

APPENDIX C: COST-EFFECTIVENESS CALCULATION METHODOLOGY

A. Introduction

Cost-effectiveness is the measure of dollars provided to a project for each ton of covered emissions reduced. Statute requires that the California Air Resources Board (CARB) update the cost-effectiveness limit and capital recovery factors (CRF) annually. In addition, changes in statute per SB 513 now allow CARB, in consultation with air quality management districts and air pollution control districts (air districts), to establish new cost-effectiveness limits that reflect the cost of regulations and technology.

To determine a project's cost-effectiveness, all Moyer Program funds, air district match funds, and local AB 923 funds must be included. Non-Moyer funds used to co-fund a Moyer eligible project do not need to be included in the cost-effectiveness calculation. Projects that include such funds must meet all Moyer requirements and the other funding source requirements.

Projects are subject to the cost-effectiveness limits in Table C-1, which shows the changes in the cost-effectiveness limit over time based on changes in the Consumer Price Index. Historically, one limit has been applied to all Moyer Program projects. Per SB 513, a second cost-effectiveness limit for school buses was added in 2016 as shown in the table.

Table C-1 Historical Cost-Effectiveness Limit Criteria 1998-2017

Year	Annual CA CPI	Percentage change (inflation rate)	Annual Change	Revised C/E Limit
1998	163.7	NA	NA	\$12,000
1999	168.5	2.93%	\$352	\$12,352
2000	174.8	3.74%	\$462	\$12,814
2001	181.7	3.95%	\$506	\$13,319
2002	186.1	2.42%	\$323	\$13,642
2003	190.4	2.31%	\$315	\$13,957
2004	195.4	2.63%	\$367	\$14,324
2005	202.6	3.68%	\$528	\$14,852
2006	210.5	3.90%	\$579	\$15,431
2007	217.4	3.28%	\$506	\$15,938
2008	224.8	3.40%	\$541	\$16,479
2009	224.1	-0.31%	(\$51)	\$16,428
2010	227	1.29%	\$212	\$16,640

Table C-1 Cost-Effectiveness Limit Criteria 1998- 2017 (Continued)

Year	Annual CA CPI	Percentage change (inflation rate)	Annual Change	Revised C/E Limit
2011	233	2.66%	\$443	\$17,084
2012	238.3	2.25%	\$385	\$17,469
2013	241.8	1.46%	\$255	\$17,724
2014	246.1	1.77%	\$313	\$18,037
2015	249.1	1.25%	\$225	\$18,262
2016 Base	No C/E update pending 2017 guideline update	n/a	n/a	\$18,262
2016 School Bus	New C/E Limit under SB 513	n/a	n/a	\$276,230
2017 Base	New C/E Limit under SB 513	n/a	n/a	\$30,000
2017 Optional Advanced Technology	New C/E Limit under SB 513	n/a	n/a	\$100,000

Table C-2 shows the 2021 cost-effectiveness limits adopted by the Board in 2021 for these Guidelines. Table C-3 shows the cost-effectiveness limits effective the date in the footer for these Guidelines, which includes adjustments due to inflation. As shown, the following cost-effectiveness limits are available: one to support conventional projects, one specific to school bus projects, and higher cost-effectiveness limits that air districts may choose to apply to the additional reductions provided by the cleanest engines or equipment, including those needed for long-term SIP commitments.

Base Limit: The base cost-effectiveness limit is \$34,000 per weighted ton of emissions reductions. This level allows full funding for a wide range of conventional projects, such as diesel replacement projects where surplus to regulations. The level is consistent with the cost of compliance with regulations and will enable grants of sufficient size to encourage off-road engines to be replaced or repowered sooner to a Tier 4 standard.

Optional Advanced Technology Limits: For advanced technology projects that are zero-emission, or alternatively meet the cleanest optional standard level certified, air districts have the option to apply a cost-effectiveness limit for the emissions reductions beyond those achieved by the required standard. For on-road heavy-duty projects that meet the optional certified advanced technology standard, like the 0.02 g/bhp-hr NOx standard engine or cleaner, air districts have the option to apply a higher cost-effectiveness of \$209,000 per weighted ton for the emissions reductions beyond the required standard. For on-road heavy-duty projects that meet the optional certified zero-emission technology standard and for off-road optional zero-emission projects, air districts have the option to apply a higher cost-effectiveness of \$522,000 per weighted ton for the emissions reductions beyond the required standard. To be eligible, the engine must be:

