Tier 3)
- Engine horsepower (application): 503 hp
- Activity (application): 700 hr/yr
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.73
- Discount rate is 1 % and project life is 5 years; CRF (Table D-24): 0.206
- MY 2006 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.32 (g/bhp-hr)	0.09 (g/bhp-hr)	0.088 (g/bhp-hr)
DR	0.000030 (g/bhp-hr-hr)	0.000023 (g/bhp-hr-hr)	0.000044 (g/bhp-hr-hr)

Reduced Technology Information

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- Engine horsepower (application): 500 hp
- Cost of new engine (application): \$92,000
- Maximum eligible percentage (Table 5-4): 85 percent
- Load factor (Table D-7): 0.73
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.0000036 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000003 (g/bhp-hr-hr)

(a) Determine deterioration calculations for a Tier 3 to Tier 4 Final Engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = [\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/bhp-hr)}] * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g}$$

(1) Calculate deterioration life (baseline equipment)(yrs):

Deterioration life (baseline equipment) (yrs) = expected first year of operation - baseline engine model year + project life / 2

$$\text{Deterioration life (baseline equipment)} = 2017 - 2006 + (5/2) = \underline{13.5 \text{ years}}$$

(2) Calculate deterioration Life (reduced equipment) (yrs):

Deterioration life (reduced equipment) (yrs) = project life/2

$$\text{Deterioration life (reduced equipment)} = 5/2 = \underline{2.5 \text{ years}}$$

(3) Calculate total equipment activity (hrs) and cap the baseline equipment activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

$$\text{Total baseline equipment activity} = 700 \text{ (hrs/yr)} * 13.5 \text{ (yrs)} = \underline{9450 \text{ hours}}$$

$$\text{Total reduced equipment activity} = 700 \text{ (hrs/yr)} * 2.5 \text{ (yrs)} = \underline{1750 \text{ hours}}$$

(4) Calculate hour-based deterioration rate for baseline and reduced equipment, for each pollutant (g/bhp-hr):

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr-hr) * total equipment activity (hrs)*

Baseline equipment:

$$\text{NOx deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 9450 \text{ hrs} = \underline{0.2835 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000023 \text{ (g/bhp-hr-hr)} * 9450 \text{ hrs} = \underline{0.2174 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000044 \text{ (g/bhp-hr-hr)} * 9450 \text{ hrs} = \underline{0.0416 \text{ g/bhp-hr}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.0000036 \text{ (g/bhp-hr-hr)} * 1750 \text{ hrs} = \underline{0.0063 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000011 \text{ (g/bhp-hr-hr)} * 1750 \text{ hrs} = \underline{0.0193 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000003 \text{ (g/bhp-hr-hr)} * 1750 \text{ hrs} = \underline{0.0005 \text{ g/bhp-hr}}$$

(b) Determine emission reductions calculations for a Tier 3 to Tier 4 Final engine:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr) *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 CA * ton / 907,200g*

Annual NOx **baseline** technology emissions
= $[(2.32 \text{ g/bhp-hr} + 0.2835 \text{ g/bhp-hr}) * 503 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.7376 tons/yr

Annual NOx **reduced** technology emissions
= $[(0.26 \text{ g/bhp-hr} + 0.0063 \text{ g/bhp-hr}) * 500 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.0750 tons/yr

Annual ROG **baseline** technology emissions
= $[(0.09 \text{ g/bhp-hr} + 0.2174 \text{ g/bhp-hr}) * 503 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.0871 tons/yr

Annual ROG **reduced** technology emissions
= $[(0.05 \text{ g/bhp-hr} + 0.0193 \text{ g/bhp-hr}) * 500 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.0195 tons/yr

Annual PM **baseline** technology emissions
= $[(0.088 \text{ g/bhp-hr} + 0.0416 \text{ g/bhp-hr}) * 503 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.0367 tons/yr

Annual PM **reduced** technology emissions
= $[(0.009 \text{ g/bhp-hr} + 0.0005 \text{ g/bhp-hr}) * 500 \text{ hp} * 0.73 * 700 \text{ hrs} * 100\%]$ *ton/907,200g
= 0.0027 tons/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr)

Formula C-9: Annual surplus emissions reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NOx surplus emission reductions
= 0.7376 tons/yr - 0.0750 tons/yr = 0.6626 tons/yr

Annual ROG surplus emission reductions
= 0.0871 tons/yr - 0.0195 tons/yr = 0.0676 tons/yr

Annual PM surplus emission reductions
= 0.0367 g/bhp-hr - 0.0027 g/bhp-hr = 0.0340 tons/yr

(3) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 0.6626 (tons/yr NOx) + 0.0676 (tons/yr ROG) + (20 * 0.0340 (tons/yr PM))
= 1.4102 weighted tons/yr

(c) **Determine the maximum grant amount**

(1) **Potential Grant Amount at \$30,000 Cost-Effectiveness Limit**

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 (\$/ton) * 1.4102 tons/yr) / 0.206 = \$205,369

(2) **Potential grant amount based on maximum percentage of eligible cost (\$)**

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (Table 5-4)*

Potential Grant Amount = \$92,000 * 85%= \$78,200

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$78,200 in grant funds.

Example 10—Repower: Tier 3 diesel stationary irrigation pump engine to electric motor ***

An applicant based in California wants to replace an existing MY 2006, Tier 3, 120 hp diesel stationary irrigation pump engine with a new (75 kW) 100 hp electric motor. The cost of the new electric motor is \$35,000. The project is eligible for a maximum ten-year project life. A Moyer-funded infrastructure project may be associated with this project. Please see Section VI (page 113), Example 3 for infrastructure project calculations.

This project is eligible for a two-step cost-effectiveness (CE) calculation. Surplus reductions calculated in the first step will be based on the regulation requirements and \$30,000 CE limit. Surplus reductions (cleaner than required) calculated in the second step will be based on the maximum project life and \$100,000 CE limit. This two-step CE calculation example consists of:

Step 1 - MY 2006 Tier 3 to MY 2017 Tier 4 Final

Step 2 - MY 2017 Tier 4 Final diesel engine to 2018 electric motor

Baseline Technology Information- Step 1

- Baseline engine (application): MY 2006 (Tier 3)
- MY 2006 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	2.32 g/bhp-hr (g/bhp-hr)	0.09 (g/bhp-hr)	0.112 (g/bhp-hr)
DR	0.000030 (g/bhp-hr-hr)	0.000030 (g/bhp-hr-hr)	0.0000080 (g/bhp-hr-hr)

- Activity (application): 1000 hrs/yr
- Engine horsepower (application): 120 hp
- Load factor (Table D-7): 0.65
- Percentage of operation in CA (application): 100%

Reduced Technology Information - Step 1

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.000004 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000004 (g/bhp-hr-hr)

- Activity (application): 1000 hrs/yr
- Engine horsepower (application): 120 hp
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.65
- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Cost-effectiveness limit: \$30,000/ weighted ton

Baseline Technology Information - Step 2

- Engine (ARB executive order): MY 2017 (Tier 4 Final)
- MY 2017 emission factors (EF) and deterioration rates (DR) (Table D-9)

	NOx	ROG	PM
EF	0.26 (g/bhp-hr)	0.05 (g/bhp-hr)	0.009 (g/bhp-hr)
DR	0.000004 (g/bhp-hr-hr)	0.000011 (g/bhp-hr-hr)	0.0000004 (g/bhp-hr-hr)

- Activity (application): 1000 hrs/yr
- Engine horsepower (application): 120 hp
- Percentage of operation in CA (application): 100%
- Load factor (Table D-7): 0.65
- Discount rate is 1% and project life is 10 years; CRF (Table D-24): 0.106

Reduced Technology Information – Step 2

- Motor (application): New electric motor
- Motor horsepower (application): 100 hp
- MY 2017 emission factors (EF) and deterioration rates (DR)

	NOx	ROG	PM
EF	0 (g/bhp-hr)	0 (g/bhp-hr)	0 (g/bhp-hr)
DR	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)	0 (g/bhp-hr-hr)

- Activity (application): 1,000 hours per year
- Cost of new motor and necessary peripheral equipment (application): \$35,000
- Maximum eligible percentage (Table 5-4): 85%
- Cost-effectiveness limit: \$100,000/weighted ton

..... Step 1 – MY 2006 Tier 3 diesel engine to MY 2017 Tier 4 Final.....

