APPENDIX C

COST-EFFECTIVENESS CALCULATION METHODOLOGY

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A. Introduction

All projects are subject to the cost-effectiveness limit defined in Appendix G: Cost Effectiveness Limit and Capital Recovery Factors. Carl Moyer Program (Moyer) funding, funding under the air district's fiduciary budget authority, other public funds from local, state, federal or any other public agency that are received by the grantee, or funding provided by a port authority (to meet the match fund requirement) must be included in determining the cost-effectiveness of surplus emission reductions. Excluded from this requirement is funding provided by federal programs designed to reduce greenhouse gas emissions (GHGs) or funding provided by the Alternative and Renewable Fuel and Vehicle Technology Program to reduce GHGs. Projects that include such funds must meet all other Carl Moyer Program requirements. For more details see Chapter 2 and 3.

B. General Cost-Effectiveness Calculations

1. Calculating Cost-Effectiveness

The cost-effectiveness of a project is determined by dividing the annualized cost of the potential project by the annual weighted surplus emission reductions that will be achieved by the project as shown in formula C-1 below.

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)

$$\text{Cost-Effectiveness (\$/ton)} = \frac{\text{Annualized Cost (\$/year(yr))}}{\text{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

Descriptions on how to calculate annual emission reductions and annualized cost are provided in the following sections.

2. Determining the Annualized Cost

Annualized cost is the amortization of the one-time incentive grant amount for the life of the project to yield an estimated annual cost. The annualized cost is calculated by multiplying the incremental cost by the capital recovery factor (CRF). The resulting annualized cost is used to complete formula C-2 to determine the cost-effectiveness of surplus emission reductions.

Formula C-2: Annualized Cost ($)

$$\text{Annualized Cost} = \text{CRF} * \text{incremental cost (\$)}$$

3. Calculating the Incremental Cost

Maximum eligible percent funding amounts define incremental cost, in many cases an applicant will provide an estimate of the cost of the reduced technology. The incremental cost is determined by multiplying the cost of the reduced technology by the maximum eligible percent funding amount (from applicable chapter), as described in formula C-3 below.

Formula C-3: Incremental Cost ($)

*Incremental Cost = Cost of Reduced Technology ($) * Maximum Eligible Percent Funding Amount*

Generally the cost of the baseline vehicle for a new purchase is assumed to be a certain percentage of the cost of a new vehicle meeting reduced emissions from the standard. The cost of the baseline technology for a repower is assumed to be a percentage of the new engine. For retrofits, there is no baseline technology cost; hence the entire cost of the retrofit may be eligible for funding in most cases, but not for on-road. Refer to the On-Road chapter for specific eligible retrofit cost.

For school bus fleet modernization projects, the incremental cost is determined by adjusting the value given to the vehicle by the National Automotive Dealership Association (N.A.D.A.), as described in formula C-4 below.

Formula C-4: Incremental Cost for School Bus Fleet Modernization Projects ($)

When the replacement school bus is not new use the N.A.D.A value:

*where the N.A.D.A value is the retail value of the used school bus * 100 percent.*

*when the replacement school bus is new then use the Invoice of the new school bus * 100 percent*

Use the results from formula C-3 or C-4 to complete formula C-2 to determine the annualized cost of a project.

4. Calculating the Annual Weighted Surplus Emission Reductions

Annual weighted emission reductions are estimated by taking the sum of the project's annual surplus pollutant reductions following formula C-5 below. This will allow projects that reduce one, two, or all three of the covered pollutants to be evaluated for eligibility to receive Carl Moyer Program funding. While oxides of nitrogen (NOx) and reactive organic gases (ROG) emissions are given equal weight; emissions of diesel (particulate matter) PM have been identified as a toxic air contaminant and thus carry a greater weight in the calculation. However, emissions of combustion PM from gasoline, spark ignition engines have not been identified as a toxic air contaminant, therefore NOx, ROG, and PM emissions are given equal weight in the calculation.

Formula C-5: Annual Weighted Surplus Emission Reductions

Weighted Emission Reductions =

*NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * (PM reductions (tons/yr)]*

The result of formula C-5 is used to complete formula C-1 to determine the cost-effectiveness of surplus emission reductions.

