THE CARL MOYER PROGRAM GUIDELINES

PART IV

APPENDICES

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APPENDIX A

ACRONYMS

APPENDIX A

ACRONYMS

AAP	Agricultural Assistance Program
AB	Assembly Bill
ABT	Average Banking and Trading
AC	Alternating Current
AECP	Alternative Emission Control Plan
AESS	Automatic Engine Start-Stop
Ah	Amp-hour
APCD	Air Pollution Control District
APCO	Air Pollution Control Officer
APU	Auxiliary Power Unit
AQMD	Air Quality Management District
ARB	California Air Resources Board
ASM	Acceleration Simulation Mode
ATCM	Airborne Toxic Control Measure
ATE	Advanced Travel Center Electrification
AVL	Automatic Vehicle Locator
BACT	Best Available Control Technology
BAR	Bureau of Automotive Repair
bhp	Brake Horsepower
BNSF	Burlington Northern and Santa Fe Railroad
BTU	British Thermal Unit
C/E	Cost Effectiveness
CAF	Confined Animal Facility
CCR	California Code of Regulations
CI	Compression Ignition
CNG	Compressed Natural Gas
CO	Carbon Monoxide
COG	Council of Governments
CRF	Capital Recovery Factor
DC	Direct Current
DDHS	Diesel Driven Heating System
DECS	Diesel Emission Control Strategy
DMV	Department of Motor Vehicles
DOC	Diesel Oxidation Catalyst
DOE	Department of Energy
DPF	Diesel Particulate Filter
E/S	Electric Standby
ECF	Energy Consumption Factor
ECF	Energy Consumption Factor
EF	Emission Factor
EGR	Exhaust Gas Recirculation

EMFAC	ARB's On-Road Motor Vehicle Emission Inventory Model
EMU	Electronic Monitoring Unit
EO	Executive Order
EQIP	Environmental Quality Incentives Program
ERCs	Emission Reduction Credits
ES	Emission Standards
FBC	Fuel-Borne Catalyst
FCF	Fuel Correction Factor
FEL	Family Emission Limit
FTA	Federal Transit Administration
FTF	Flow-Through Filter
FY	Fiscal Year
g	gram
g/bhp-hr	gram per brake horsepower-hour
gal	Gallon
GPS	Geographic Positioning System
GSE	Ground Support Equipment
GTL	Gas-to-Liquid
GVWR	Gross Vehicle Weight Rating
HC	Hydrocarbons
HD	Heavy-Duty
HDDE	Heavy-Duty Diesel Engine
HDT	Heavy-Duty Truck
HDV	Heavy-Duty Vehicle
HEB	Hybrid-Electric Bus
HHDV	Heavy Heavy-Duty Vehicle
hp	Horsepower
hr	Hour
HSC	California Health and Safety Code
HVAC	Heating, Ventilation and Air Conditioning
IC	Internal Combustion
ICE	Internal Combustion Engine
ILD	Idle Limiting Device
IMO	International Maritime Organization
IPI Team	Incentive Program Implementation Team
IRS	Internal Revenue Service
ISO	International Standards Organization
kW	Kilowatt
lbs	Pounds
LETRU	Low Emission Transport Refrigeration Unit
LF	Load Factor
LHD	Light Heavy-Duty
LNG	Liquefied Natural Gas
LPG	Liquefied Propane Gas
LSI	Large Spark Ignited
MDO	Marine Diesel Oil

MGO	Marine Gas Oil
MHDV	Medium Heavy-Duty Vehicle
mi	Mile
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MV Fee	Motor Vehicle Registration Fee
MY	Model Year
NADA	National Automotive Dealership Association
NMHC	Non-Methane Hydrocarbons
NOFA	Notice of Funds Available
NOx	Oxides of Nitrogen
OBD II	On-Road Diagnostics, Phase II
OEM	Original Equipment Manufacturer
PAH	Polycyclic Aromatic Hydrocarbons
PEM	Proton Exchange Membrane
PG&E	Pacific Gas and Electric
PM	Particulate Matter
PM10	Inhalable Particulate Matter
RFP	Request for Proposals
ROG	Reactive Organic Gas
RSD	Remote Sensing Device
SB	Senate Bill
SCAB	South Coast Air Basin
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SCR	Selective Catalytic Reduction
SIP	State Implementation Plan
SMAQMD	Sacramento Metropolitan Air Quality Management District
SOF	Soluble Organic Fraction
SOFC	Solid Oxide Fuel Cell
SOP	Statement of Principles
SORE	Small Off Road Engine
STB	Surface Transportation Board
STD	Standard
SULEV	Super Ultra Low Emission Vehicle
SUV	Sport-Utility Vehicle
SWCV	Solid Waste Collection Vehicle
TAC	Toxic Air Contaminant
TFV	Transit Fleet Vehicle
THC	Total Hydrocarbon
TIP	Transportation Implementation Plan
tpd	Tons Per Day
TRU	Transport Refrigeration Unit
TSE	Truck Stop Electrification
U.S. EPA	U.S. Environmental Protection Agency
UB	Urban Bus

ULETRU	Ultra Low Emission Transport Refrigeration Unit
ULEV	Ultra Low Emission Vehicle
UP	Union Pacific Railroad
V	Volt
VAVR	Voluntary Accelerated Vehicle Retirement
VIN	Vehicle Identification Number
VMT	Vehicle Miles Traveled
VOC	Volatile Organic Compound
VVR	Voluntary Vehicle Repair
yr	Year
ZEB	Zero Emission Bus

APPENDIX B

TABLES FOR EMISSION REDUCTION AND COST-EFFECTIVENESS CALCULATIONS

APPENDIX B

TABLES FOR EMISSION REDUCTION AND COST-EFFECTIVENESS CALCULATIONS

This appendix presents tables summarizing the data needed to calculate the emission reductions and cost-effectiveness of potential projects. Included are data such as engine emission factors, load factors, and other conversion factors used in the calculations discussed in Appendix C: Cost-Effectiveness Calculation Methodology and Appendix D: Example Calculations.

The emission factors in the tables reflect preliminary data developed by ARB staff as part of a comprehensive effort to update the emissions models used for on-road motor vehicles and off-road mobile sources. These draft data were made available on ARB's website in early 2005, but are subject to change as staff completes its analyses and the associated model development. ARB staff will issue Carl Moyer Program Advisories to update the tables as necessary.

ALL PROJECTS

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

Project Life	CRF
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

HEAVY-DUTY ON-ROAD VEHICLES

Table B-2
Heavy-Duty Engines 2004-2006 Certified to Optional Standard
Converted Optional Emission Standards
(g/bhp-hr)

EO Certification Level	Converted Emission Standards		
NOx + NMHC	**Diesel NOx**	**Diesel ROG**	**Alternative Fuel NOx**
1.8	1.59	0.09	1.44
1.5	1.33	0.07	1.20
1.2	1.06	0.06	0.96
0.9	0.80	0.04	0.72
0.6	0.53	0.03	0.48
0.3	0.27	0.01	0.24
PM10	**Diesel PM10**		**Alternative Fuel PM10**
0.03	0.023		0.030
0.02	0.015		0.020
0.01	0.008		0.010

Table B-3
Heavy-Duty Alternative Fuel Engines
Converted Emission Standards
(g/bhp-hr)

Model Year	NOx	PM10
1988 – 1989	6.0	0.60
1990	6.0	0.60
1991 – 1993	5.0	0.25
1994 – 1997	5.0	0.10
1998 - September 2002	4.0	0.10
October 2002 – 2006	2.0	0.10
2007	1.2	0.01
2010	0.2	0.01

Table B-4
Medium Heavy-Duty Vehicles 14,001-33,000 lbs GVWR
NOx, ROG, and PM10 Emission Factors
(g/mile)