(a) Determine deterioration calculations for a uncontrolled diesel engine to Tier 4 final engine:

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

*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 CA * ton / 907,200g*

(1) Calculate deterioration life (baseline equipment):

Deterioration life (baseline equipment) (yrs) = expected first year of operation – + project life/2

Deterioration life (baseline equipment) = 2017 – 2006 + (7 / 2) = 14.5 years

(2) Calculate deterioration life (reduced equipment):

Deterioration life (reduced equipment) (yrs) = project life/2

Deterioration life (reduced equipment) = (7 / 2) = 3.5 years

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable:

$$\text{Total equipment activity (hrs)} = \text{activity (hrs/yr)} * \text{deterioration life (yrs)}$$

$$\text{Total baseline equipment activity} = 1,000 \text{ (hrs/yr)} * 14.5 \text{ (yrs)} = \underline{14,500 \text{ hours}}$$

$$\text{Total reduced equipment activity} = 1,000 \text{ (hrs/yr)} * 3.5 \text{ (yrs)} = \underline{3,500 \text{ hours}}$$

(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 deterioration product for baseline and reduced equipment, for each pollutant:

$$\text{Hour-based deterioration product (g/bhp-hr)} = \text{deterioration rate (g/bhp-hr-hr)} * \text{activity (hrs/yr)} * \text{deterioration life (yrs)}$$

Baseline equipment:

$$\text{NOx deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.3600 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000030 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.3600 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000080 \text{ (g/bhp-hr-hr)} * 12,000 \text{ hrs} = \underline{0.0960 \text{ g/bhp-hr}}$$

Reduced equipment:

$$\text{NOx deterioration product} = 0.000004 \text{ (g/bhp-hr-hr)} * 3,500 \text{ hrs} = \underline{0.0140 \text{ g/bhp-hr}}$$

$$\text{ROG deterioration product} = 0.000011 \text{ (g/bhp-hr-hr)} * 3,500 \text{ hrs} = \underline{0.0385 \text{ g/bhp-hr}}$$

$$\text{PM deterioration product} = 0.0000004 \text{ (g/bhp-hr-hr)} * 3,500 \text{ hrs} = \underline{0.0014 \text{ g/bhp-hr}}$$

(b) Determine emission reductions calculations for a 2006 Tier 3 to 2017 Tier 4 Final:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = (\text{emission factor (g/bhp-hr)} + \text{deterioration product (g/hp-hr)}) * \text{horsepower (hp)} * \text{load factor} * \text{activity (hrs/yr)} * \text{percent operation in CA} * \text{ton/907,200 g}$$

Annual NOx **baseline** technology emissions (tons/yr)

$$= [(2.32 \text{ g/bhp-hr} + 0.3600 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton/907,200g}$$

$$= \underline{0.2304 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions (tons/yr)

$$= [(0.26 \text{ g/bhp-hr} + 0.0140 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton/907,200g}$$

$$= \underline{0.0236 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions (tons/yr)
 = $[(0.09 \text{ g/bhp-hr} + 0.3600 \text{ /bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g} =$
0.0387 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)
 = $[(0.05 \text{ g/bhp-hr} + 0.0385 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
 = 0.0076 tons/yr

Annual PM **baseline** technology emissions (tons/yr)
 = $[(0.112 \text{ g/bhp-hr} + 0.0960 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
 = 0.0179 tons/yr

Annual PM **reduced** technology emissions (tons/yr)
 = $[(0.009 \text{ g/bhp-hr} + 0.0014 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1,000 \text{ hrs} * 100\%] * \text{ton}/907,200\text{g}$
 = 0.0009 tons/yr

(2) Calculate the annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions

0.2304 tons/yr - 0.0236 tons/yr = 0.2068 tons/yr

Annual ROG surplus emission reductions

0.0387 tons/yr - 0.0076 tons/yr = 0.0311 tons/yr

Annual PM surplus emission reductions

0.0179 tons/yr - 0.0009 tons/yr = 0.0170 tons/yr

(3) Calculate annual weighted surplus emission reductions(tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Annual weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

= 0.2068 (tons/yr NOx) + 0.0311 (tons/yr ROG) + (20 * 0.0170 (tons/yr PM))

= 0.5779 weighted tons /yr

(c) Determine the potential maximum grant amount (Step 1):

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000/ton * 0.5779+ tons/yr)/ 0.149 = \$116.356

Maximum grant amount for Step 1: \$116.356

.....Step 2 – MY 2017 Tier 4 Final to 2017 electric motor.....

(d) Determine deterioration calculations for a Tier 4 Final to Electric Motor:

(1) Calculate deterioration life (baseline equipment):

Deterioration life (baseline equipment)(yrs) = expected first year of operation – + project life/2

Deterioration life (baseline equipment) = 2017 – 2017 + (10 / 2) = 5 years

(2) Calculate deterioration life (reduced equipment):

Deterioration life (reduced equipment) (yrs) = project life/2

Deterioration life (reduced equipment) = (10 / 2) = 5 years

(3) Calculate total equipment activity and cap the baseline equipment activity when applicable:

*Total equipment activity (hrs) = activity (hrs/yr) * deterioration life (yrs)*

Total baseline equipment activity = 1000 (hrs/yr) * 5 (yrs) = 5,000 hours

Total baseline equipment activity = 1000 (hrs/yr) * 5 (yrs) = 5,000 hours

(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 deterioration product for baseline and reduced equipment, for each pollutant:

*Hour-based deterioration product (g/bhp-hr) = deterioration rate (g/bhp-hr) * activity (hrs/yr) * deterioration life (yrs)*

Baseline equipment:

NOx deterioration product = 0.000004 (g/bhp-hr-hr) * 5,000 hrs = 0.0200 g/bhp-hr

ROG deterioration product = 0.000011 (g/bhp-hr-hr) * 5,000 hrs = 0.0550 g/bhp-hr

PM deterioration product = 0.0000004 (g/bhp-hr-hr) * 5,000 hrs = 0.0020 g/bhp-hr

Reduced equipment:

NOx deterioration product = 0 (g/bhp-hr-hr) * 5,000 hrs = 0 g/bhp-hr

ROG deterioration product = 0 (g/bhp-hr-hr) * 5,000 hrs = 0 g/bhp-hr

PM deterioration product = 0 (g/bhp-hr-hr) * 5,000 hrs = 0 g/bhp-hr

(e) Determine emission reductions calculations for a Tier 4 Final to Electric Motor:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: *Annual emissions (tons/yr) = (emission factor (g/bhp-hr) + deterioration product (g/hp-hr)) * horsepower (hp) * load factor * activity (hrs/yr) * percent operation in CA * ton/907,200 g*