- Zero-emission or meet the cleanest optional emission standard where applicable
 - o For on-road optional advanced technologies, a certified 0.02 g/bhp-hr NOx standard or cleaner;
 - o For on-road zero-emission technologies, a certified zero-emission standard;
- Commercially available and offered for sale; and
- Certified or verified by CARB or the United States Environmental Protection Agency

The optional Advanced Technology's higher cost-effectiveness limits are applied only to the incremental emission reductions beyond what the conventional project would achieve. An air district would apply the base cost-effectiveness limit for costs associated with getting engines to the cleanest required standard, and then could apply the appropriate advanced technology limit to the additional costs of getting emissions down to or below the cleanest optional standard.

**Table C-2
Cost-Effectiveness Limit Criteria 2021**

Year	Project	Proposed Change or Status	Revised C/E Limit
2021	Base Limit	New C/E Limit	\$33,000
2021	Optional Advanced Technology Limit	New C/E Limit for incremental reductions from specified advanced technologies	\$109,000
2021	On-road Optional Advanced Technology Limit	New C/E Limit for incremental reductions from on-road advanced technologies	\$200,000
2021	On-road Zero-Emission Technology Limit	New C/E Limit for incremental reductions from on-road zero-emission technologies	\$500,000
2021	School Bus	2016 C/E Limit retained in 2017 Guidelines	\$300,000

**Table C-3
Cost-Effectiveness Limit Criteria effective December 2022**

Year	Project	Proposed Change or Status	Revised C/E Limit
2022	Base Limit	New C/E Limit	\$34,000
2022	Off-road Zero-Emission Technology Limit	New C/E Limit for incremental reductions from off-road zero-emission technologies	\$522,000
2022	On-road Optional Advanced Technology Limit	New C/E Limit for incremental reductions from on-road advanced technologies	\$209,000
2022	On-road Zero-Emission Technology Limit	New C/E Limit for incremental reductions from on-road zero-emission technologies	\$522,000
2022	School Bus	2016 C/E Limit retained in 2017 Guidelines	\$313,000

For projects in source categories without optional standards, only vehicles certified as zero-emission would be eligible for the higher cost-effectiveness limit. In these cases, the higher limit would apply to the incremental reductions below the most stringent standard for that category. General calculations for determining cost-effectiveness and other calculations needed to administer the Moyer Program are described in the following pages.

B. General Cost-Effectiveness Calculations

1. Determining the Maximum Grant Amount

The calculation methodology below must be applied in order to ensure final grant amounts meet the cost-effectiveness limit requirement, and do not exceed incremental cost based on the maximum percentage or any other funding caps. For advanced technology projects that include a baseline vehicle dirtier than the cleanest required standard, the calculations in (A), (B), and (C) below must be applied twice. The project life may differ between the first and second series of calculations, depending on availability of surplus emission reductions. The first series of calculations is made using the base cost-effectiveness limit and the emission reductions going up to the cleanest required standard (including deterioration), and the second series of calculations is made using the advanced technology cost-effectiveness limit and the emission reductions beyond the cleanest required standard. The final maximum grant amount is equal to the combined total of the lowest values from each series. Note that school bus projects are subject to funding caps and a separate cost-effectiveness limit as listed above in Table C-2. The maximum grant amount for any given project is the lowest of the three following calculations:

- The potential grant amount at the cost-effectiveness limit;
- The potential grant amount based on maximum percentage of eligible cost; or
- The potential grant amount based on any maximum dollar amount or other funding cap specified in the relevant source category chapter.

Each of the above values is calculated as follows:

- (A) The potential grant amount at the cost-effectiveness limit is determined by multiplying the cost-effectiveness limit by the estimated annual emission reductions and dividing by the CRF in formula C-1 below.

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

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

The CRF is based on a discount rate. The CRF uses an interest rate and project life to determine the rate at which earnings could reasonably be expected to accrue if the same funds were invested over that length of time. The CRF may be calculated using Formula C-2 below, or you may refer to Tables D-24 and D25 in Appendix D for CRFs at various project lives. Each source category chapter will specify which project lives are acceptable to determine which CRF value to use.

Formula C-2: Capital recovery factor

$$\text{Capital recovery factor} = (1 + \text{discount rate}^{(a)})^{\text{project life}} * \text{discount rate} / ((1 + \text{discount rate})^{\text{project life}} - 1)$$

(1) Calculating the Annual Weighted Surplus Emission Reductions

Annual weighted surplus emission reductions are calculated using Formula C-3 below. Note that particulate matter (PM) is weighted by a factor of 20.