Model Year	NOx	ROG	PM10
Pre-1984	17.21	0.29	0.792
1984 – 1986	16.65	0.29	0.720
1987 – 1990	14.60	0.18	0.504
1991 – 1993	12.18	0.16	0.288
1994 – 1997	10.70	0.10	0.216
1998 – 2002	9.77	0.08	0.144
2003+	5.39	0.08	0.216
2004 – 2006	5.12	0.08	0.216
2007+	0.51	0.02	0.024

Table B-5
Diesel Heavy Heavy-Duty Vehicles 33,000+ lbs GVWR
NOx, ROG, and PM10 Emission Factors
(g/mile)

Model Year	NOx	ROG	PM10
Pre-1975	26.23	1.65	2.225
1975 – 1976	25.02	1.50	2.002
1977 – 1979	23.72	1.31	1.735
1980 – 1983	22.23	1.08	1.397
1984 – 1986	21.02	0.88	1.123
1987 – 1990	19.72	0.55	0.950
1991 – 1993	18.23	0.45	0.641
1994 – 1997	18.41	0.26	0.475
1998	23.72	0.22	0.281
1999 – 2002	18.51	0.21	0.389
2003 – 2006	13.21	0.22	0.360
2007 – 2009	7.26	0.14	0.040
2010+	1.32	0.06	0.040

Table B-6
Diesel Urban Buses
NOx, ROG, and PM10 Emission Factors
(g/mile)

Model Year	NOx	ROG	PM10
Pre-1987	42.95	1.78	0.929
1987 – 1990	37.39	1.78	0.878
1991 – 1993	23.71	1.75	0.835
1994 – 1995	27.75	1.72	1.015
1996 – 1998	36.43	1.71	1.217
1999 – 2002	18.96	1.71	0.418
2003	9.49	0.73	0.086
2004 – 2006	2.37	0.73	0.086
2007+	0.95	0.73	0.096

Table B-7
Natural Gas Urban Buses
NOx and PM10 Emission Factors
(g/mile)

Model Year	NOx	PM10
1991 – 1993	25.40	0.020
1994 – 1995	11.20	0.020
1996 – 1998	20.00	0.020
1999 – 2002	20.00	0.020
2003	10.00	0.004
2004 – 2006	7.50	0.004
2007+	1.00	0.004

Table B-8
Conversion Factors for NOx, ROG and PM10
Heavy-Duty Vehicle Projects
(bhp-hr/mile)

Model Year	Medium Heavy-Duty Diesel 14,001-33,000 lbs.	Heavy Heavy-Duty Diesel 33,000 lbs. +	Urban Bus 33,000 lbs. +	School Bus
Pre-1978	2.3	2.9	4.3	2.3
1978 – 1981	2.3	2.8	4.3	2.3
1982 – 1983	2.3	2.8	4.3	2.3
1984 – 1990	2.3	2.7	4.3	2.3
1991 – 1995	2.3	2.7	4.3	2.3
1996+	2.3	2.6 [a]	4.3	2.3

a - 2.6 bhp-hr/mile is for all heavy-duty line haul trucks (class 8).

HEAVY-DUTY TRUCK IDLE REDUCTION

Table B-9
Heavy Heavy-Duty Vehicle Idling Emission Factors*
(g/hr)

Model Years	NOx	ROG	PM10
Pre-1975	54.50	186.85	25.30
1975 – 1976	63.45	164.42	21.05
1977 – 1979	74.65	139.65	16.70
1980 – -1983	90.35	111.32	12.11
1984 – 1986	106.00	88.29	8.77
1987 – 1989	121.50	70.42	6.34
1991 – 1993	120.50	65.61	6.11
1994 – 1997	136.00	52.26	4.43
1998	164.50	37.77	2.62
1999-2002	171.00	34.28	2.28
2003	187.00	27.24	1.65
2004 – 2006	191.50	25.56	1.50
2007 – 2009	191.50	25.56	0.83
2010+	191.50	25.56	0.15

*Factors are for truck idling at a RPM >800

Table B-10
Emission Factors for Small Off-Road Diesel Engines
(g/bhp-hr)

Horsepower	Model Year	NOx	ROG	PM10
< 11	Pre-1995	9.30	1.26	0.720
< 11	1995 – 1999	8.70	0.88	0.410
< 11	2000 – 2004	5.76	0.57	0.376
< 11	2005 – 2007	4.14	0.41	0.304
< 11	2008 – 2020	4.14	0.41	0.152
11 - <25	Pre-1995	6.44	1.54	0.550
11 - <25	1995 – -1999	6.44	0.75	0.413
11 - <25	2000 – -2004	5.49	0.54	0.306
11 - <25	2005 – 2007	4.33	0.43	0.306
11 - <25	2008 – 2020	4.33	0.43	0.152

TRANSPORT REFRIGERATION UNITS

Table B-11
TRU Engine Load Factors
(Default Values)

Engine Horsepower	Load Factor
<25 hp	0.64
25 to 50 hp	0.53

OFF-ROAD EQUIPMENT
AND
STATIONARY AND PORTABLE AGRICULTURAL ENGINES

Table B-12
Emission Factors for Off-Road
Diesel Engines
(g/bhp-hr)

Horsepower	Tier	NOx	ROG	PM10
25-49	Uncontrolled pre-1988	6.51	2.21	0.547
	Uncontrolled post-1988	6.42	2.17	0.547
	1	5.26	1.74	0.480
	2	4.63	0.29	0.280
	4a	4.55	0.12	0.128
	4b	2.75	0.12	0.008
50-74	Uncontrolled pre-1988	12.09	1.73	0.605
	Uncontrolled post-1988	8.14	1.19	0.497
	1	6.54	1.19	0.552
	2	4.75	0.23	0.192
	4a	2.74	0.12	0.064
	4b	2.74	0.12	0.008
75-99	Uncontrolled pre-1988	12.09	1.73	0.605
	Uncontrolled post-1988	8.14	1.19	0.497
	1	6.54	1.19	0.552
	2	4.75	0.23	0.192
	3	2.74	0.12	0.192
	4a	2.15	0.11	0.008
	4b	0.26	0.06	0.008
100-174	Uncontrolled pre-1970	13.02	1.59	0.554
	Uncontrolled 1970 – 1971	12.09	1.32	0.475
	Uncontrolled 1972 – 1979	11.16	1.20	0.396
	Uncontrolled 1980 – 1984	10.23	1.13	0.396
	Uncontrolled 1985- – 1987	10.23	1.06	0.396
	Uncontrolled post-1987	7.60	0.82	0.274
	1	6.54	0.82	0.304
	2	4.17	0.19	0.128
	3	2.32	0.12	0.112
	4a	2.15	0.11	0.008
	4b	0.26	0.06	0.008
175-299	Uncontrolled pre-1970	13.02	1.52	0.554
	Uncontrolled 1970 – 1971	12.09	1.26	0.475
	Uncontrolled 1972 – 1979	11.16	1.14	0.396
	Uncontrolled 1980 – 1984	10.23	1.08	0.396
	Uncontrolled 1985- – 1987	10.23	1.01	0.396

Horsepower	Tier	NOX	ROG	PM10
	Uncontrolled post-1987	7.60	0.82	0.274
	1	5.93	0.38	0.120
	2	4.15	0.12	0.088
	3	2.32	0.12	0.088
	4a	1.29	0.08	0.008
	4b	0.26	0.06	0.008
300-750	Uncontrolled pre 1970	13.02	1.52	0.533
	Uncontrolled 1970 – 1971	12.09	1.26	0.454
	Uncontrolled 1972 – 1979	11.16	1.14	0.382
	Uncontrolled 1980 – 1984	10.23	1.08	0.382
	Uncontrolled 1985 – 1987	10.23	1.01	0.382
	Uncontrolled post 1987	7.60	0.82	0.274
	1	5.93	0.38	0.120
	2	3.79	0.12	0.088
	3	2.32	0.12	0.088
	4a	1.29	0.08	0.008
	4b	0.26	0.06	0.008
>750	Uncontrolled pre 1970	13.02	1.52	0.533
	Uncontrolled 1970 – 1971	12.09	1.26	0.454
	Uncontrolled 1972 – 1979	11.16	1.14	0.382
	Uncontrolled 1980 – 1984	10.23	1.08	0.382
	Uncontrolled 1985 – 1987	10.23	1.01	0.382
	Uncontrolled post 1987	7.60	0.82	0.274
	1	5.93	0.38	0.120
	2	3.87	0.12	0.088
	4a	2.24	0.12	0.048
	4b	2.24	0.06	0.016

