APPENDIX C

METHODOLOGY FOR DETERMINING COST-EFFECTIVENESS

This appendix is an excerpt from the Board approved
2008 Carl Moyer Program Guidelines Part IV Appendixes

The complete Carl Moyer Program Document including all appendices can be found at:
http://www.arb.ca.gov/msprog/moyer/2008guideline_updates.htm

TABLES FOR EMISSION REDUCTION AND COST-EFFECTIVENESS CALCULATIONS

This appendix presents tables summarizing the data and instructions needed to calculate the emissions reductions and cost-effectiveness of potential lawn and garden equipment demonstration projects. The examples provided below where modified to better fit the parameters of this demonstration project and are for reference only. The following examples do not constitute additional demonstration project types or categories and the Carl Moyer funding amounts do not limit the amount of funding that may be available for demonstration projects.

Table B-1
Capital Recovery Factors (CRF) for Various Project Life
At Four Percent Discount Rate

Project Life	CRF
1	1.040
2	0.530
3	0.360
4	0.275
5	0.225
6	0.191
7	0.167
8	0.149
9	0.134
10	0.123
11	0.114
12	0.107
13	0.100
14	0.095
15	0.090
16	0.086
17	0.082
18	0.079
19	0.076
20	0.074

Table – AQIP 1
Exhaust Emission Standards for Spark-Ignition Engines*
(grams per kilowatt-hour)

Model Year	Displacement Category	HC+NOx	PM10
2005 and subsequent (2-stroke)	<50 cc	50	2.0
	50 - 80 cc, inclusive	72	2.0
2008 and subsequent (4-stroke)	> 80 cc - < 225 cc	10.0	-
	>255 cc	8.0	-
Zero-Emission	All	0	0

*Title 13, California Code of Regulations, section 2403 (a)(b)(1)

Table – AQIP 2
Gas-Powered Commercial Lawn and Garden Equipment Load Factors*

Equipment	Load Factor
Lawn Mowers (2-stroke + 4-stroke)	0.36
Leaf Blowers/Vacuums (2-stroke)	0.5
Leaf Blowers/Vacuums (4-stroke)	0.36
Hedge Trimmers (2-stroke)	0.5
Hedge Trimmers (4-stroke)	0.36

*ARB's Off-Road Emissions Inventory: http://www.arb.ca.gov/msei/offroad/offroad.htm

Example cost effectiveness calculations are show below.

II. General Cost-Effectiveness Calculations

The cost-effectiveness of a project is determined by dividing the annual 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):

$$\frac{\textit{Annualized Cost (\$/yr)}}{\textit{Annual Weighted Surplus Emission Reductions (tons/yr)}}$$

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

A. 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-2 below. Emissions of combustion PM10 (such as diesel exhaust PM10 emissions) have been identified as a toxic air contaminant and thus carry a greater weight in the calculation.

Formula C-2: Annual Weighted Surplus Emission Reductions:

*HC+NOx reductions (tons/yr) + [20 * (PM10 reductions (tons/yr)]*

The result of formula C-2 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, the formula below must be completed for each pollutant (HC+NOx and PM10), for the baseline technology, totaling up to 2 calculations:

1. Annual emissions of HC+NOx for the baseline technology
2. Annual emissions of PM10 for the baseline technology

Conversion Factor 1*: $\left(\frac{1.341kW-hr}{bhp-hr}\right)$

Conversion Factor 2*: $\left(\frac{bhp-hr}{1.341kW-hr}\right)$

* 1.341kW - hr/bhp - hr conversion factor is derived from the Portable Diesel Engine Air Toxic Control Measure Fleet Calculator Instructions at: http://www.arb.ca.gov/portable/perp/fleetemissions/calculatorinstructions.htm .

The **baseline technology** is the technology applied under normal business practices, such as, an engine certified by ARB to the current emission standards for new purchases.

The **reduced technology** is the zero-emission technology used by the applicant to obtain surplus emission reductions and annual surplus emission reductions are not required.

1. Calculating Annual Emissions Based on Hours of Operation

Engine load factors are available in Table – AQIP 2 Gas-Powered Commercial Lawn and Garden Equipment Load Factors. The method for calculating emission reductions based on hours of operation is described in formula C-4 below.

Formula C-4: Estimated Annual Emissions based on hours of Operation (tons/yr):*
**Assuming bhp-hr = hp*

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

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-5 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-5: Replacement Load Factor:

$$Load\ Factor_{baseline} * hp_{baseline}/hp_{reduced}$$

B. 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-12 to determine the cost-effectiveness of surplus emission reductions.

Formula C-12: Annualized Cost ($):

*CRF * incremental cost ($)*

1. Calculating the CRF

The CRF is the level of earnings reasonably expected by investing state funds in various financial instruments over the length of a Carl Moyer Program project. The CRF uses an interest rate and project life to determine the rate at which earnings could reasonably be expected if the same funds were invested over a length of time equaling the project life. The CRF is calculated following formula C-13 below.

Formula C-13: Capitol Recovery Factor (CRF):

$$[(1 + i)^n (i)] / [(1 + i)^n - 1]$$

Where
i = discount rate (4 percent)
n = project life (at least 3 years see specific project criteria for default maximums)

The discount rate of 4 percent reflects the prevailing earning potential for state funds that could reasonably be expected by investing state funds in various financial instruments over the length of the minimum project life of Carl Moyer Program projects.

Table B-1 in Appendix B lists the CRF for various project lives using a discount rate of 4 percent. Use the result from formula C-13 to complete formula C-12 to determine the annualized cost of a project.