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

$$\text{Weighted emission reductions (weighted tons/yr)} = \text{NOx reductions (tons/yr)} + \text{ROG reductions (tons/yr)} + (20 * \text{PM reductions (tons/yr)})$$

The result of Formula C-3 is used to complete Formula C-1 to determine the potential grant amount at the cost-effectiveness limit, as well for Formula C-14 to determine the cost-effectiveness if not at the limit.

In order to determine the annual surplus emission reductions by pollutant, Formula C-4, C-5, C-6, C-7, or C-8 below must be completed for each pollutant (NOx, ROG, and PM), for the baseline technology and the reduced technology. Formula C-4 is the general calculation and can be applied to any project, whereas Formulas C-5, C-6, C-7 and C-8 are specific variations of Formula C-4 for use with mileage, hours of operation, fuel use, and shore power systems, respectively.

All five formulas involve multiplying the engine emission factor (found in Appendix D) by the annual activity level and by other adjustment factors (such as load factor in the case of off-road equipment calculations) as specified for the calculation methodologies presented. Emission factors are also adjusted to account for in-use deterioration where applicable.

Formula C-4: Estimated annual emissions (tons/yr)

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

$$\text{Deterioration product} = \text{deterioration rate} * \text{total equipment activity}$$

$$\text{Total equipment activity} = \text{annual activity} * \text{deterioration life (yrs)}$$

^(a) Discount rate varies from year to year. See Tables D-24 and D-25 in Appendix D for CRF values at a one percent and two percent discount rate, respectively.

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

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

The Moyer Program allows the emission reductions from a project to be calculated using a variety of methods, but mileage and hours of operation are the primary methods. Specific activity factors allowed for each project category may differ and are identified in the source category chapters.

a. Calculating Annual Emissions Based on Annual Miles Traveled

Calculations based on annual miles traveled are used for on-road projects only. Mileage records must be maintained by the engine owner as described in Chapter 4: On-Road Heavy-Duty Vehicles. Formula C-5 below describes the method for calculating pollutant emissions based on miles traveled, including the method for calculating mile-based deterioration products.

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) (if applicable)) * annual activity (mi/yr) *
 percentage operation in California / 907,200 (g/ton)*

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

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

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

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

b. Calculating Annual Emissions Based on Hours of Operation

When hours of equipment operation are the basis for determining emissions, the horsepower rating of the engine and an engine load factor found in Appendix D must be used. The method for calculating emissions based on hours of operation is described in Formula C-6 below, and includes the method for calculating hour based deterioration product.

^(b) Total equipment activity for mile-based calculations is limited to 400,000 miles for school buses or 800,000 miles for other on-road vehicles. Used heavy heavy-duty replacement vehicles add 500,000 miles, medium heavy-duty vehicles add 250,000 miles, or light heavy-duty vehicles add 150,000 miles.

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

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

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

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

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

$$\text{Deterioration life (reduced equipment) (yrs)} = \text{project life} / 2$$

The engine load factor is an indicator of the nominal amount of work done by the engine for a particular application. It is given as a fraction of the rated horsepower of the engine and varies with engine application. Load factors for a variety of equipment types may be found in Appendix D.

c. Calculating Annual Emissions Based on Fuel Consumption

In some cases as outlined in each source category chapter, fuel consumption may be used to calculate annual emissions. In such cases a fuel consumption rate factor must be used to convert emissions given in g/bhp-hr to units of grams of emissions per gallon of fuel used (g/gal). The fuel consumption rate factor is a number that combines the effects of engine efficiency and the energy content of the fuel used in that engine into an approximation of the amount of work output by an engine for each unit of fuel consumed. Formula C-7 below is used to calculate the annual emissions based on annual fuel consumed.

^(c) Total equipment activity for hour-based calculations is limited to a maximum of 12,000 hours for diesel engines, 3,500 hours for large-spark ignition (LSI) engines with a model year of 2006 or older, or 5,000 hours for LSI engines with a model year of 2007 or newer.

Formula C-7: Estimated annual emissions based on fuel consumption (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = \text{emission factor (g/bhp-hr)} * \text{fuel consumption rate factor (bhp-hr/gal)} * \text{annual activity (gal/yr)} * \text{percentage operation in California} / 907,200 \text{ (g/ton)}$$

d. Calculating Annual Emissions for Shore Power Systems

For marine shore power systems, calculate the estimated annual emissions by pollutant as shown in Formula C-8 below.