Table B-13
Default Load Factors for Off-Road Heavy-Duty Diesel Engines
In Agricultural and Construction Applications

Category	Equipment Type	Load Factor
Agriculture	Agricultural Mowers	0.43
	Agricultural Tractors	0.7
	Balers	0.58
	Combines	0.7
	Hydro Power Units	0.48
	Sprayers	0.5
	Swathers	0.55
	Tillers	0.78
	Irrigation Pumps	0.65
	Other Agricultural Equipment	0.51
Construction	Cranes	0.43
	Crawler Tractors	0.64
	Crushing/Processing	0.78
	Excavators	0.57
	Graders	0.61
	Off-Highway Tractors	0.65
	Off-Highway Trucks	0.57
	Pavers	0.62
	Other Paving Equipment	0.53
	Rollers	0.56
	Rubber-Tired Dozers	0.59
	Rubber-Tired Loaders	0.54
	Scrapers	0.72
	Signal Boards	0.78
	Skid Steer Loaders	0.55
	Surfacing Equipment	0.45
	Tractors/Loaders/Backhoes	0.55
	Trenchers	0.75
	Other Construction Equipment	0.62

LARGE SPARK IGNITION ENGINES

Table B-14
Emission Factors for Off-Road LSI Engines by Model Year
(g/bhp-hr)

Horsepower	Fuel	Model Year	NOx	ROG	PM10
25-49	Gasoline	Uncontrolled – all years	8.01	3.81	0.060
		2001	6.91	3.00	0.060
		2002	5.52	2.37	0.060
		2003	4.52	1.64	0.060
		2004-2006	1.33	0.72	0.060
		2007-2009	0.89	0.48	0.060
		2010+	0.27	0.14	0.060
	Alt Fuel	Uncontrolled – all years	13.00	1.25	0.060
		2001	10.40	1.05	0.060
		2002	7.79	0.84	0.060
		2003	5.19	0.64	0.060
		2004-2006	1.95	0.13	0.060
		2007-2009	1.30	0.08	0.060
		2010+	0.39	0.03	0.060
50-120	Gasoline	Uncontrolled – all years	11.84	2.66	0.060
		2001	9.58	2.11	0.060
		2002	7.32	1.56	0.060
		2003	5.06	1.00	0.060
		2004-2006	1.78	0.26	0.060
		2007-2009	1.19	0.18	0.060
		2010+	0.36	0.05	0.060
	Alt Fuel	Uncontrolled – all years	10.51	1.40	0.060
		2001	8.54	1.16	0.060
		2002	6.56	0.92	0.060
		2003	4.57	0.68	0.060
		2004-2006	1.58	0.14	0.060
		2007-2009	1.05	0.10	0.060
		2010+	0.32	0.03	0.060
>120	Gasoline	Uncontrolled – all years	12.94	1.63	0.060
		2001	10.29	1.35	0.060
		2002	7.64	1.07	0.060
		2003	4.98	0.79	0.060
		2004-2006	1.94	0.16	0.060

Horsepower	Fuel	Model Year	NOx	ROG	PM10
		2007-2009	1.29	0.11	0.060
		2010+	0.39	0.03	0.060
	Alt Fuel	Uncontrolled – all years	10.51	1.25	0.060
		2001	8.53	1.05	0.060
		2002	6.54	0.85	0.060
		2003	4.56	0.64	0.060
		2004-2006	1.58	0.13	0.060
		2007-2009	1.05	0.08	0.060
		2010+	0.32	0.03	0.060

AIRPORT GROUND SUPPORT EQUIPMENT

Table B-15
Default Load Factors and Annual Operating Hours

Equipment	Horsepower	Load Factor	Annual Hours	
			LSI	Diesel
Belt Loader	51-120	0.50	810	1038
Baggage Tug	130-175	0.55	876	1624
Cargo Loaders	51-120	0.50	719	902
A/C Tugs wide body	250-500	0.80	515	759
A/C Tugs narrow body	121-175	0.80	551	606
Lifts	51-120	0.50	376	917
Ground Power Units	120-175	0.75	796	968

LOCOMOTIVES

Table B-16
Locomotive Emission Factors[a]
(g/bhp-hr)

Engine Model Year	Type	NOx	PM10[b]	ROG[b,c]
Pre-1973 (Uncontrolled)	Line-haul	11.70	0.288	0.47
	Switcher	15.66	0.396	0.99
1973-2001 (Tier 0)	Line-haul	7.74	0.288	0.47
	Switcher	11.34	0.396	0.99
2002-2004 (Tier 1)	Line-haul	6.03	0.288	0.47
	Switcher	8.91	0.396	0.99
2005 and later (Tier 2)	Line-haul	4.50	0.153	0.26
	Switcher	6.57	0.189	0.51

a - Emission factors from *U.S. EPA Technical Highlights - Emission Factors for Locomotives*, December 1997, with fuel correction factors (FCF) applied. NOx and PM10 FCFs for all Carl Moyer Program categories is 0.9

b - HC and PM standards are less stringent than actual emission rates. Emission factors reflect actual emission rates per U.S. EPA document cited above.

c - HC to ROG conversion rate = 0.98.

Table B-17
NOx and PM10 Idle-Limiting Device
Emission Reduction Factors

Type	Factor
Switchers	0.90
Line-Haul	0.97
Passenger	0.97

Note: Factors based on assumption ILD reduces locomotive engine idling by 50 percent.

MARINE VESSELS

Table B-18
Harbor Craft Propulsion and Auxiliary Engine Emission Factors
(g/bhp-hr)

Horsepower	Year	NOx	ROG	PM10
50-99	pre-1988	12.09	1.73	0.605
	1988-2004	8.14	1.19	0.497
	2005+	4.22	0.54	0.320
100-174	pre-1970	13.02	1.59	0.554
	1970-1971	12.09	1.32	0.475
	1972-1979	11.16	1.20	0.396
	1980-1984	10.23	1.13	0.396
	1985-1987	10.23	1.06	0.396
	1988-2003	7.60	0.82	0.274
	2004+	4.17	0.39	0.240[a]
175-299	pre-1970	13.02	1.52	0.554
	1970-1971	12.09	1.26	0.475
	1972-1979	11.16	1.14	0.396
	1980-1984	10.23	1.08	0.396
	1985-1987	10.23	1.01	0.396
	1988-2003	7.60	0.82	0.274
	2004+	4.17	0.39	0.160[b]
300-750	pre-1970	13.02	1.52	0.533
	1970-1971	12.09	1.26	0.454
	1972-1979	11.16	1.14	0.382
	1980-1984	10.23	1.08	0.382
	1985-1987	10.23	1.01	0.382
	1988-2003	7.60	0.82	0.274
	2004+	4.17	0.39	0.160
>750	pre-1970	13.02	1.52	0.533
	1970-1971	12.09	1.26	0.454
	1972-1979	11.16	1.14	0.382
	1980-1984	10.23	1.08	0.382
	1985-1987	10.23	1.01	0.382
	1988-2006	7.60	0.82	0.274
	2007+ ($1.2 \leq D < 5.0$[c])	4.17	0.39	0.160
	2007+ ($5 \leq D < 15$[c])	4.60	0.44	0.216
	2007+ ($15 \leq D < 20$[c])	5.03	0.48	0.400
	2007+ ($20 \leq D < 25$[c])	5.77	0.54	0.400
	2007+ ($25 \leq D < 30$[c])	6.35	0.59	0.400

a - If engine displacement < 0.9 liters/cyl, PM10 = 0.320 g/bhp-hr; If engine displacement ≥1.2 liters/cyl.,PM10 =0.160 g/bhp-hr.
b – If engine displacement < 1.2 liters/cyl., PM10 = 0.24 g/bhp-hr.
c – Engine displacement in liters per cylinder.