Annual NOx **baseline** technology emissions (tons/yr)
= $[(0.26 \text{ g/bhp-hr} + 0.0200 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1000 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0241 tons/yr

Annual NOx **reduced** technology emissions (tons/yr)
= 0 tons/yr

Annual ROG **baseline** technology emissions (tons/yr)
= $[(0.05 \text{ g/bhp-hr} + 0.0550 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1000 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0090 tons/yr

Annual ROG **reduced** technology emissions (tons/yr)
= 0 tons/yr

Annual PM **baseline** technology emissions (tons/yr)
= $[(0.009 \text{ g/bhp-hr} + 0.0020 \text{ g/bhp-hr}) * 120 \text{ hp} * 0.65 * 1000 \text{ hrs} * 100\%]$ * ton/907,200g
= 0.0009 tons/yr

Annual PM **reduced** technology emissions (tons/yr)
= 0 tons/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions = 0.0241 tons/yr – 0 tons/yr = 0.0241 tons/yr

Annual ROG surplus emission reductions = 0.0090 tons/yr – 0 tons/yr = 0.0090 tons/yr

Annual PM surplus emission reductions = 0.0009 tons/yr – 0 tons/yr = 0.0009 tons/yr

(3) Calculate annual weighted surplus emission reductions(tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

= 0.0241 (tons/yr NOx) + 0.0090 (tons/yr ROG) + (20 * 0.0009 (tons/yr PM))

= 0.0511 weighted tons /yr

(f) Determine the potential maximum grant amount (Step 2):

(1) Potential grant amount at the \$100,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 100,000 (\$/ton) * 0.0511 (tons/yr) / 0.106 = \$48,208 **Maximum**

grant amount for Step 2: \$48,208

..... *Maximum grant amount*

(g) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 and \$100,000 cost-effectiveness limits:

*Potential grant amount (\$) = grant amount at the 30,000 cost-effectiveness limit (\$) +
grant amount at the 100,000 cost-effectiveness limit (\$)*

$$\text{Potential grant amount} = \$116,356 + \$48,208 = \underline{\$164,563}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost
(\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of
eligible cost (%)*

$$\text{Potential grant amount} = \$35,000 * 85\% = \underline{\$29,750}$$

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$29,750** in grant funds.

..... Project's total estimated cost-effectiveness**

(h) Determine the projects overall cost-effectiveness

(1) Determine annual average emission reductions for total project life

Formula C-15: split project lives

*Total annual weighted surplus emission reductions (tons/yr) = (fraction project life / total project life * annual weighted surplus emission from transaction 1) + (fraction project life / total project life * annual weighted surplus emission from transaction 2)*

Total annual weighted surplus emission reductions

$$= 0.5779 \text{ tons/yr} * (7 / 10) + 0.0511 \text{ tons/yr} * (10 / 10) = \underline{0.4556 \text{ tons/yr.}}$$

(2) Total estimated cost-effectiveness

Formula C-18: Cost-effectiveness of estimated surplus emission reductions (\$/tons)

*Cost-effectiveness(\$/tons) = Grant amount (\$) * CRF / Annual weighted surplus emission reductions (weighted tons/yr)*

$$\text{Estimated cost-effectiveness} = \$29,750 * 0.106 / 0.4556 \text{ tons/yr} = \underline{\$6,921}$$

Project's estimated cost-effectiveness: \$6,921

***Note that for two-step calculations local air districts may specify alternative methods to determine overall project cost-effectiveness based on local priorities.*

III. Locomotives

Example 1 – Switch Locomotive Engine Repower (Class 3 Railroad)

A Class 3 railroad operator opts to repower an existing 1971 model year uncontrolled switch locomotive engine with a U.S. EPA-certified and CARB verified Tier 4 Engine repower. The existing locomotive consumes 40,000 gallons of fuel per year, with 100 percent operation in California. The cost of the repower is \$800,000. The railroad company will commit to a 10 year project life.

Baseline Technology Information

- Locomotive model year (application): 1971 (Uncontrolled)
- Locomotive emission rate (Table D-14a):

Engine Model Year	Type	NOx	ROG	PM10
Pre-1973	Switcher	16.36 g/bhp-hr	1.06 g/bhp-hr	0.378 g/bhp-hr

- Activity (application): 40,000 gal/yr
- Fuel Consumption Rate (Table D-21): 15.2 bhp-hr/gal

Reduced Technology Information

- Locomotive emission rate (Table D-14b):

Engine Model Year	Type	NOx	ROG	PM10
2015 Tier 4	Switcher	1.22 g/bhp-hr	0.15 g/bhp-hr	0.026 g/bhp-hr

- Activity (application): 40,000 gal/yr
- Fuel Consumption Rate (Table D-21): 15.2 bhp-hr/gal
- Discount rate is 1% and project life is 10 years; CRF (Table D-24): 0.106
- Maximum eligible percentage: 85%
- Cost of new engine (application): \$800,000
- Cost-effectiveness limit: \$30,000/weighted ton

(a) Calculate emission reductions for uncontrolled to Tier 4

Formula C-7: Estimated annual emissions based on fuel consumed using emission factors or converted emission standard (tons/yr):

$$\text{Annual emissions by pollutant (tons/yr)} = (\text{emission factor (g/bhp-hr)} * \text{Fuel Consumption Rate (bhp-hr/gal)}) * (\text{activity (gal/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g})$$

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

$$\begin{aligned} &\text{Annual NOx } \mathbf{baseline} \text{ technology emissions} \\ &(16.36 \text{ g/bhp-hr} * 15.2 \text{ bhp-hr/gal}) (40,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g}) \\ &= \underline{10.9644 \text{ ton/yr}} \end{aligned}$$

$$\begin{aligned} &\text{Annual NOx } \mathbf{reduced} \text{ technology emissions} \\ &(1.22 \text{ g/bhp-hr} * 15.2 \text{ bhp-hr/gal}) (40,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g}) \\ &= \underline{0.8176 \text{ ton/yr}} \end{aligned}$$

Annual ROG **baseline** technology emissions
(1.06 g/bhp-hr * 15.2 bhp-hr/gal) (40,000 gal/yr) * 100% * (ton/907,200 g)
= 0.7104 ton/yr

Annual ROG **reduced** technology emissions
(0.15 g/bhp-hr * 15.2 bhp-hr/gal) (40,000 gal/yr) * 100% * (ton/907,200 g)
= 0.1005 ton/yr

Annual PM **baseline** technology emissions
(0.378 g/bhp-hr * 15.2 bhp-hr/gal) (40,000 gal/yr) * 100% * (ton/907,200 g)
= 0.2533 ton/yr

Annual PM **reduced** technology emissions
(0.026 g/bhp-hr * 15.2 bhp-hr/gal) (40,000 gal/yr) * 100% * (ton/907,200 g)
= 0.0174 ton/yr

(2) Calculate the annual surplus emission reductions for each pollutant(tons/yr)

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions (tons/yr)
= 10.9644 tons/yr - 0.8176 tons/yr = 10.1468 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= 0.7104 tons/yr - 0.1005 tons/yr = 0.6099 tons/yr

Annual PM surplus emission reductions (tons/yr)
= 0.2533 tons/yr - 0.0174 tons/yr = 0.2359 tons/yr

(3) Calculate annual weighted surplus emission reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 10.1468 (tons/yr NOx) + 0.6099 (tons/yr ROG) + (20 * 0.2359 (tons/yr PM))
= 15.4747 weighted tons /yr

(b) Determine the maximum grant amount

(4) Potential grant amount at the \$30,000 cost-effectiveness limit

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 15.4747 tons/yr) / 0.106 = \$4,379,632.08

(5) Potential grant amount based on maximum percentage of eligible cost (\$)

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$800,000 * 85% = \$680,000

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$680,000 in grant funds.