Formula C-8: Estimated annual emissions for shore power systems (tons/yr)

$$\text{Annual emissions by pollutant (tons/yr)} = \text{ship emission factor (g/kW-hr)} * \text{power requirements (kW)} * \text{berthing time (hrs/visit)} * \text{annual number of visits (visits/yr)} * 0.9 / 907,200 \text{ (g/ton)}$$

(2) Calculating Annual Surplus Emission Reductions by Pollutant

Subtract the annual emissions for the reduced technology from the annual emissions for the baseline technology as shown in Formula C-9 below, for NO_x, ROG and PM emissions.

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

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

For marine vessels with a wet exhaust system, a wet exhaust factor of 0.80 must be applied; calculate the annual surplus emission reductions as shown in Formula C-10 below.

Formula C-10: Annual surplus emission reductions for marine vessels with wet exhaust systems (tons/yr)

$$\text{Annual surplus emission reductions by pollutant (tons/yr)} = 0.80 * (\text{annual emissions for the baseline technology (tons/yr)} - \text{annual emissions for the reduced technology (tons/yr)})$$

For retrofits, multiply the baseline technology pollutant emissions by the percentage of emission reductions that the CARB-verified reduced technology is verified to following Formula C-11 below.

Formula C-11: Annual surplus emission reductions for retrofits (tons/yr)

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

For on-road heavy-duty projects, the baseline will be the newer vehicle emissions.

For marine vessel hybrid systems, calculate the annual surplus emission reductions as shown in Formula C-12 below.

Formula C-12: Annual surplus emission reductions for marine vessel hybrid systems (tons/yr)

$$\text{Annual surplus emission reductions by pollutant (tons/yr)} = \text{total annual emissions (all engines on vessel) for the baseline technology (tons/yr)} - (\text{total annual emissions (all engines on vessel) for the baseline technology (tons/yr)} * \text{reduced technology verification percentage})$$

For marine vessels, calculate the annual surplus emission reductions for each pollutant as shown in Formula C-13 below.

Formula C-13: Total annual surplus emission reductions for marine vessels (tons/yr)

$$\text{Total annual surplus emission reductions for marine vessels by pollutant (tons/yr)} = (\text{propulsion engine annual surplus emission reductions (tons/yr)} * \text{number of propulsion engines}) + (\text{auxiliary engine annual surplus emission reductions (tons/yr)} * \text{number of auxiliary engines})$$

- (B) The potential grant amount based on maximum percentage of eligible cost is a measure of the incremental cost as determined by multiplying the cost of the reduced technology by the maximum percentage of eligible cost (from the applicable chapter) as described in Formula C-14 below.

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

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

- (C) The potential grant amount based on any maximum dollar amount or other funding cap is specified in the relevant source category chapter

2. Calculating Two for One Projects

In Two for One equipment replacement projects, two baseline technology equipment are replaced with one reduced technology equipment. First, calculate the emission reduction benefits based on activity for each baseline engine separately using Formulas C-4, C-5, C-6, C-7, or C-8. These emission reductions will then be summed together before deducting the emission reduction benefits of the reduced technology using Formula C-9. See the sample calculations supplemental document for an example on this calculation methodology.

3. Calculating Split Project Life Projects

Split Project Life: Split Project Life Projects must use a separate project life for the two baseline technology scenarios. First, Formulas C-4, C-5, C-6, C-7, or C-8 must be used to calculate emission reduction by pollutant for the two baseline scenarios:

- (A) Baseline technology to phase 1 reduced technology
- (B) Phase 1 reduced technology to phase 2 reduced technology

Formula C-3 is used to calculate the annual emission reductions for each baseline technology. Next, a fraction of the project life must be applied to the annual emission reductions for each of the baseline scenarios, as outlined below in Formula C-15.