Table B-19
Harbor Craft Load Factors

Engine	Vessel Type	Factor
Propulsion	Commercial Fishing	0.27
	Charter Fishing	0.52
	Ferry/Excursion	0.76
	Crew & Supply	0.45
	Pilot	0.51
	Tow	0.68
	Tug	0.50
	Work	0.45
	Other	0.52
Auxiliary	Tug	0.31
	Other	0.43

Table B-20
Harbor Craft
Fuel Consumption Rate Factors
(bhp-hr/gal)

Engine Displacement	Fuel Consumption Rate
< 5 liters/cylinder	18.5
≥ 5 liters/cylinder	20.8

LIGHT-DUTY VEHICLES

Table B-21
Voluntary Accelerated Light-Duty Vehicle Retirement Program
Emission Reductions for Calendar Year 2006*
Total Pounds Per Vehicle Over 3 Year Credit Life

	Emission Reductions (pounds) – 3 Year Credit Life			
Model Year	**NOx**	**ROG****	**CO**	**PM10**
65 and earlier	151	496	2,757	0.68
66	145	471	2,552	0.67
67	148	477	2,611	0.65
68	156	492	2,731	0.81
69	162	504	2,841	0.56
70	169	438	2,971	0.99
71	172	449	2,990	0.95
72	177	458	3,037	0.83
73	180	469	3,082	0.64
74	159	401	2,859	1.20
75	145	345	2,861	1.17
76	130	222	2,673	1.04
77	108	183	2,546	1.13
78	107	186	2,493	1.10
79	95	168	1,625	0.90
80	85	129	1,373	1.13
81	62	108	1,092	1.22
82	66	101	1,085	1.36
83	73	85	934	1.22
84	73	74	883	1.05
85	69	59	575	0.89
86	71	61	527	0.91
87	67	71	468	0.92
88	67	65	430	0.85
89	50	46	492	0.84
90	38	45	529	0.81
91	38	42	514	0.76
92	40	41	510	0.71
93	35	31	279	0.64
94	19	17	21	0.54

* Table is repeated in the Light-Duty Vehicle Chapter, Table 11-2
** Includes exhaust and evaporative emissions

<u>Source:</u> EMFAC2002, Version 2.2, statewide, annual average. Assumes average 1965 through 2006 vehicle as replacement vehicle for vehicles retired in calendar year 2006.

This table updates the emission reductions provided in ARB's VAVR regulation consistent with the methodology in the staff report, *Proposed Regulations for Voluntary Accelerated Light-Duty Vehicle Retirement Enterprises*, released October 23, 1998, and approved by ARB on December 10, 1998.

REFERENCES

The information in these tables has already been incorporated into the preceding emission factor tables. These tables are included for informational purposes.

Table B-22
NOx and NMHC Fraction Default Values
For All Engines Except TRUs

Diesel Engines		Alternative Fuel Engines	
NOx	NMHC	NOx	NMHC
0.95	0.05	0.80	0.20

Table B-23
NOx and NMHC Fractions for TRUs

Horsepower Category	Model Year	NOx	NMHC
< 25 hp	All	0.80	0.20
25 to 50 hp	2004 and earlier	0.80	0.20
25 to 50 hp	2005 to 2008	0.90	0.10
25 to 50 hp	2008 and later	0.95	0.05

Table B-24
Fuel Correction Factors for On-Road Diesel Engines

		SCAB and Ventura			All Other Areas		
Calendar Year	Model Year	NOx	PM10	HC	NOx	PM10	HC
Pre 1985	All	1.00	1.00	1.00	1.00	1.00	1.00
1985 - 1993	All	1.00	0.96	1.00	1.00	1.00	1.00
1994 - 2006	All	0.93	0.75	0.72	0.93	0.75	0.72
2007+	Pre-2007	0.93	0.72	0.72	0.93	0.72	0.72
2007+	2007+	0.93	0.80	0.72	0.93	0.80	0.72

Table B-25
Fuel Correction Factors for California Clean Diesel Fuel (pre-2007) and Ultra Low Sulfur Diesel (post-2007) for Off-Road Diesel Engines

Area	HP Group	Calendar Years	Model Years	NOx	PM10
South Coast and Ventura	All	Pre-1985	All	1.000	1.000
	All	1985-1993	All	1.000	0.950
All	All	Pre-1994	All	1.000	1.000
	<25	1994-2006	Pre-1995	0.930	0.750
			1995+	0.950	0.822
		2007+	Pre-1995	0.930	0.720
			1995-2010	0.948	0.800
	25-50	1994-2006	Pre-1999	0.930	0.750
			1999-2010	0.948	0.822
		2007+	Pre-1999	0.930	0.720
			1999-2010	0.948	0.800
	51-100	1994-2006	Pre-1998	0.930	0.750
			1998-2010	0.948	0.822
		2007+	Pre-1998	0.930	0.720
			1998-2010	0.948	0.800
	101-175	1994-2006	Pre-1997	0.930	0.750
			1997-2010	0.948	0.822
		2007+	Pre-1997	0.930	0.720
			1997-2010	0.948	0.800
	176+	1994-2006	Pre-1996	0.930	0.750
			1996-2010	0.948	0.822
		2007+	Pre-1996	0.930	0.720
			1996-2010	0.948	0.800
	All	2007+	2011+	0.948	0.852

APPENDIX C

COST-EFFECTIVENESS CALCULATION METHODOLOGY

APPENDIX C

COST-EFFECTIVENESS CALCULATION METHODOLOGY

I. Introduction

To receive Carl Moyer Program funding, each project must meet the maximum cost-effectiveness limit of $14,300 per weighted ton of surplus NOx, ROG, and PM10 (PM10 means combustion PM) emissions reduced. Only Carl Moyer Program funding, funding under the district's fiduciary budget authority, or funding provided by a port authority (to meet the match fund requirement) are included in determining the cost-effectiveness of surplus emission reductions. For more details see Part 1, Program Overview and Administrative Requirements, Chapter 2 Administration of the Carl Moyer Program.

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. 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 NOx and ROG emissions are given equal weight; emissions of combustion PM10 (such as diesel exhaust PM10 emissions) has been identified as a toxic air contaminant and thus carry a greater weight in the calculation.

Formula C-2: Annual Weighted Surplus Emission Reductions:

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

The annual surplus weighted emission reduction result 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-3 below must be completed for each pollutant (NOx, ROG, and PM10), for the baseline technology and the reduced technology, totaling up to 6 calculations:

1. Annual emissions of NOx for the baseline technology
2. Annual emissions of NOx for the reduced technology
3. Annual emissions of ROG for the baseline technology
4. Annual emissions of ROG for the reduced technology
5. Annual emissions of PM10 for the baseline technology
6. Annual emissions of PM10 for the reduced technology

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

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; or the existing engine in a vehicle or equipment for repowers and retrofits.

The **reduced technology** is the newer technology used by the applicant to obtain surplus emission reductions. The newer technology may be one of the following:

- For a new purchase it would be the engine certified by ARB to reduce NOx emissions by at least 30 percent less than the current NOx emission standard, or certified by ARB to the optional NOx or NOx+NMHC emission standard. Locomotive and marine vessel new purchases have slightly different criteria. Please see the specific source category cost-effectiveness criteria for more information.
- For a repower it would be the replacement engine certified by ARB (for locomotives and marine vessels it would be EPA verified) to a minimum of 15 percent less than the NOx emissions from the baseline technology (existing engine).
- For a NOx retrofit it would be an ARB-verified retrofit technology that will reduce NOx emissions by a minimum of 15 percent from the NOx emissions of the baseline technology.
- For a PM retrofit it would be the ARB-verified diesel emission control strategy (DECS) that reduces PM emissions as level 1 (25 percent reduction), level 2 (50 percent reduction), or level 3 (85 percent reduction).