Example 2 – Multiple Engine Switcher Replacement (Class 1 Railroad)

A Class 1 railroad operator has the opportunity to replace an existing 1993 Tier 0 switcher locomotive with a U.S. EPA-certified and CARB verified Tier 4 multi-engine switcher locomotive. The baseline locomotive uses a single 1600hp engine and the reduced uses two 800 hp off-road engines. Fuel receipts indicate the baseline switch locomotive consumes 35,000 gallons of fuel per year with 100 percent operation in California. Baseline emissions rates are based on the federal remanufacture requirement for the engine, equivalent to Tier 0+. The cost of the new multi-engine switcher is \$2 million. The project life is 12 years.

Baseline Technology Information

- Locomotive model year (application): 1993 (Tier 0+)
- Locomotive emission rate (Table D-14b):

Engine Model Year	Type	NOx	ROG	PM10
1973-2001 Tier 0+	Switcher	11.09 g/bhp-hr	2.21 g/bhp-hr	0.224 g/bhp-hr

- Activity (application): 35,000 gal/yr
- Fuel Consumption Rate (Table D-21): 15.2 bhp-hr/gal

Reduced Technology Information

- Locomotive emission rate (Table D-14b):

Engine Model Year	Type	NOx	ROG	PM10
2015 Tier 4	Switcher	1.22 g/bhp-hr	0.15 g/bhp-hr	0.026 g/bhp-hr

- Activity (application): 35,000 gal/yr
- Fuel Consumption Rate (Table D-21): 15.2 bhp-hr/gal
- Discount rate is 1% and project Life is 12 years; CRF (Table D-24): 0.089
- Maximum eligible percentage: 75%
- Cost of new engine (application): \$2,000,000
- Cost-effectiveness limit: \$30,000/weighted ton

(a) Calculate emission reductions for a Tier 0+ to Tier 4

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

$$\text{Annual emissions by pollutant (tons/yr)} = (\text{emission factor (g/bhp-hr)} * \text{Fuel Consumption Rate (bhp-hr/gal)}) * (\text{activity (gal/yr)} * \text{percentage operation in CA} * \text{ton} / 907,200\text{g})$$

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

$$\begin{aligned} &\text{Annual NOx } \mathbf{baseline} \text{ technology emissions} \\ &(11.09 \text{ g/bhp-hr} * 15.2 \text{ bhp-hr/gal}) (35,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200\text{g}) \\ &= \underline{6.5034 \text{ ton/yr}} \\ &\text{Annual NOx } \mathbf{reduced} \text{ technology emissions} \\ &(1.22 \text{ g/bhp-hr} * 15.2 \text{ bhp-hr/gal}) (35,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200\text{g}) \\ &= \underline{0.7154 \text{ ton/yr}} \end{aligned}$$

Annual ROG **baseline** technology emissions
(2.21 g/bhp-hr * 15.2 bhp-hr/gal) (35,000 gal/yr) * 100% * (ton/907,200g)
= 1.2960 ton/yr

Annual ROG **reduced** technology emissions
(0.15 g/bhp-hr * 15.2 bhp-hr/gal) (35,000 gal/yr) * 100% * (ton/907,200g)
= 0.0880 ton/yr

Annual PM **baseline** technology emissions
(0.224 g/bhp-hr * 15.2 bhp-hr/gal) (35,000 gal/yr) * 100% * (ton/907,200g)
= 0.1314 ton/yr

Annual PM **reduced** technology emissions
(0.026 g/bhp-hr * 15.2 bhp-hr/gal) (35,000 gal/yr) * 100% * (ton/907,200g)
= 0.0152 ton/yr

(2) Calculate annual surplus emission reductions by pollutant(tons/yr)

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Annual NOx surplus emission reductions (tons/yr)
= 6.5034 tons/yr – 0.7154 tons/yr = 5.7880 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= 1.2960 tons/yr – 0.0880 tons/yr = 1.2080 tons/yr

Annual PM surplus emission reductions (tons/yr)
= 0.1314 tons/yr – 0.0152 tons/yr = 0.1162 tons/yr

(3) Calculate annual weighted surplus emission reductions(tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 5.7880 (tons/yr NOx) + 1.2080 (tons/yr ROG) + (20 * 0.1162 (tons/yr PM))
= 9.3200 weighted tons /yr

(b) Determine the maximum grant amount

(1) Potential grant amount at the \$30,000 cost-effectiveness limit

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 9.3200 tons/yr) / 0.089 = \$3,141,573

(2) Potential grant amount based on maximum percentage of eligible cost (\$)

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$2,000,000 * 75% = \$1,500,000

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$1,500,000 in grant funds.

Example 3 – Passenger Replacement with HEP (Class 3 Railroad)

A railroad wants to replace a 1998 Tier 0+ passenger locomotives (with Tier 2 off-road head-end power unit (HEP)), with a U.S. EPA-certified and CARB verified Tier 4 Passenger locomotive (with Tier 4 Final off-road HEP). Fuel receipts indicate the baseline locomotive consumes a combined 60,000 gallons of fuel per year (with the HEP portion consuming 12,000 gallons). This project has 100 percent operation in California. The cost of the new passenger locomotive (with HEP) is \$6 million. The project life is 15 years.

Baseline Technology Information

- Locomotive model year (application): 1998 (Tier 0+)
- Locomotive emission rate (Table D-14b):

Engine Model Year	Type	NOx	ROG	PM10
1973-2001 Tier 0+	Line-haul and Passenger	6.96 g/bhp-hr	0.58 g/bhp-hr	0.189 g/bhp-hr

- Locomotive Activity (application): 48,000 gal/yr
- Locomotive Fuel Consumption Rate (Table D-21): 20.8 bhp-hr/gal
- HEP Engine (application): Tier 2 and 550 Horsepower
- HEP emission rate (Table D-9):

Horsepower	Tier	NOx	ROG	PM10
300-750	2	3.79 g/bhp-hr	0.09 g/bhp-hr	0.088 g/bhp-hr

- HEP Activity (application): 12,000 gal/yr
- HEP Fuel Consumption Rate (Table D-21): 18.5 bhp-hr/gal

Reduced Technology Information

- Locomotive emission rate (Table D-14b):

Engine Model Year	Type	NOx	ROG	PM10
2015 Tier 4	Line-haul and Passenger	1.22 g/bhp-hr	0.15 g/bhp-hr	0.026 g/bhp-hr

- Locomotive Activity (application): 48,000 gal/yr
- Locomotive Fuel Consumption Rate (Table D-21): 20.8 bhp-hr/gal
- HEP Engine: Tier 4 (Final) and 550 Horsepower
- HEP emission rate (Table D-9):

Horsepower	Tier	NOx	ROG	PM10
300-750	4 (Final)	0.26 g/bhp-hr	0.05 g/bhp-hr	0.009 g/bhp-hr