In order to determine the annual surplus emission reductions by pollutant, formula C-15 below must be completed for each pollutant (NOx, ROG, and PM), for the baseline technology and the reduced technology, totaling up to six calculations:

Baseline Technology	Reduced Technology
1. Annual emissions of NOx	4. Annual emissions of NOx
2. Annual emissions of ROG	5. Annual emissions of ROG
3. Annual emissions of PM	6. Annual emissions of PM

These calculations are completed for each pollutant by multiplying the engine emission factor or converted emission standard (found in Appendix D) by the annual activity level and by other adjustment factors as specified for the calculation methodologies presented.

5. Calculating Annual Emission Reductions Based on Usage

Usage: The Carl Moyer Program allows the emissions reductions from a project to be calculated using the following activity factors on an annual basis:

(A) Hours of operation,
(B) Fuel consumption, or
(C) Miles traveled.

Specific activity factors allowed for each project category may differ and are identified in the source category chapters of the Carl Moyer Program Guidelines.

(A) Calculating Annual Emissions Based on Hours of Operation

When actual annual hours of equipment operation are the basis for determining emission reductions, the equipment activity level must be based on a properly functioning hour meter (See Chapter 2 and the relevant source category chapter for additional information on this topic). In addition, the horsepower rating of the engine and an engine load factor found in Appendix D must be used. A default load factor of 0.43 is used for those projects where no specific equipment load factor is available in Appendix D. The method for calculating emission reductions based on hours of operation is described in formula C-6 below.

Formula C-6: Estimated Annual Emissions based on hours of Operation (tons/yr)

Annual Emission Reductions =

*Emission Factor or Converted Emission Standard (grams per brake horsepower-hour)(g/bhp-hr)) * Horsepower * Load Factor * Activity (hours(hrs)/yr) * Percent Operation in California (CA) * ton/907,200grams (g)*

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. For projects in which the horsepower of the baseline technology and reduced technology are different by more than 25 percent, the load factor must be adjusted following formula C-7 below. It is important to understand the replacement load factor must never exceed 100 percent in cases where the reduced technology engine is significantly smaller than the baseline technology engine.

Formula C-7: Replacement Load Factor

$$\textit{Replacement Load Factor} = \textit{Load Factor}_{baseline} * hp_{baseline}/hp_{reduced}$$

(B) Calculating Annual Emissions Based on Fuel Consumption

When annual fuel consumption is used for determining emission reductions, the equipment activity level must be based on annual fuel usage within California provided by the applicant. Fuel records must be maintained by the engine owner as described in the relevant source category chapter for additional information on this topic.

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. The fuel consumption rate factor is found in Table D-24 in Appendix D. Formulas C-8 and C-9 below are the formulas for calculating annual emissions based on annual fuel consumed.

Formula C-8: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr)

Annual Emission Reductions =

*Emission Factor or Converted Emission Standard (g/bhp-hr) * fuel consumption rate factor (bhp-hr/gallon (gal)) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g*

Formula C-9: Estimated Annual Emissions based on Fuel using Emission Factors (tons/yr)

Annual Emission Reductions =

*Emission Factor (g/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g*

(C) 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.

<u>Calculations Using Emission Factors:</u> There is no conversion since the emission factors for on-road projects provided are given in units of g/mile. Formula C-10 describes the method for calculating pollutant emissions based on emission factors and miles traveled.

Formula C-10: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr)

Annual Emission Reductions =

*Emission Factor (g/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g*

<u>Calculating Annual Emissions Based on Converted Standards</u>: The unit conversion factor found in Tables D-5 and D-6 (Appendix D) are used to convert the units of the converted emission standard (g/bhp-hr) to g/mile. Formula C-11 describes the method for calculating pollutant emissions using converted emission standards.

Formula C-11: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr)

Annual Emission Reductions =

*Converted Emission Standard (g/bhp-hr) * Unit Conversion (bhp-hr/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g*

6. Calculating Two for One Projects

Two for One Projects: For equipment replacement of Two for One Project, two baseline technology equipment will be replaced for one reduced technology. First, calculate the emission reduction benefits based on activity for each baseline engine separately using formulas C-6, C-8 or C-10. These emission reductions will then be summed together before deducting the emission reduction benefits of the reduced technology using formula C-13. See the sample calculations supplemental document for an example on this calculation methodology.