Since the emission factor or converted standard is given in units of grams, a conversion from grams to tons is also required, as described in formula C-3 below.

Formula C-3: Estimated Annual Emissions by Pollutant (tons/yr):

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

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

- Hours of operation,
- Fuel consumption, or
- 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.

1. 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 Part 1, Program Overview and Administrative Requirements, Chapter 2 Administration of the Carl Moyer Program, section VII and the relative 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 B 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 B. 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):

*Emission Factor or Converted Emission Standard (g/bhp-hr) * Horsepower * Load Factor* Activity (hrs/yr) * 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 reduced technology horsepower exceeds that of the baseline technology horsepower, 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 replacement engine is significantly smaller than the existing engine.

Formula C-5: Replacement Load Factor:

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

2. 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 Part 1, Program Overview and Administrative Requirements, Chapter 2 Administration of the Carl Moyer Program, section VII.

An energy consumption factor (ECF) 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 ECF 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-6 below is the formula for calculating annual emissions based on annual fuel consumed.

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

*Emission Factor or Converted Emission Standard (g/bhp-hr) * ECF (hp-hr/gal) * Activity (gal/yr) * ton/907,200g*

For on-road projects, if the emission factor is in g/mile, a unit conversion factor (bhp-hr/mile) found in Table B-8 in Appendix B must be used to convert from g/mile to g/bhp-hr. This is completed by dividing the emission factor (g/mile) by the conversion factor (bhp-hr/mile) resulting in (g/bhp-hr). Formula C-7 below is used to calculate annual emissions for fuel based on-road calculations.

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr):

*[On-Road Emission Factor (g/mile)/Unit Conversion Factor (bhp-hr/mile)] * ECF (hp-hr/gal) * Activity (gal/yr) * ton/907,200g*

3. Calculating Annual Emissions Based on Annual Miles Traveled

Calculations based on annual miles traveled are only used for on-road projects. Mileage records must be maintained by the engine owner as described in Part 1, Program Overview and Administrative Requirements, Chapter 2 Administration of the Carl Moyer Program, section VII and the relative source category chapter.

Calculations Using Emission Factors: There is no conversion since the emission factors for on-road projects provided are given in units of g/mile. Formula C-8 describes the method for calculating pollutant emissions based on emission factors and miles traveled.

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr):

*Emission Factor (g/mile) * Activity (miles/yr) * ton/907,200g*

Calculating Annual Emissions Based on Converted Standards**:** The unit conversion factor found in Table B-8 in Appendix B is used to convert the units of the converted emission standard (g/bhp-hr) to g/mile. Formula C-9 describes the method for calculating pollutant emissions using converted emission standards.

Formula C-9: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr):

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

4. 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-10 below.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases:

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-11 below.

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:

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

Calculations must be done for each pollutant, NOx, PM10, and ROG, giving a total of three calculations.

For a repower + retrofit calculation the baseline to be used for the retrofit portion of the calculation will be the repower's reduced technology emissions. 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-2 to calculate the annual surplus emission reductions.

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

The incremental cost is determined by subtracting the cost of the baseline technology from the cost of the reduced technology, as described in formula C-14 below.

Formula C-14: Incremental Cost ($):

Cost of Reduced Technology ($) – Cost of Baseline Technology ($)

Generally the cost of the baseline technology for a new purchase is the price of a new piece of equipment meeting the current emission standards. The cost of the baseline technology for a repower is the cost of rebuilding the existing engine. For retrofits, there is no baseline technology cost; hence the entire cost of the retrofit is eligible for funding.

For 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-15 below.

Formula C-15: Incremental Cost for Fleet Modernization Projects ($):

When the replacement vehicle is not new:

N.A.D.A value

where the N.A.D.A value is the retail value of the used vehicle * 72 percent.

When the replacement vehicle is new:

*Invoice of the New Vehicle * 80 percent*

Use the results from formula C-14 or C-15 to complete formula C-12 to determine the annualized cost of a project.

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.

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:

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

Formula C-3: Estimated Annual Emissions by Pollutant (tons/yr):

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

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

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

Formula C-5: Replacement Load Factor:

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

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

Emission Factor or Converted Emission Standard (g/bhp-hr) * ECF (hp-hr/gal) * Activity (gal/yr) * ton/907,200g

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr):

[On-Road Emission Factor (g/mile)/Unit Conversion Factor (bhp-hr/mile)] * ECF (hp-hr/gal) * Activity (gal/yr) * ton/907,200g

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors (tons/yr):

Emission Factor (g/mile) * Activity (miles/yr) * ton/907,200g

Formula C-9: Estimated Annual Emissions based on Mileage using Converted Emission Standards (tons/yr):

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

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases:

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

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:

Annual Emissions for the Baseline Technology *
Reduced Technology Verification Percent

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 ($) – Cost of Baseline Technology ($)

Formula C-15: Incremental Cost for Fleet Modernization Projects ($):

When the replacement vehicle is not new:

N.A.D.A value

where the N.A.D.A value is the retail value of the used vehicle * 72 percent.

When the replacement vehicle is new:

Invoice of the New Vehicle * 80 percent

APPENDIX D

EXAMPLE CALCULATIONS

APPENDIX D

EXAMPLE CALCULATIONS

TABLE OF CONTENTS

I. On-Road Heavy-Duty Vehicles

This section provides several examples of calculations for determining the cost-effectiveness of surplus emission reductions for on-road projects.

A. General Criteria for On-Road Cost-Effectiveness Calculations

- Funded projects must have a minimum project life of 3 years. Project life is the number of years that a Carl Moyer Program project will operate in California under the conditions specified in the grant funding agreement.

- The default project life for on-road projects are as follows:

School buses $\geq$ 33,000 GVWR - New	20 years
Buses $\geq$ 33,000 GVWR - New	12 years
Other On-Road - New	10 years
Repowers + Retrofits	5 years
Retrofits	5 years

  Applicants must provide documentation to justify a longer project life.

- Only the minimum verified levels of NOx and PM10 emission reductions will be used to calculate cost-effectiveness for retrofit projects.

- In these calculations, PM10 refers to combustion particulate matter.

- ROG reductions cannot be counted in projects where the new engine or retrofit device are not verified or certified for ROG.

- When the model year of the vehicle chassis and the model year of the existing engine are different, the newer of the two model years, either the vehicle or the engine, shall be used to determine the baseline emissions for calculations.

- When calculating the baseline emissions for a glider kit repower project, the baseline for the project is the chassis year or the old engine model year, whichever is newer.

- The incremental emission difference between the lower FEL level to the required emission standard cannot be used for the purpose of calculating Carl Moyer Program emission benefits. The maximum amount of emission reduction that can be claimed is the difference between the applicable required emission standard for the replacement engine (not the FEL level) and the baseline emission level of the existing engines.

- Most on-road calculations will be based on mileage. Refuse haulers and street sweepers may have fuel based calculations if fuel receipts can be provided to document previous usage. Other vehicles may also use fuel based calculations on a case-by-case basis.

- Refuse vehicles and street sweepers often have two engines, one for motive power and one for auxiliary operations. Emission benefits are calculated individually for each engine using fuel consumption rates for each unit if available. If individual engine fuel consumption information is not available, the applicant must provide and document an estimate for the typical activities of each engine based on best engineering judgment so that emissions can be determined. Factors such as fuel economy, typical operating loads, and hours of operation for each engine must be provided.

- Table D-1 provides the source of emission factors to be used in on-road cost-effectiveness calculations.