- HEP Activity (application): 12,000 gal/yr
- HEP Fuel Consumption Rate (Table D-21): 18.5 bhp-hr/gal
- Discount rate is 1% and project life is 15 years; CRF (Table D-24): 0.072
- Maximum eligible percentage: 85%
- Cost of new engine (application): \$6,000,000
- Cost-effectiveness limit: \$30,000/weighted ton

(a) Calculate emission reductions for a Tier 0+ to a Tier 4

Formula C-7: Estimated annual emissions based on fuel consumed using emission factors or converted emission standard (tons/yr):

*Annual emissions by pollutant (tons/yr) = (emission factor (g/bhp-hr) * Fuel Consumption Rate (bhp-hr/gal)) * (activity (gal/yr) * percentage operation in CA * ton / 907,200g*

(1) Calculate the estimated annual emissions for baseline and reduced locomotive, for each pollutant (tons/yr):

Annual NOx **baseline** technology emissions
(6.96 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 7.6597 ton/yr

Annual NOx **reduced** technology emissions
(1.22 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 1.3426 ton/yr

Annual ROG **baseline** technology emissions
(0.58 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 0.6383 ton/yr

Annual ROG **reduced** technology emissions
(0.15 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 0.1651 ton/yr

Annual PM **baseline** technology emissions
(0.189 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 0.2080 ton/yr

Annual PM **reduced** technology emissions
(0.026 g/bhp-hr * 20.8 bhp-hr/gal) (48,000 gal/yr) * 100% * (ton/907,200 g)
= 0.0286 ton/yr

(2) Calculate the estimated annual emissions for baseline and reduced HEP, for each pollutant (tons/yr):

Annual NOx **baseline** technology emissions
 $(3.79 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.9274 \text{ ton/yr}}$

Annual NOx **reduced** technology emissions
 $(0.26 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.0636 \text{ ton/yr}}$

Annual ROG **baseline** technology emissions
 $(0.09 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.0220 \text{ ton/yr}}$

Annual ROG **reduced** technology emissions
 $(0.05 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.0122 \text{ ton/yr}}$

Annual PM **baseline** technology emissions
 $(0.088 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.0215 \text{ ton/yr}}$

Annual PM **reduced** technology emissions
 $(0.009 \text{ g/bhp-hr} * 18.5 \text{ bhp-hr/gal}) (12,000 \text{ gal/yr}) * 100\% * (\text{ton}/907,200 \text{ g})$
 $= \underline{0.0022 \text{ ton/yr}}$

(3) Calculate annual surplus emission reductions by pollutant(tons/yr)

Formula C-9: Annual surplus emission reductions (tons/yr)
Annual surplus emission reductions (by pollutant) = annual emissions for the baseline technology – annual emissions for the reduced technology

Locomotive Portion:

Annual NOx surplus emission reductions (tons/yr)
 $= 7.6597 \text{ tons/yr} - 1.3426 \text{ tons/yr} = \underline{6.3171 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.6383 \text{ tons/yr} - 0.1651 \text{ tons/yr} = \underline{0.4732 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0.2080 \text{ tons/yr} - 0.0286 \text{ tons/yr} = \underline{0.1794 \text{ tons/yr}}$

HEP Portion:

Annual NOx surplus emission reductions (tons/yr)
 $= 0.9274 \text{ tons/yr} - 0.0636 \text{ tons/yr} = \underline{0.8638 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.0220 \text{ tons/yr} - 0.0122 \text{ tons/yr} = \underline{0.0098 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0.0215 \text{ tons/yr} - 0.0022 \text{ tons/yr} = \underline{0.0193 \text{ tons/yr}}$

(4) Calculate annual weighted surplus emission reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

$$\begin{aligned} &\text{Annual weighted surplus emission reductions (weighted tons/yr)} \\ &= (6.3171 + 0.8638) \text{ (tons/yr NOx)} + (0.4732 + 0.0098) \text{ (tons/yr ROG)} + \\ &\quad (20 * (0.1794 + 0.0193) \text{ (tons/yr PM)}) \\ &= \underline{\underline{11.6379 \text{ weighted tons /yr}}} \end{aligned}$$

(b) Determine the maximum grant amount

(1) Potential grant amount at the \$30,000 cost-effectiveness limit

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

$$\text{Potential grant amount} = (\$30,000 * 11.6379 \text{ tons/yr}) / 0.072 = \underline{\underline{\$4,849,125}}$$

(2) Potential grant amount based on maximum percentage of eligible cost (\$)

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

$$\text{Potential grant amount} = \$6,000,000 * 85\% = \underline{\underline{\$5,100,000.00}}$$

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$4,849,125** in grant funds.

IV. Marine Vessels

Example 1 – Repower: Fishing Vessel Propulsion Engine

An applicant wants to repower a propulsion engine on a charter fishing vessel. The baseline engine is uncontrolled and is model year (MY) 2003. The applicant wishes to replace it with a MY 2017 Tier 3 engine. The Commercial Harbor Craft Regulation does not require charter-fishing vessels to replace their engines so there is no regulatory deadline for the project. The owner will commit to a project life of 7 years.

Baseline Technology Information

- Baseline technology (application): EMY 2003 uncontrolled charter fishing vessel
- Emission factors (EF) (Table D-15a):

	NOx	ROG	PM
EF	8.97 g/bhp-hr	0.49 g/bhp-hr	0.260 g/bhp-hr

- Activity (application): 1300 hrs/yr
- Horsepower: 330 hp
- Load factor (Table D-18b): 0.52
- Discount rate is 1% and project life is 7 years; CRF (Table D-24): 0.149
- Percentage operation in California (application): 100%

Reduced Technology Information

- Reduced technology (application): EMY 2017 Tier 3 charter fishing vessel
- Emission factors (EF) (Table D-15b):

	NOx	ROG	PM
EF	3.87 g/bhp-hr	0.49 g/bhp-hr	0.068 g/bhp-hr

- Horsepower: 330 hp
- Wet exhaust multiplier (Chapter 7: L(1),(I)): 0.8
- Cost of reduced technology: \$60,000
- Maximum eligible amount for a charter fishing vessel repower (Table 7-2): 80%
- Cost-effectiveness limit: \$30,000 per weighted ton of emission reductions

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

- (1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr):

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

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

Annual NOx **baseline** technology emissions

$$8.97 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$$

$$= \underline{2.2057 \text{ tons/yr}}$$

Annual NOx **reduced** technology emissions

$$3.87 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$$

$$= \underline{0.9516 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions
 $0.49 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.1205 \text{ tons/yr}}$

Annual ROG **reduced** technology emissions
 $0.49 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.1205 \text{ tons/yr}}$

Annual PM **baseline** technology emissions
 $0.260 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0639 \text{ tons/yr}}$

Annual PM **reduced** technology emissions
 $0.068 \text{ (g/bhp-hr)} * 330 \text{ (hp)} * 0.52 * 1,300 \text{ (hrs/yr)} * 100\% / 907,200 \text{ (g/ton)}$
 $= \underline{0.0167 \text{ tons/yr}}$

(2) Calculate the estimated annual emission reductions for each pollutant (tons/yr):

Formula C-9: Annual surplus emission reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual NO_x surplus emission reductions (tons/yr)
 $= 2.2057 \text{ (tons/yr)} - 0.9516 \text{ (tons/yr)} = \underline{1.2541 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.1205 \text{ (tons/yr)} - 0.1205 \text{ (tons/yr)} = \underline{0.0000 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0.0639 \text{ (tons/yr)} - 0.0167 \text{ (tons/yr)} = \underline{0.0472 \text{ tons/yr}}$