7. 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, formula C-6, C-8, or C-10 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-5 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-12.

Formula C-12: Split Project Life

Total Annual Weighted Surplus Emission Reductions =

*(Fraction project life / Total project life * Annual weighted surplus emissions from transaction 1) + Fraction project life / Total project life * Annual weighted surplus transaction from transaction 2)*

Total Annual Weighted Surplus Emission Reductions = $(n^1 / t * a^1) + (n^2 / t * a^2)$

n^1 = *fraction project life from transaction 1*
n^2 = *fraction project life from transaction 2*
a^1 = *Annual weighted surplus emissions from transaction 1*
a^2 = *Annual weighted surplus transaction from transaction 2*
t = *total project life*

8. Calculating Annual Surplus Emission Reductions by Pollutant

The final step in this portion of the calculations is to determine the annual surplus emission reductions by pollutant. For new purchases and repower projects, subtract the annual emissions for the reduced technology from the annual emissions for the baseline technology following formula C-13 below.

Formula C-13: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

Annual Surplus Emission Reductions (by pollutant) =

Annual Emissions for the Baseline Technology – Annual Emissions for the Reduced Technology

For retrofits, multiply the baseline technology pollutant emissions by the percent of emission reductions that the ARB-verified reduced technology is verified to following formula C-14 below.

Formula C-14: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

Annual Surplus Emission Reductions (by pollutant) =

*Annual Emissions for the Baseline Technology * Reduced Technology Verification Percent*

Calculations must be done for each pollutant, NOx, PM, and ROG, giving a total of three calculations.

For fleet modernization projects the baseline will be the newer vehicle emissions.

The annual surplus emission reductions by pollutant would be used in Formula C-5 to calculate the annual surplus emission reductions.

9. Calculating a Conversion from Grams to Tons per Year

Conversion to Tons per Year: Since the emission factor or converted standard is given in units of grams, a conversion from grams to tons is also required, as illustrated in formula C-15 below.

Formula C-15: Estimated Annual Emissions by Pollutant (tons/yr)

Annual Emission Reduction =

*Emission Factor or Converted Emission Standard (g/bhp-hr) * Annual Activity * Adjustment Factor(s) * Percent Operation in CA * ton/907,200g*

10. Calculations for Comingling Moyer and Public Funds

Other public financial incentive funds received by the grantee directly must be deducted from the incremental cost. Air districts must request information from grantee to determine what other public financial incentive funds will be used for the project. If the other public financial incentive funds are not intended to be used to pay for eligible costs, then the incremental cost is not reduced by the other public financial incentive funds. Use formula C-16 below to determine the amount that is cost-effective to be annualized in C-2.

Formula C-16: Moyer Grant for Grantees receiving other Public Financial Incentive Funds

Maximum Moyer Grant Amount (if project is cost-effective) =

Incremental Cost (from formula C-2 or C-3) - Other Public Financial Incentive Funds

In addition to Carl Moyer Program funds, air districts must also include non-Moyer funds provided by the air district when calculating cost-effectiveness for the project; the <u>total</u> funds contributed by the air district must meet current cost-effectiveness limits. The final Moyer grant amount for a project is derived once the air district funds are deducted. Use formula C-17 below to determine the amount of funds the grantee will receive from the Carl Moyer Program.

Formula C-17: Moyer Grant for Grantees receiving public funds from Air District

Moyer Grant Amount to Grantee =

Cost-effective Grant Amount (from formula C-1) – Air District Funds

Beginning July 1, 2011, federal funding from programs that reduce greenhouse gas emissions (GHGs) or funding provided by the Alternative and Renewable Fuel and Vehicle Technology Program to reduce GHGs are not required to be included in formulas C-16 and C-17; for more details see Chapter 2 and 3.

11. Calculation for projects exceeding the Cost Effectiveness Limit

For projects that have exceeded the weighted cost effectiveness limit, the calculation methodology below must be applied in order to ensure final grant amounts meet the cost effectiveness limit requirement. The grant amount is determined by multiplying the maximum allowed cost-effectiveness limit by the estimated annual emission reductions and dividing by the capital recovery factor in the C-18 formula below.