Table D-1
On-Road Heavy-Duty Vehicle Calculations
Source of Emission Factors

	New		**Repower**		**Retrofit**	
Vehicle Type	**Baseline Factor**	**Reduced Factor**	**Baseline Factor**	**Reduced Factor**	**Baseline Factor**	**Reduced Factor**
Medium Heavy Duty Vehicle	B-4	B-2 or B-3	B-3 or B-4	B-3 or B-4	B-4	% verified as shown on Executive Order
Heavy Duty Vehicle	B-5	B-2 or B-3	B-3 or B-5	B-3 or B-5	B-5	% verified as shown on Executive Order
Urban Bus (Alternative Fuel)	B-7	B-2 or B-3	B-7	B-7	B-7	% verified as shown on Executive Order
Urban Bus (Diesel)	B-6	B-2 or B-3	B-6	B-6 or B-7	B-6	% verified as shown on Executive Order

- The energy consumption factor to be used for all on-road fuel based calculations is 18.5 bhp/hr-gal.

- The baseline cost for retrofit projects is zero ($0). The full cost of a retrofit is potentially eligible for funding.

- For retrofit projects that only take credit for NOx reductions from a Level 3 DECS (because the PM10 reductions are required by regulation) the baseline cost is $8,000, unless the applicant documents a lower cost. The maximum funding for such projects would be the retrofit cost minus the default cost.

- Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

- Although electronic monitoring units are not required by the ARB, when an EMU is required by a district, it is an eligible expense for any category.

- FTA provides up to an 80 percent grant for new urban bus purchases. For these projects the incremental cost would be the difference between the FTA grant amount and the cost of the reduced technology or baseline technology.

- The cost of alternative fuel projects must be based on the total amortized cost of hardware (i.e., new engine or repower), and fuel, if applicable.

- If all Carl Moyer Program criteria are met and the project is not a "fuel-only" project, the incremental cost of alternative fuel can be considered a qualified matching contribution from a district.

B. Examples

Example 1 – New Purchase of LNG Heavy-Duty Truck

A trucking company proposes to purchase a new 2005 model year heavy heavy-duty truck equipped with a LNG engine certified to the optional standard of 1.8 g/bhp-hr NOx + NMHC instead of a new heavy heavy-duty truck equipped with a diesel engine. This vehicle operates 100 percent of the time in California.

Baseline Technology Information:
- Baseline technology (application): 2005 diesel heavy heavy-duty on road truck
- Cost (quote provided with application): $180,000
- New diesel vehicle emission rates (Table B-5): 13.21 g/mi NOx, 0.22 g/mi ROG, 0.360 g/mi PM10
- Activity (application): 100,000 mi/yr
- Percent operate in California (application): 100 percent

Reduced Technology Information:
- Reduced technology (application): 2005 heavy-duty LNG truck
- Cost (quote provided with application): $220,000
- New LNG vehicle emission standard (Table B-2): 1.44 g/bhp-hr NOx, 0.030 g/bhp-hr PM10

- Conversion factor to convert g/bhp-hr to g/mi (Table B-8): 2.6 bhp-hr/mi

Emission Reduction Calculations:
Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors (use for baseline calculations)

Formula C-9: Estimated Annual Emissions based on Mileage using a Converted Emission Standards (use for reduced calculations)

1. Annual NOx baseline technology emissions
   (13.21 g/mi * 100,000 mi/yr)(ton/907,200 g) = 1.46 tons/yr NOx
2. Annual NOx reduced technology emissions
   (1.44 g/bhp-hr * 2.6 bhp-hr/mi * 100,000 mi/yr)(ton/907,200 g)
   = 0.41 tons/yr NOx
3. Annual PM10 baseline technology emissions
   (0.360 g/mi * 100,000 mi/yr)(ton/907,200 g) = 0.04 tons/yr PM10
4. Annual PM10 reduced technology emissions
   (0.030 g/bhp-hr * 2.6 bhp-hr/mi * 100,000 mi/yr)(ton/907,200 g)
   = 0.009 tons/yr PM10

ROG emission factors not available for reduced technology therefore ROG emission reductions cannot be calculated.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 1.46 tons/yr – 0.41 tons/yr = 1.05 tons/yr NOx
- PM10 emission benefits = 0.040 tons/yr – 0.009 tons/yr = 0.031 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions
1.05 + 20(0.031) = 1.67 weighted tons/yr

Annualized Cost:
Project Life: 10 years
CRF (Table B-1) = 0.123

Formula C-14: Incremental Cost
$220,000 -$180,000 = $40,000

Formula C-12: Annualized Cost
$40,000 * 0.123 = $4,920/yr

Cost-Effectiveness:

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

($4,920/yr)/(1.67 weighted tons/yr)

= $2,946/ton of weighted surplus emissions reduced

The weighted cost-effectiveness for the example is less than $14,300 per ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 2 – Diesel to Diesel Heavy-Duty Truck Repower + Retrofit

A line haul trucking company proposes to repower a 1994 heavy heavy-duty diesel truck with a model year 2003 certified diesel engine and retrofit the engine with a Level 3 retrofit that is verified for both PM10 and NOx reductions. This vehicle operates 90 percent of the time in California.

Baseline Technology Information:

- Baseline technology (application): 1994 diesel heavy heavy-duty engine
- Cost rebuild (quote provided with application): $8,000
- Baseline cost of retrofit: $0
- Emission rates (Table B-5): 18.41 g/mi NOx, 0.26 g/mi ROG, 0.475 g/mi PM10
- Activity (application): 60,000 mi/yr
- Percent operated in California (application): 90 percent

Reduced Technology Information:

- Reduced technology (application): 2003 diesel heavy heavy-duty engine
- Repower cost (quote provided with application): $35,000
- Retrofit cost (quote provided with application): $18,000 + $600 annual filter maintenance
- Emission rates (Table B-5): 13.21 g/mi NOx, 0.22 g/mi ROG, 0.360 g/mi PM10
- Retrofit verification emission levels (EO): 25 percent reduction of NOx and 85 percent reduction of PM10. ROG is not counted since the retrofit device is not verified for ROG.

Emission Reduction Calculations:

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors

1. Annual NOx baseline technology emissions
   (18.41 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 1.10 tons/yr NOx
2. Annual NOx reduced technology emissions
   (13.21 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 0.79 tons/yr NOx
3. Annual ROG baseline technology emissions
   (0.26 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 0.02 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.22 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 0.01 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.475 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 0.028 tons/yr PM10

6. Annual PM10 reduced technology emissions
   (0.360 g/mi * 0.90 * 60,000 mi/yr)(ton/907,200 g) = 0.021 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 1.10 tons/yr – 0.79 tons/yr = 0.31 tons/yr NOx
- ROG emission benefits = 0.02 tons/yr – 0.01 tons/yr = 0.01 tons/yr ROG
- PM10 emission benefits= 0.028 tons/yr – 0.021 tons/yr = 0.007 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

0.79 tons/yr NOx * 0.25 = 0.20 tons/yr NOx
0.021 tons/yr PM10 * 0.85 = 0.018 tons/yr PM10

Total NOx Emission Benefits

0.31 + 0.20 = 0.51 tons/yr NOx

Total PM10 Emission Benefits

0.007 + 0.018 = 0.025 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.51 + 0.01 + 20(0.025) = 1.02 weighted tons/yr

Annualized Cost:
Project Life: 5 years
CRF (Table B-1) = 0.225

Formula C-14: Incremental Cost

($35,000 + $18,000 + ($600*5) -$8,000 = $48,000

Formula C-12: Annualized Cost

$48,000 * 0.225 = $10,800/yr

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

($10,800/yr)/(1.02 weighted tons/yr) =
$10,588/ton of weighted surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per ton of weighted pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 3 – Diesel Heavy-Duty Truck Retrofit

A trucking company proposes to retrofit a 2005 heavy heavy-duty diesel truck with a Level 3 retrofit that is verified for both PM and NOx reductions. This vehicle operates 80 percent of the time in California.