(3) Apply a wet exhaust factor of 0.80 (Chapter 7, Section C.1.(I)) to each pollutant (tons/yr):

Annual NO_x surplus emission reductions (tons/yr)
 $= 0.80 * 1.2541 \text{ (tons/yr)} = \underline{1.0033 \text{ tons/yr}}$

Annual ROG surplus emission reductions (tons/yr)
 $= 0.80 * 0.1205 \text{ (tons/yr)} = \underline{0.0000 \text{ tons/yr}}$

Annual PM surplus emission reductions (tons/yr)
 $= 0.80 * 0.0472 \text{ (tons/yr)} = \underline{0.0378 \text{ tons/yr}}$

(4) Calculate annual weighted surplus emission reductions (weighted tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NO_x reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 1.0033 (tons/yr NO_x) + 0.0000 (tons/yr ROG) + (20 * 0.0378 (tons/yr PM))
= **1.7593 weighted tons/yr**

(b) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit (\$):

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)
*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = 30,000 (\$/ton) * 1.7593 (tons/yr) / 0.149 = **\$354,221**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)
*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$60,000 * 80% = **\$48,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$48,000** in grant funds.

Example 2 – Repower: Tow Boat Auxiliary Engine

A participant wants to repower an auxiliary engine on a tow boat. The current engine is a 2007 Model Year Tier 1 engine and the participant wishes to replace it with a 2017 Tier 3 engine. Since the Commercial Harbor Craft Regulation requires this engine to be replaced with a Tier 3 by December 31st, 2022 the project life may not extend beyond this date. The repower shall be completed by December 31, 2018, so the owner agrees to the maximum project life of 4 years.

Baseline Technology Information

- Baseline technology (application): EMY 2007
- Emission Certification: Tier 1
- Horsepower: 115
- Emission factor (EF) (Table D-17b)

	NOx	ROG	PM
EF	6.93 (g/bhp-hr)	0.85 (g/bhp-hr)	0.464 (g/bhp-hr)

- Activity (application): 925 hours/year

Reduced Technology Information

- Reduced technology (application): EMY 2017
- Emission Certification: Tier 3
- Emission rates (Table D-17b)

	NOx	ROG	PM
EF	5.04 (g/bhp-hr)	0.85 (g/bhp-hr)	0.176 (g/bhp-hr)

- Horsepower: 115
- Activity (application): 925 hours/year
- Load Factor (Table D-18): .43
- Discount rate 1% and project life is 4 years; CRF (Table D-24):0.256
- 100% operated in California
- Moyer Eligible Project Cost: \$25,000
- Maximum eligible funding amount for a tow boat repower (Table 7-2):50%
- Cost-effectiveness limit: \$30,000 per weighted ton

(a) Determine emission reduction calculations for a Tier 1 to Tier3:

(1) Calculate the estimated annual emissions for baseline and reduced equipment, for each pollutant (tons/yr)

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)

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

Annual NOx **baseline** technology emissions

$(6.93\text{g/bhp}\cdot\text{hr}) * 115 \text{ horsepower} * .43 * 925 \text{ hours/yr} * 100\% * 1/907,200\text{g}$
= 0.3494 tons/yr

Annual NOx **reduced** technology emissions

$(5.04 \text{ g/bhp}\cdot\text{hr}) * 115 \text{ horsepower} * .43 * 925 \text{ hours/yr} * 100\% * 1/907,200\text{g}$
= 0.2541 tons/yr

Annual ROG **baseline** technology emissions
(.85 g/bhp*hr) * 115 horsepower * .43 * 925 hours/yr * 100% * 1/907,200g)
= 0.0429 tons/yr

Annual ROG **reduced** technology emissions
(.85 g/bhp*hr) * 115 horsepower * .43 * 925 hours/yr * 100% * 1/907,200g)
= 0.0429 tons/yr

Annual PM **baseline** technology emissions
(.464g/bhp*hr * 115 horsepower * .43 * 925 hours/yr * 100% * 1/907,200g)
= 0.0234 tons/yr

Annual PM **reduced** technology emissions
(.176 g/bhp*hr * 115 horsepower * .43 * 925 hours/yr * 100% *
1/907,200g) = 0.0089 tons/yr

(2) Calculate Annual Surplus Emission Reductions by Pollutant (tons/yr) Formula

C-9: Annual surplus emissions reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual vessel surplus NOx emissions reductions (tons/yr)

= 0.3494 tons/yr - 0.2541 tons/year = 0.0953 tons/yr NOx

Annual vessel surplus ROG emission reductions (tons/yr)

= 0.0429 tons/yr - 0.0429 tons/yr = 0.000 tons/yr ROG

Annual vessel surplus PM emission reductions (tons/yr)

= 0.0234 tons/yr - 0.0089 tons/yr = 0.0145 tons/yr PM

(3) Calculate annual weighted surplus emission reductions (tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

= 0.0953(tons/yr NOx) + 0.000 (tons/yr ROG) + (20 * 0.0145 (tons/yr PM))

= 0.3853 weighted tons /yr

(b) Determine the maximum grant amount:

(1) Calculate the potential grant amount at the \$30,000 cost-effectiveness limit

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 0.3853 tons/yr) / 0.256 = \$45,152

(2) Potential grant amount based on maximum percentage of eligible cost (\$) Formula

C-14: Potential grant amount based on maximum percentage of eligible cost (\$) *Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount = \$25,000 * 50% = \$12,500

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$12,500 in grant funds.

Example 3 – Container Vessel (Ship Side) Shore Power

A shipping company wants to install ship side shore power on one of its container vessels. The vessel's capacity is 3,500 twenty-foot equivalent units and it typically uses marine gas oil (MGO) with a sulfur content of less than 0.10 percent. The fleet's strategy for compliance with the Shore Power Regulation uses other vessels to satisfy the required fraction of visits using shore power at all future milestones, so the vessel in this project is therefore surplus to the requirement. The applicant has committed to a 5 year project life.

Baseline Technology Information

- Vessel emission factor (EF) (Table D-19):

	NO_x	ROG	PM
EF	13.9 (g/kW-hr)	0.49 (g/kW-hr)	0.25 (g/kW-hr)

- Average Berthing Time: 24 hours per visit
- Number of Visits to California Ports: 5 visits per year
- Ship Capacity: 3,500 twenty-foot equivalent units
- Ship Power Requirement (Table D-20): 1,900 kW
- Moyer Eligible Project Cost:
 - \$350,000 for ship retrofit
 - \$150,000 for transformer
- Maximum Eligible Funding Percentage (Table 7-3):
 - 100% of ship retrofit
 - 50% of transformer
- Shore Power Emission Reduction Factor (Chapter 7, Section 6 (H)): 0.9
- Discount rate 1% and project life is 5 years; CRF (Table D-24): 0.206

(a) Determine emission reduction calculations for shore power conversion:

(1) Calculate the estimated annual emission reductions by pollutant(tons/yr):

Formula C-8: Estimated annual emissions for shore power systems (tons/yr)
*Annual emission reductions by pollutant (tons/yr) = ship emission factor (g/kW-hr) * power requirements (kW) * berthing time (hrs/visit) * annual number of visits * shore power emission reduction factor * 1 ton/907,200g*

Annual NO_x surplus emission reductions (tons/yr)
= 13.9 g/kW-hr * 1,900 kW * 24 hrs/visit * 5 visits * 0.9 * 1 ton /907,200g = 3.1440 tons/yr

Annual ROG surplus emission reductions (tons/yr)
= .49 g/kW-hr * 1,900 kW * 24 hrs/visit * 5 visits * 0.9 * 1 ton /907,200g = 0.1108 tons/yr

Annual PM surplus emission reductions (tons/yr)
=.25 g/kW-hr * 1,900 kW * 24 hrs/visit * 5 visits * 0.9 * 1 ton /907,200g = 0.0565 tons/yr

(2) Calculate annual weighted surplus emission reductions (tons/yr):

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)
*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)
= 3.1440 (tons/yr NOx) + 0.1108 (tons/yr ROG) + (20 * 0.0565 (tons/yr PM))
= **4.3848 weighted tons/yr**

(b) Determine the maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 4.3848 tons/yr) / 0.206 = **\$638,563**

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Ship Retrofit = \$350,000 * 100% = \$350,000

Transformer Cost = \$150,000 * 50% = \$75,000

Potential grant amount = **\$425,000**

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to **\$425,000** in grant funds.