Formula C-18: Maximum Grant Amount for projects exceeding Cost Effectiveness Limit

Maximum Grant Amount =

*(Cost-effectiveness limit * estimated annual emission reductions)/CRF*

C. List of Formulas

For an easy reference, the necessary formulas to calculate the cost-effectiveness of surplus emission reductions for a project funded through the Carl Moyer Program are provided below.

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton):

$$\text{Cost-Effectiveness (\$/ton)} = \frac{\text{Annualized Cost (\$/yr)}}{\text{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

Formula C-2: Annualized Cost ($)

Annualized Cost = CRF * incremental cost ($)

Formula C-3: Incremental Cost ($)

Incremental Cost = Cost of Reduced Technology ($) * Maximum Eligible Percent Funding Amount

Formula C-4: Incremental Cost for School Bus Fleet Modernization Projects ($)

When the replacement school bus is not new use the N.A.D.A value:

where the N.A.D.A value is the retail value of the used school bus * 100 percent.

when the replacement school bus is new then us the Invoice of the new school bus * 100 percent

Formula C-5: Annual Weighted Surplus Emission Reductions

Weighted Emission Reductions =

NOx reductions (tons/yr) + ROG reductions (tons/yr) + [20 * (PM reductions (tons/yr)]

Formula C-6: Estimated Annual Emissions based on hours of Operation (tons/yr)

Annual Emission Reductions =

Emission Factor or Converted Emission Standard (g/bhp-hr) * Horsepower * Load Factor * Activity (hrs/yr) * Percent Operation in CA * ton/907,200g

Formula C-7: Replacement Load Factor

$$\text{Replacement Load Factor} = \text{Load Factor}_{\text{baseline}} * \text{hp}_{\text{baseline}}/\text{hp}_{\text{reduced}}$$

Formula C-8: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr)

Annual Emission Reductions =

Emission Factor or Converted Emission Standard (g/bhp-hr) * fuel consumption rate factor (bhp-hr/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g

Formula C- 9: Estimated Annual Emissions based on Fuel using Emission Factors (tons/yr)

Annual Emission Reductions =

Emission Factor (g/gal) * Activity (gal/yr) * Percent Operation in CA * ton/907,200g

Formula C-10: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr)

Annual Emission Reductions =

Emission Factor (g/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g

Formula C-11: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr)

Annual Emission Reductions =

Converted Emission Standard (g/bhp-hr) * Unit Conversion (bhp-hr/mile) * Activity (miles/yr) * Percent Operation in CA * ton/907,200g

Formula C-12: Split Project Life

Total Annual Weighted Surplus Emission Reductions =

(Fraction project life / Total project life * Annual weighted surplus emissions from transaction 1) + Fraction project life / Total project life * Annual weighted surplus transaction from transaction 2)

Total Annual Weighted Surplus Emission Reductions = $(n^1 / t * a^1) + (n^2 / t * a^2)$

n^1 = fraction project life from transaction 1
n^2 = fraction project life from transaction 2
a^1 = Annual weighted surplus emissions from transaction 1

a^2 = Annual weighted surplus transaction from transaction 2
t = total project life

Formula C-13: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

Annual Surplus Emission Reductions (by pollutant) =

Annual Emissions for the Baseline Technology – Annual Emissions for the Reduced Technology

Formula C-14: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

Annual Surplus Emission Reductions (by pollutant) =

Annual Emissions for the Baseline Technology * Reduced Technology Verification Percent

Formula C-15: Estimated Annual Emissions by Pollutant (tons/yr)

Annual Emission Reduction =

Emission Factor or Converted Emission Standard (g/bhp-hr) * Annual Activity * Adjustment Factor(s) * Percent Operation in CA * ton/907,200g

Formula C-16: Moyer Grant for Grantees receiving other Public Financial Incentive Funds

Maximum Moyer Grant Amount (if project is cost-effective) =

Incremental Cost (from formula C-2 or C-3) - Other Public Financial Incentive Funds

Formula C-17: Moyer Grant for Grantees receiving public funds from Air District

Moyer Grant Amount to Grantee =

Cost-effective Grant Amount (from formula C-1) – Air District Funds

Formula C-18: Maximum Grant Amount for projects exceeding Cost Effectiveness Limit

Maximum Grant Amount =

(Cost-effectiveness limit * estimated annual emission reductions)/CRF