2. Calculating the Incremental Cost

In previous guidelines, incremental cost was determined by calculating the difference in cost between the new reduced technology and the baseline technology, making it necessary for the applicant to receive quotes for both the reduced and the baseline technologies. ARB staff decided to streamline this process by applying maximum eligible percent funding amounts to define incremental cost, eliminating the need to receive quotes for the baseline technology. An applicant would only need to provide an estimate of the cost of the reduced technology. Therefore, 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-14 below.

Formula C-14: Incremental Cost ($):

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

Generally the cost of the baseline equipment for a new purchase is assumed to be a certain percentage of the cost of a new unit of equipment meeting reduced emissions from the standard.

III. 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.

Conversion Factor 1: Conversion from kilowatt-hour (kW-hr) to brake horsepower-hour (bhp-hr):

$$\left(\frac{1.341\,kW-hr}{bhp-hr}\right)$$

Conversion Factor 2: Conversion from kilowatt-hour (kW-hr) to brake horsepower-hour (bhp-hr) to obtain horsepower (hp), assuming bhp-hr = hp:

$$\left(\frac{bhp-hr}{1.341kW-hr}\right)$$

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

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

Formula C-2: Annual Weighted Surplus Emission Reductions:

HC+NOx reductions (tons/yr) + [20 * PM10 reductions (tons/yr)]

Formula C-4*: Estimated Annual Emissions based on hours of Operation (tons/yr):

*Assuming bhp-hr = hp

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

Formula C-5: Replacement Load Factor:

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

Formula C-12: Annualized Cost ($):

CRF * incremental cost ($)

Formula C-13: Capitol Recovery Factor (CRF):

$$[(1 + i)^n (i)] / [(1 + i)^n - 1]$$

Where i = discount rate (4 percent) and n = project life (at least 3 years see specific project criteria for default maximums)

Formula C-14: Incremental Cost ($):

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

The above excerpt from the 2008 Carl Moyer Program Guidelines does not contain all the information that is found in the complete 2008 guidelines.

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http://www.arb.ca.gov/msprog/moyer/2008guideline_updates.htm

Example Lawn and Garden Equipment Calculation

This section provides an example of the calculations for estimating cost-effectiveness of surplus emission reductions for commercial lawn and garden equipment. Example calculations are provided as an illustration only of the methodology for performing a commercial lawn and garden equipment cost effectiveness calculation. The specific

project that is used as an example below does not constitute an additional project type that AQIP demonstration project funds will be allocated towards, rather the example below is provided as a reference only.

Example – Commercial Lawn and Garden Equipment Replacement

Baseline Technology Information:

- Baseline technology (application): 2011 gas-powered commercial hedge trimmer (<50 cc)
- Emission standard (Table – AQIP 1): 50/kW-hr HC+NOx and 2g/kW-hr PM10
- Activity: 300 hr/yr
- Engine Power: 0.65 kW
- Load Factor: 0.5 (Table – AQIP 2)
- Percent operated in California: 100 percent
- 2 year project life (Table B-1 = 0.53 CRF)

Reduced Technology Information:

- Reduced technology (application): 2011 cordless zero-emission commercial trimmer and battery
- Reduced technology emission standard (application): 0g/kW-hr HC+NOx and 0g/kW-hr PM
- Cost of reduced technology (equipment and battery): $450
- Maximum eligible percent funding amount: 50%

Emission Reduction Calculations:

Conversion Factor 1 – Kilowatt-hour (kW-hr) to brake horsepower-hour (bhp-hr)
Exhaust emission standards for spark-ignited engines are in grams per kilowatt-hour (g/kW-hr) and conversion factor is needed to convert g/kW-hr to g/bhp-hr (grams per brake horsepower-hour):

$$\left(\frac{1.341\,kW-hr}{bhp-hr}\right)$$

(50g HC+NOx/kW-hr)(1.341 kW-hr/bhp-hr) = 67.05g HC+NOx/bhp-hr

(2.0g PM10/kW-hr)(1.341 kW-hr/bhp-hr) = 2.682g PM10/bhp-hr

Conversion Factor 2 – Kilowatt-hour (kW-hr) to horsepower (hp)
Engine power for spark-ignited engines are in kilowatts (kW) and conversion factor is needed to convert kW to bhp-hr (assuming bhp-hr = hp).

$$\left(\frac{bhp-hr}{1.341kW-hr}\right)$$

(0.65 kW)(bhp-hr/1.341 kW-hr) = 0.48 hp

Formula C-4*: Estimated Annual Emissions based on hours of Operation (tons/yr)
*Assuming bhp-hr = hp

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

67.05g HC+NOx/bhp-hr * 0.48 hp * 0.5 * 300 (hrs/yr) * 1.0 * ton/907,200g = 0.005 tons/yr HC+NOx

2.682g PM10/bhp-hr * 0.48 hp * 0.5 * 300 (hrs/yr) * 1.0 * ton/907,200g = 0.0002 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions:
HC+NOx reductions (tons/yr) + [20 * PM10 reductions (tons/yr)]

0.005 tons/yr HC+NOx + 0.004 tons/yr PM10 = 0.009 weighted tons/yr

Formula C-14: Incremental Cost ($):
Cost of Reduced Technology ($) * Maximum Eligible Percent Funding Amount

$450 * 0.5 = $225

Formula C-12: Annualized Cost ($):
CRF * Incremental cost ($)

0.53 * $225 = $119

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

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

$119/0.009 weighted tons/yr = **$13,222**