Formula C-15: Split project life

$$\begin{aligned} & \text{Total annual weighted surplus emission reductions (tons/yr) =} \\ & (\text{fraction project life (yrs)} * \text{annual weighted surplus emissions from transaction 1 (tons/yr)} / \\ & \quad \text{total project life (yrs)}) + (\text{fraction project life (yrs)} * \\ & \quad \text{annual weighted surplus emissions from transaction 2 (tons/yr)} / \text{total project life (yrs)}) \end{aligned}$$

$$\begin{aligned} & \text{Total annual weighted surplus emission reductions (tons/yr) =} \\ & \quad (n_1 * a_1 / t) + (n_2 * a_2 / t) \\ & \quad \text{where:} \end{aligned}$$

n_1 = fraction project life from transaction 1 (yrs)

n_2 = fraction project life from transaction 2 (yrs)

a_1 = annual weighted surplus emissions from transaction 1 (tons/yr)

a_2 = annual weighted surplus emissions from transaction 2 (tons/yr)

t = total project life (yrs)

4. Calculating the Applicant Cost Share

Moyer eligible costs are costs associated with a project that are eligible for reimbursement under the program prior to considering the cost-effectiveness limit or any project cap restrictions. Guidance on these costs is contained in Chapters 2, 3, and the applicable chapter for the Moyer project. The applicant cost share is determined by multiplying the Moyer eligible cost by 15 percent, as described in Formula C-16 below. Applicant cost share is determined from the Moyer eligible costs, but the value itself is not an ineligible Moyer cost. A public entity applicant may other use public funds toward meeting this requirement.

Formula C-16: Applicant cost share (\$)

$$\begin{aligned} & \text{Applicant cost share (\$)} \geq \\ & 15 \text{ percent} * \text{Moyer eligible costs (\$)} \end{aligned}$$

5. Calculation for Co-funding Moyer Funds with Other Sources

Air districts must request information from grantee to determine what other funds will be used toward the project. This information will be utilized to ensure that the

applicant is not overpaid for the project by adding the Applicant Cost Share contribution and the grants paid toward the project, as shown in Formula C-17 below and comparing against the total project cost value. The total project cost includes both Moyer eligible and Moyer ineligible costs. Refer to Chapters 2 and 3 for additional criteria and guidance related to co-funding projects.

Formula C-16: Project overpayment check (\$)

$$\text{Total project cost} \geq \text{applicant cost share } (\$) + \sum \text{grants paid } (\$)$$

If the total project cost is exceeded then adjustments must be made to ensure the project applicant is not overpaid for the project.

6. Calculating the Cost-Effectiveness of a Grant Amount

The cost-effectiveness of a grant amount is determined by multiplying the CRF as calculated in Formula C-18 by the grant amount, and dividing that by the annual weighted surplus emission reductions that will be achieved by the project as calculated in Formula C-3.

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

$$\text{Cost-effectiveness } (\$/\text{tons}) = \text{grant amount } (\$) * \text{CRF} / \text{annual weighted surplus emission reductions } (\text{weighted tons}/\text{yr})$$

C. List of Formulas

The necessary formulas to calculate the cost-effectiveness of surplus emission reductions for a project funded through the Moyer Program are provided below.

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

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

Formula C-2: Capital recovery factor (CRF)

$$\text{Capital recovery factor} = (1 + \text{discount rate}^{(d)}) ^ \text{project life} * \text{discount rate} / ((1 + \text{discount rate}) ^ \text{project life} - 1)$$

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

$$\text{Weighted emission reductions (weighted tons/yr)} = \text{NO}_x \text{ reductions (tons/yr)} + \text{ROG reductions (tons/yr)} + (20 * \text{PM reductions (tons/yr)})$$

Formula C-4: Estimated annual emissions (tons/yr)

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

$$\text{Deterioration product} = \text{deterioration rate} * \text{total equipment activity}$$

$$\text{Total equipment activity} = \text{annual activity} * \text{deterioration life (yrs)}$$

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

$$\text{Deterioration life (reduced) (yrs)} = \text{project life} / 2$$

^(d) Discount rate varies from year to year. See Tables D-24 and D-25 in Appendix D for CRF values at a 1 percent and 2 percent discount rate, respectively.

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

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

$$\text{Mile-based deterioration product (g/mi)} = \text{deterioration rate (g/mi-10,000 mi)} * \text{total equipment activity (mi)}$$

$$\text{Total equipment activity}^{(e)} \text{ (miles)} = \text{annual activity (mi/yr)} * \text{deterioration life (yrs)}$$

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

$$\text{Deterioration life (reduced) (yrs)} = \text{project life} / 2$$

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

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

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

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

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

$$\text{Deterioration life (reduced) (yrs)} = \text{project life} / 2$$

^(e) Total equipment activity for mile-based calculations is limited to 400,000 miles for school buses or 800,000 miles for other on-road vehicles. Used heavy heavy-duty replacement vehicles add 500,000 miles, medium heavy-duty vehicles add 250,000 miles, or light heavy-duty vehicles add 150,000 miles.