Example 4 – Installation of an EPA verified Hybrid System on a Tug Boat

A participant wants to install a verified hybrid system on a tug boat. The hybrid system is verified by EPA to reduce the total NOx, ROG, and PM emitted by the vessel. The Moyer eligible cost of this system is \$1,500,000. The tug boat has two identical Tier 3 propulsion engines and two identical Tier 2 Auxiliary engines. The vessel operates 100% of the time in California waters. Under the Commercial Harbor Craft Regulation there is no requirement for this vessel to upgrade the baseline engines. The applicant has committed to a 5 year project life.

Baseline Technology Information

Propulsion Engine (application)

- Emission certification: Tier 3
- Horsepower: 2,000
- Emission factors (EF) (Table D-15b):

	NOx	ROG	PM
EF	4.14 (g/kW-hr)	0.49 (g/kW-hr)	0.085 (g/kW-hr)

- Activity (application): 2,500 hrs/yr
- Load factor (Table D-18): 0.50

Auxiliary Engine (application)

- Emission certification: Tier 2
- Horsepower: 200
- Emission factors (EF) (Table D-17b):

	NOx	ROG	PM
EF	4.84 (g/kW-hr)	0.58 (g/kW-hr)	0.120 (g/kW-hr)

- Activity (application): 3,200 hrs/yr
- Load factor (Table D-18): 0.31

Reduced Technology Information

- Reduced technology (application): EPA Verified Marine Vessel Hybrid System
- EPA Verified Hybrid System emission reduction amounts (total vessel emissions):

	NOx	ROG	PM
Emission Reduction Percentage	30%	15%	25%

- Cost of reduced technology: \$1,500,000
- Maximum eligible amount for a hybrid system (Table 7- 2): 85%
- Cost-effectiveness limit: \$30,00 per weighted ton
- Discount rate 1% and protect life is 5 years; CRF (Table D-24): 0.206
- Percentage of operation in California (application): 100%

(a) Determine emission reduction calculations for a hybrid system:

(1) Calculate the estimated annual emissions for each pollutant (tons/yr)

Formula C-6: Estimated annual emissions based on hours of operation (tons/yr)
*Annual emissions by pollutant (tons/yr) = [emission factor (g/bhp-hr) + deterioration product (g/bhp-hr) (if applicable)] * horsepower (hp) * load factor * activity (hrs/yr) * percentage operation in CA * ton / 907,200g*

Propulsion engine:

Annual NOx **baseline** technology emissions

$$(4.14 \text{ g/bhp*hr}) * 2000 \text{ horsepower} * .50 * 2500 \text{ hours/yr} * 100\% * 1/907,200\text{g}$$

$$= \underline{11.4087 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions

$$(.49 \text{ g/bhp*hr}) * 2000 \text{ horsepower} * .50 * 2500 \text{ hours/yr} * 100\% * 1/907,200\text{g}$$

$$= \underline{1.3503 \text{ tons/yr}}$$

Annual PM **baseline** technology emissions

$$(.085\text{g/bhp*hr} * 2000 \text{ horsepower} * .50 * 2500 \text{ hours/yr} * 100\% * 1/907,200\text{g})$$

$$= \underline{0.2342 \text{ tons/yr}}$$

Auxiliary engine:

Annual NOx **baseline** technology emissions

$$(4.84 \text{ g/bhp*hr}) * 200 \text{ horsepower} * .31 * 3200\text{hours/yr} * 100\% * 1/907,200\text{g}$$

$$= \underline{1.0585 \text{ tons/yr}}$$

Annual ROG **baseline** technology emissions

$$(.58 \text{ g/bhp*hr}) * 200 \text{ horsepower} * .31 * 3200 \text{ hours/yr} * 100\% * 1/907,200\text{g}$$

$$= \underline{0.1268 \text{ tons/yr}}$$

Annual PM **baseline** technology emissions

$$(.120 \text{ g/bhp*hr} * 200 \text{ horsepower} * .31 * 3200 \text{ hours/yr} * 100\% * 1/907,200\text{g})$$

$$= \underline{0.0262 \text{ tons/yr}}$$

(2) Combine emissions for all engines on the vessel to total vessel baseline emissions for each pollutant:

Formula C-13: Total annual surplus emission reductions for marine vessels (tons/yr)

*Total annual surplus emission reductions for marine vessels by pollutant (tons/yr) = (propulsion engine annual surplus emission reductions (tons/yr) * number of propulsion engines + (auxiliary engine annual surplus emission reductions (tons/yr) * number of auxiliary engines)*

Total Vessel NOx **baseline** technology emissions (tons/yr)

= 11.4087 tons/yr * 2 propulsion engines + 1.0585 tons/yr * 2 auxiliary engines

= 24.9344 tons/yr

Total Vessel ROG **baseline** technology emissions (tons/yr)

= 1.3503 tons/yr * 2 propulsion engines + .1268 tons/yr * 2 auxiliary engines

= 2.9542 tons/yr

Total Vessel PM **baseline** technology emissions (tons/yr)

= 0.2342 tons/yr * 2 propulsion engines + .0262 tons/yr * 2 auxiliary engines

= 0.5208 tons/yr

(3) Calculate annual surplus emission reductions by pollutant(tons/yr)

Formula C-9: Annual surplus emissions reductions (tons/yr)

Annual surplus emission reductions by pollutant (tons/yr) = annual emissions for the baseline technology (tons/yr) – annual emissions for the reduced technology (tons/yr)

Annual Vessel Surplus NOx Reductions (tons/yr)

24.9344 tons/yr * 30%= 7.4803 tons/yr

Annual Vessel Surplus ROG Reductions (tons/yr)

2.9542 tons/yr * 15%= 0.4431 tons/yr

Annual Vessel Surplus PM Reductions (tons/yr)

0.5208 tons/yr * 25%= 0.1302 tons/yr

(4) Calculate annual weighted surplus emission reductions (weighted tons/yr)

Formula C-3: Annual weighted surplus emission reductions (weighted tons/yr)

*Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

= 7.4803 (tons/yr NOx) + 0.4431 (tons/yr ROG) + (20 * 0.1302 (tons/yr PM))

= 10.5274 weighted tons /yr

(b) Determine the Maximum Grant Amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 10.5274 tons/yr) / 0.206 = \$1,533,117

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost (%)*

Potential grant amount for a hybrid system = \$1,500,000 * 85% = \$1,275,000

The lower result of the two calculations above is the maximum grant amount:

Maximum grant amount: This project qualifies for up to \$1,275,000 in grant funds.