Baseline Technology Information:

- Baseline technology (application): 2005 heavy heavy-duty diesel truck
- Cost (retrofits are eligible for full cost unless being installed to meet regulatory requirements): $0
- New diesel vehicle emission rates (Table B-5): 13.21 g/mi NOx; 0.360 g/mi of PM10
- Activity (application): 100,000 mi/yr
- Percent operated in California (application): 80 percent

Reduced Technology Information:

- Retrofit verification emission levels (EO): 25 percent reduction of NOx and 85 percent reduction of PM10. ROG is not counted since the retrofit device is not verified for ROG.
- Retrofit cost (quote provided with application): $18,000 + $600 annual filter maintenance

Emission Reduction Calculations:

Formula C-8: Estimated Annual Emissions based on Mileage using Emission Factors

1. Annual NOx baseline technology emissions
   (13.21 g/mi * 0.80 * 100,000 mi/yr)(ton/907,200 g) = 1.16 tons/yr NOx
2. Annual PM10 baseline technology emissions
   (0.360 g/mi * 0.80 * 100,000 mi/yr)(ton/907,200 g) = 0.032 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

1.16 * 0.25 = 0.29 tons/yr NOx

0.032 * 0.85 = 0.027 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.29 + 0 + 20(0.027) =0.83 weighted tons/yr

Annualized Cost:

Project Life: 5 years

CRF (Table B-1): = 0.225

Formula C-14: Incremental Cost

($18,000 + ($600*5) -$0 = $21,000

Formula C-12: Annualized Cost

0.225 * 21,000 =$4,725/yr

Cost-Effectiveness:

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

($4,725/yr)/(0.83 weighted tons/yr) =

$5,693/ton of weighted surplus emissions reduced

For retrofit projects that only take credit for NOx reductions from a Level 3 DECS (because the PM reductions are required by regulation) the baseline cost is $8,000, unless an applicant documents a lower cost. The maximum funding for such projects would be the retrofit cost minus the default cost.

The cost-effectiveness for the example is less than $14,300 per ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 4 –Purchase of a New CNG Street Sweeper

A company proposes to purchase a new CNG street sweeper instead of a diesel sweeper. The GVWR of the new vehicle is 24,000 lbs. The CNG engine is certified to the optional emission standard of 1.2 g/bhp-hr for NOx+NMHC and 0.01 g/bhp-hr for PM10. This vehicle operates 100 percent of the time in California.

Baseline Technology Information:

- Baseline technology (application): 2005 heavy heavy-duty diesel vehicle
- Cost (quote provided with application): $125,000
- New diesel vehicle emission rates (Table B-5): 5.12 g/mi NOx, 0.08 g/mi ROG, 0.216 g/mi PM10
- Conversion factor to convert g/mile to g/bhp-hr (Table B-8): 2.3 bhp-hr/mi
- Energy consumption factor: 18.5 bhp-hr/gal
- Activity (application): 5,000 gal/yr
- Percent operated in California (application): 100 percent

Reduced Technology Information:

- Reduced technology (application): 2005 heavy heavy-duty CNG vehicle
- Cost (quote provided with application): $160,000
- New CNG vehicle emission standard (Table B-2): 0.96 g/bhp-hr NOx, 0.01 g/bhp-hr PM10
- Energy consumption factor: 18.5 bhp-hr/gal

Emission Reduction Calculations:

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr)

1. Annual NOx baseline technology emissions
   (5.12 g/mi / 2.3 bhp-hr/mi)(5,000 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.23 tons/yr NOx
2. Annual PM10 baseline technology emissions
   (0.216 g/mi / 2.3 bhp-hr/mi)(5,000 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.01 tons/yr PM10

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factor or Converted Emission Standards (tons/yr)

3. Annual NOx reduced technology emissions
   (0.96 g/bhp-hr)(5,000 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.10 tons/yr NOx

4. Annual PM10 reduced technology emissions
   (0.01 g/bhp-hr)(5,000 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.001 tons/yr PM10

ROG emission factors not available for reduced technology therefore ROG emission reductions cannot be calculated.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 0.23 tons/yr – 0.10 tons/yr = 0.13 tons/yr NOx
- PM10 emission benefits = 0.01 tons/yr – 0.001 tons/yr = 0.009 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.13 + 20(0.009) = 0.31 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost

$160,000 -$125,000 = $35,000

Formula C-12: Annualized Cost

0.123 * $35,000 = $4,305/yr

Cost-Effectiveness:

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

($4,305/yr)/(0.31 weighted tons/yr) =

$13,887/ton of weighted surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 5 - Repower + Retrofit of Street Sweeper

A company proposes to repower a 2001 diesel street sweeper with a 2006 diesel engine certified to the optional heavy-duty engine standard of 1.8 g/bhp-hr NOx + NMHC and 0.3 g/hbp-hr PM10. The company will also retrofit the engine with a Level 3 retrofit that is verified for both PM and NOx reductions. This vehicle has a GVWR of 19,000 lbs. and operates 100 percent of the time in California.

Baseline Technology Information:

- Baseline technology (application): 2001 diesel heavy heavy-duty engine
- Cost of rebuild (quote provided with application): $14,000
- Emission rates (Table B-4): 9.77 g/mi NOx, 0.08 g/mi ROG, 0.144 g/mi PM10
- Conversion factor to convert g/mile to g/bhp-hr (Table B-8): 2.3 bhp-hr/mi

- Energy consumption factor: 18.5 bhp-hr/gal
- Activity (application): 7,667 gal/yr
- Percent operated in California (application): 100 percent

<u>Reduced Technology Information</u>:
- Reduced technology (application): 2006 diesel heavy heavy-duty engine
- Cost (quote provided with application): $47,750
- Converted emission standard (Table B-2): 1.44 g/bhp-hr NOx; 0.030 g/bhp-hr PM10
- Retrofit Cost (quote provided with application): $18,000 + $600 annual filter maintenance
- Retrofit verification emission levels (EO): 25 percent reduction of NOx and 85 percent reduction of PM10. ROG is not counted since the retrofit device is not verified for ROG.
- Energy consumption factor: 18.5 bhp-hr/gal

<u>Emission Reduction Calculations</u>:
Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standards (tons/yr)
1. Annual NOx baseline technology emissions
   (9.77 g/mi / 2.3 bhp-hr/mi)(7,667 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.66 tons/yr NOx
2. Annual PM10 baseline technology emissions
   (0.144 g/mi / 2.3 bhp-hr/mi)(7,667 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.010 tons/yr PM10

Formula C-7: Estimated Annual Emissions based on Fuel Consumed using On-Road Emission Factors (tons/yr)
3. Annual NOx reduced technology emissions
   (1.44 g/bhp-hr)(7,667 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.23 tons/yr NOx
4. Annual PM10 reduced technology emissions
   (0.030 g/bhp-hr)(7,667 gal/yr)(18.5 bhp-hr/gal)(ton/907,200 g)
   = 0.005 tons/yr PM10

ROG emission factors not available for reduced technology therefore
ROG emission reductions cannot be calculated.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases
- NOx emission benefits = 0.66 tons/yr - 0.23 tons/yr = 0.43 tons/yr NOx
- PM10 emission benefits = 0.010 tons/yr – 0.005 tons/yr = 0.005 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

0.23 tons/yr NOx * 0.25 = 0.06 tons/yr NOx
0.005 tons/yr PM10 * 0.85 = 0.004 tons/yr PM10

Total NOx Emission Benefits

0.43 + 0.06 = 0.49 tons/yr NOx

Total PM10 Emission Benefits

0.005 + 0.004 = 0.009 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.49 +20(0.009) = 0.67 weighted tons/yr

Annualized Cost:

Project Life: 5 years

CRF (Table B-1) = 0.225

Formula C-14: Incremental Cost

$68,750 -$14,000 = $54,750

Formula C-12: Annualized Cost

0.225 * $54,750 = $12,319/yr

Cost-Effectiveness:

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

($12,319/yr)/(0.67 weighted tons/yr) =

$18,387/ton of weighted surplus emissions reduced

The cost-effectiveness for this example is greater than the $14,300 per ton weighted cost-effectiveness requirement. In order to meet the $14,300 per ton weighted cost-effectiveness requirement, this project would only qualify for a fraction of the incremental cost – $42,582. This amount is determined by multiplying the maximum allowed cost-effectiveness by the estimated annual emission reductions and dividing by the capital recovery factor:

($14,300 * 0.67)/0.225 = $42,582

Example 6 –Purchase of a New CNG Bus

A transit agency proposes to purchase a new 2005 CNG bus certified to the alternative fuel optional standard of 1.2 g/bhp-hr NOx + NMHC and 0.01 g/bhp-hr PM10 instead of a new CNG bus certified to the current alternative fuel standard of 2.5g/bhp-hr NOx+NMHC. The baseline cost for this project is based on a diesel engine. This new CNG bus is surplus to the ARB transit bus fleet rule. The CNG engine was certified to the optional NOx+NMHC emission standard of 1.2 g/bhp-hr and 0.01 g/bhp-hr of PM10. The new bus will operate 100 percent of the time in California.