^(f) Total equipment activity for hour-based calculations is limited to a maximum of 12,000 hours for diesel engines, 3,500 hours for large-spark ignition (LSI) engines with a model year of 2006 or older, or 5,000 hours for LSI engines with a model year of 2007 or newer.

Formula C-7: Estimated annual emissions based on fuel consumption (tons/yr)

$$\begin{aligned} \text{Annual emissions by pollutant (tons/yr)} = \\ \text{Emission factor (g/bhp-hr)} * \text{fuel consumption rate factor (bhp-hr/gal)} * \text{annual activity (gal/yr)} \\ * \text{percentage operation in California / 907,200 (g/ton)} \end{aligned}$$

Formula C-8: Estimated annual emissions for shore power systems (tons/yr)

$$\begin{aligned} \text{Annual emissions by pollutant (tons/yr)} = \\ \text{Ship emission factor (g/kW-hr)} * \text{power requirements (kW)} * \text{berthing time (hrs/visit)} * \text{annual} \\ \text{number of visits (visits/yr)} * 0.9 / 907,200 \text{ (g/ton)} \end{aligned}$$

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

$$\begin{aligned} \text{Annual surplus emission reductions by pollutant (tons/yr)} = \text{annual} \\ \text{emissions for the baseline technology (tons/yr)} - \\ \text{annual emissions for the reduced technology (tons/yr)} \end{aligned}$$

Formula C-10: Annual surplus emission reductions for marine vessels with wet exhaust systems (tons/yr)

$$\begin{aligned} \text{Annual surplus emission reductions by pollutant (tons/yr)} = \\ 0.80 * (\text{annual emissions for the baseline technology (tons/yr)} - \text{annual} \\ \text{emissions for the reduced technology (tons/yr)}) \end{aligned}$$

Formula C-11: Annual surplus emission reductions for retrofits (tons/yr)

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

Formula C-12: Annual surplus emission reductions for marine vessel hybrid systems (tons/yr)

$$\begin{aligned} \text{Annual surplus emission reductions by pollutant (tons/yr)} = \\ \text{total annual emissions (all engines on vessel) for the baseline technology (tons/yr)} - \\ (\text{total annual emissions (all engines on vessel) for the baseline technology (tons/yr)} * \text{reduced} \\ \text{technology verification percentage}) \end{aligned}$$

Formula C-13: Total annual surplus emission reductions for marine vessels (tons/yr)

$$\begin{aligned} \text{Total annual surplus emission reductions for marine vessels by pollutant (tons/yr)} = \\ (\text{propulsion engine annual surplus emission reductions (tons/yr)} * \\ \text{number of propulsion engines}) + (\text{auxiliary engine annual surplus emission reductions (tons/yr)} * \\ \text{number of auxiliary engines}) \end{aligned}$$

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

$$\text{Incremental cost (\$)} = \text{cost of reduced technology (\$)} * \text{maximum percentage of eligible cost}$$

Formula C-15: Split project life

$$\text{Total annual weighted surplus emission reductions (tons/yr)} = (\text{fraction project life (yrs)} * \text{annual weighted surplus emissions from transaction 1 (tons/yr)} / \text{total project life (yrs)}) + (\text{fraction project life (yrs)} * \text{annual weighted surplus emissions from transaction 2 (tons/yr)} / \text{total project life (yrs)})$$

$$\text{Total annual weighted surplus emission reductions (tons/yr)} = (n_1 * a_1 / t) + (n_2 * a_2 / t) \text{ where:}$$

$$n_1 = \text{fraction project life from transaction 1 (yrs)} \quad n_2 = \text{fraction project life from transaction 2 (yrs)}$$

$$a_1 = \text{annual weighted surplus emissions from transaction 1 (tons/yr)}$$

$$a_2 = \text{annual weighted surplus emissions from transaction 2 (tons/yr)} \quad t = \text{total project life (yrs)}$$

Formula C-16: Applicant cost share (\$)

$$\text{Applicant cost share (\$)} \geq 15 \text{ percent} * \text{moyer eligible costs (\$)}$$

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

$$\text{Total project cost} \geq \text{applicant cost share (\$)} + \sum \text{grants paid (\$)}$$

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

$$\text{Cost-effectiveness (\$/ton)} = \text{grant amount (\$)} * \text{CRF} / \text{annual weighted surplus emission reductions (weighted tons/yr)}$$