V. Light-Duty Vehicles

Example 1 – Conventional VAVR Project

A district pays \$1,000 to an enterprise operator to retire a model year (MY) 1995 light-duty gasoline powered vehicle in calendar year (CY) 2017. District costs including vehicle testing and dismantler fees are an additional \$125 for a total project cost of \$1,125. All VAVR projects have a three-year project life and are eligible for up to 100 percent of funding or \$1,500, whichever is less.

Baseline Technology / Retired Vehicle Information

- MY of retired vehicle: 1995 gasoline powered light-duty vehicle
- Calendar year of vehicle retirement: 2017
- Emission rates (ER) (Table 8-2):

	ROG	NOx	PM10
ER	75.7 lbs/3yr	52.7 lbs/3yr	0.59 lbs/3 yr

- Discount rate is 1% and project life is 3 years; CRF (Table D-24): 0.340
- Cost-effectiveness limit: \$30,000
- Project cap (Chapter 8, Section B): \$1,500

(a) Determine emission reductions for 1995 MY vehicle in the CY of retirement:

(1) Convert emission rates to tons/yr:

$$\text{ROG} = 75.7 \text{ lbs} / (3 \text{ yrs} * 2,000 \text{ lbs/ton}) = 0.0126 \text{ tons/yr ROG}$$

$$\text{NOx} = 52.7 \text{ lbs} / (3 \text{ yrs} * 2,000 \text{ lbs/ton}) = 0.0088 \text{ tons/yr NOx}$$

$$\text{PM} = 0.59 \text{ lbs} / (3 \text{ yrs} * 2,000 \text{ lbs/ton}) = 0.0001 \text{ tons/yr PM}$$

(2) Calculate the annual weighted surplus emission reductions (tons/yr): Formula

C-3: Annual weighted surplus emission reductions (weighted tons/yr) *Weighted emission reductions (weighted tons/yr) = NOx reductions (tons/yr) + ROG reductions (tons/yr) + (20 * PM reductions (tons/yr))*

Annual weighted surplus emission reductions (weighted tons/yr)

$$= 0.0126 \text{ tons/yr ROG} + 0.0088 \text{ tons/yr NOx} + (20 * 0.0001 \text{ (tons/yr PM)})$$

$$= \mathbf{0.0234 \text{ weighted tons/yr}}$$

(b) Determine the potential maximum grant amount:

(1) Potential grant amount at the \$30,000 cost-effectiveness limit:

Formula C-1: Potential grant amount at the cost-effectiveness limit (\$)

*Potential grant amount (\$) = cost-effectiveness limit (\$/ton) * estimated annual emission reductions (weighted tons/yr) / CRF*

Potential grant amount = (\$30,000 * 0.0234 tons/yr) / 0.340 = \$2,065

(2) Potential grant amount based on maximum percentage of eligible cost (\$):

Formula C-14: Potential grant amount based on maximum percentage of eligible cost (\$)

*Potential grant amount (\$) = cost of reduced technology (\$) * maximum percentage of eligible cost*

Potential grant amount = \$1,125 * 100% = \$1,125

(3) Potential grant amount at the funding cap when applicable (\$):

VAVR project funding cap (Chapter 8, Section B)

Potential grant amount = \$1,500

The lowest result of the three calculations above is the maximum grant

amount: Maximum grant amount: This project qualifies for up to \$1,125 in grant funds.

VI. Infrastructure

Example 1 – Natural Gas Fueling Station to support an On-Road Heavy Duty CNG Refuse Hauler

This infrastructure calculation is a continuation of the On-Road Heavy-duty diesel to CNG refuse hauler truck replacement example calculation located in Section I (page 23), Example 6.

A refuse fleet owner, a public entity, is seeking Moyer funding for a new, medium sized, fast-fill natural gas fueling station. The natural gas fueling station will be publicly accessible, and the air district board has approved this project under its competitive bidding process. Since this project is publicly accessible, it is eligible to receive up to 60 percent of the total eligible project costs. The eligible cost estimates as outlined in the bid are \$1.0 million. The following calculation will be used to determine the applicant's eligible grant amount:

*Applicant Eligible Grant Amount for Infrastructure = (Moyer Eligible Project Cost) * (Maximum Percentage of Eligible Cost)*

Applicant Eligible Grant Amount for Infrastructure = \$1,000,000 * 0.60 = \$600,000

As a result, the applicant is eligible to receive up to an amount of \$600,000 towards the natural gas fueling station. Also, with the grant of up to \$34,699 for the CNG refuse hauler replacement, the applicant is eligible for a combined grant of up to 634,699.

Example 2 – Battery Charging Station to support an Off-Road Electric Forklift

This infrastructure calculation is a continuation of the Off-Road LSI to electric forklift replacement example calculation located in Section II (page 62), Example 6.

Company X, a non-public entity, is seeking Moyer funds for a battery charger for an electric forklift capacity located at a privately situated distribution center. The eligible cost estimates as outlined in the bid are \$4,500. The applicant is eligible to receive up to 50 percent of the total eligible project cost. The following will be used to determine the applicant's eligible grant amount:

*Applicant Eligible Grant Amount for Infrastructure = (Moyer Eligible Project Cost) * (Maximum Percentage of Eligible Cost)*

Applicant Eligible Grant Amount for Infrastructure = \$4,500 * 0.50 = \$2,250

As a result, the applicant is eligible to receive up to \$2,250 towards the battery charger. Also, with the grant of up to \$56,480 for the electric forklift replacement, the applicant is eligible for a combined grant of up to \$58,730.

Example 3 – Stationary Agricultural Pump Electrification to support a Stationary Agricultural Pump

This infrastructure calculation is a continuation from the Stationary Agricultural Pump diesel to electric repower example calculation located in Section II (page 79), Example 9.

An applicant is seeking Moyer funding for an electrification project to serve a 75 kW (100 hp) electric stationary agricultural pump. The necessary infrastructure including 1500 feet of underground wire installation, transformer etc. costs \$32,000. The applicant is eligible to receive up to 50 percent of the total eligible project cost. The following calculation will be used to determine the applicant's eligible grant amount:

*Applicant Eligible Grant Amount for Infrastructure = (Moyer Eligible Project Cost) * (Maximum Percentage of Eligible Cost)*

Applicant Eligible Grant Amount for Infrastructure = \$32,000 * 0.50 = \$16,000

As a result, the applicant is eligible to receive up to \$16,000 towards the stationary agricultural pump electrification. Also, with a grant of up to \$29,750 for the diesel to electric stationary agricultural pump repower, the applicant is eligible for a combined grant of up to \$45,750.

Example 4 – Battery Charging Station with Solar Power System to support a Light-Duty Vehicle

An applicant is seeking funding for a Level 2, publicly accessible, battery charging station with a solar power system. At least 50 percent of the energy provided to covered sources by the project is generated from solar. Since this project is publicly accessible and includes a solar power system, it is eligible to receive up to 75 percent funding. The air district board has approved this project under its competitive bidding process. The eligible cost estimates as outlined in the bid are \$65,000. The following calculation will be used to determine the applicant's eligible grant amount:

*Applicant Eligible Grant Amount for Infrastructure = (Moyer Eligible Project Cost) * (Maximum Percentage of Eligible Cost)*

Applicant Eligible Grant Amount for Infrastructure = \$65,000 * 0.75 = \$48,750

As a result, the applicant is eligible to receive up to an amount of \$48,750.