Baseline Technology Information:

- Baseline technology (application): 2005 CNG urban bus
- Cost (quote provided with application): $350,000

- Emission standard (Table B-7): 7.50 g/mi NOx and 0.004 g/mi PM10
- Activity (application): 50,000 mi/yr
- Percent operated in California (application): 100 percent

Reduced Technology Information:
- Reduced technology (application): 2005 CNG urban bus certified to optional standard
- Cost (quote provided with application): $390,000
- Converted emission standard (Table B-2): 0.96 g/bhp-hr NOx and 0.010 g/bhp-hr PM10
- Conversion factor to convert the standard in g/bhp-hr to g/mi (Table B-8): 4.3 bhp-hr/mi

Emission Reduction Calculations:
Formula C-8:   Estimated Annual Emissions based on Mileage using Emission Factors
1. Annual NOx baseline technology emissions
   (7.5 g/mi)(50,000 mi/yr)(ton/907,200 g)   = 0.41 tons/yr NOx
2. Annual PM10 baseline technology emissions
   (0.004 g/mi)(50,000 mi/yr)(ton/907,200 g)   = 0.0002 tons/yr PM10

Formula C-9:   Estimated Annual Emissions based on Mileage using a Converted Emission Standards
3. Annual NOx reduced technology emissions
   (0.96 g/bhp-hr * 4.3 bhp-hr/mi)(50,000 mi/yr)(ton/907,200 g)
   = 0.23 tons/yr NOx
4. Annual PM10 reduced technology emissions
   (0.010 g/bhp-hr * 4.3 bhp-hr/mi)(50,000 mi/yr)(ton/907,200 g)
   = 0.002 tons/yr PM10

ROG emission factors not available for reduced technology therefore
ROG emission reductions cannot be calculated.

Formula C-10:   Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 0.41 tons/yr – 0.23 tons/yr   = 0.18 tons/yr NOx
- PM10 emission benefits = 0.0002 tons/yr – 0.002 tons/yr =(-)0.002 tons/yr PM10

Formula C-2:   Annual Weighted Surplus Emission Reductions
0.18 + 20(-0.002)   = 0.14 weighted tons/yr

Annualized Cost:
Project Life: 12 years
CRF (Table B-1)   = 0.107

Transit agencies receive an 80 percent grant from the Federal Transportation Agency for most new vehicle purchases. This grant must be subtracted before calculating the incremental cost.

Transit agency's cost for baseline technology: $350,000 * 0.20 = $70,000
Transit agency's cost for reduced technology: $390,000 * 0.20 = $78,000

Formula C-14: Incremental Cost
$78,000 - $70,000 = $8,000

Formula C-12: Annualized Cost
0.107 * $8,000 = $856/yr

Cost-Effectiveness:
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($856/yr)/(0.14 weighted tons/yr) =
$6,114/ton of weighted surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

C. Auxiliary Engine Calculations

To calculate the emission benefits of an auxiliary engine, see the Example #3 in the off-road section of this Appendix.

II. On-Road Heavy-Duty Fleet Modernization

This section provides examples of calculations for determining the cost-effectiveness of surplus emission reductions for fleet modernization projects.

A. General Criteria for Fleet Modernization Cost-Effectiveness Calculations

- Target vocations are eligible for a five year project life.

- Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

- For these calculations, PM10 refers to combustion PM10.

B. Examples

Example 1 – Replacement of a Heavy-Heavy Duty Truck from a Targeted Vocation
A participant wants to scrap an old, heavy heavy-duty truck used to haul cargo from the Port of Long Beach and replace it with a newer, used truck. The participant has provided conclusive documentation that for the last three years the old truck operated 100 percent of the time in and around the Port area. The replacement truck will be equipped with a Level 1 diesel emission control system (DECS) and an electronic monitoring unit (EMU). The replacement truck is required to continue operating in the same vocation and location for the life of the project.

Baseline Technology Information

- Baseline technology (application): 1983 heavy heavy-duty diesel truck
- Emission rates (Table B-5): 22.23 g/mi NOx, 1.08 g/mi ROG, 1.397 g/mi PM10
- Activity (application): 42,000 miles/year
- Percent operated in California (application): 100 percent
- Vocation (application): Port hauling

Reduced Technology Information:

- Reduced technology (application): 2000 heavy heavy-duty diesel truck
- Emission rates (Table B-5): 18.51 g/mi NOx, 0.21 g/mi ROG, 0.389 g/mi PM10

- Retrofit verification emission levels (EO): 25 percent NOx; 85 percent PM reduction
- Cost (quote provided with application): $40,000
- DECS cost (quote provided with application): $18,300
- EMU cost: $1,150 (Includes installation and monitoring for five years)

<u>Emission Reduction Calculations:</u>

Formula C-8: Estimated Annual Emissions Based on Mileage Using Emission Factors

1. Annual NOx baseline technology emissions
   (22.23 g/mi * 42,000 mi)(ton/ 907,200 g) = 1.029 tons/yr NOx
2. Annual NOx reduced technology emissions
   (18.51 g/mi * 42,000 mi)(ton/ 907,200 g) = 0.857 tons/yr NOx
3. Annual ROG baseline technology emissions
   (1.08 g/mi * 42,000 mi) (ton/ 907,200 g) = 0.05 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.21 g/mi * 42,000 mi)(ton/ 907,200 g) = 0.010 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (1.397 g/mi * 42,000 mi)(ton/ 907,200 g) = 0.065 tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0.389 g/mi * 42,000 mi)(ton/ 907,200 g) = 0.018 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases:

- NOx Emission Benefits = 1.029 tons/yr - 0.857 tons/yr = 0.172 tons/yr NOx
- ROG Emission Benefits = 0.050 tons/yr - 0.010 tons/yr = 0.040 tons/yr ROG
- PM10 Emission Benefits = 0.065 tons/yr - 0.018 tons/yr = 0.047 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:
Emission benefits of the replacement truck with the DECS providing an additional 25 percent NOx and 85 percent PM reduction

0.857 tons/yr NOx * 0.25 = 0.214 tons/yr NOx
0.018 tons/yr PM10 * 0.85 = 0.015 tons/yr PM10

Total NOx Emission Benefits

0.172 tons/yr + 0.214 tons/yr = 0.386 tons/yr NOx

Total PM10 Emission Benefits

0.047 tons/yr + 0.015 tons/yr = 0.062 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.386 tons/yr + 0.040 tons/yr + 20(0.062 tons/yr) = 1.666 weighted tons/yr

<u>Annualized Cost</u>

Project Life = 5 Years
CRF (Table B-1) = 0.225

Formula C-15: Incremental Cost
NADA Value of Replacement Truck:
    0.72 * $40,000 = $28,800
Replacement Truck + DECS + EMU:
    $28,800 + $18,300 + $1,150 = $48,250
Formula C-12: Annualized Cost
    $48,250 * 0.225 = $10,856/yr

<u>Cost-Effectiveness</u>
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions
    =($10,856/yr) / (1.666 weighted tons/yr)
    = $6,516 weighted tons/yr

In this example, the cost-effectiveness is less than threshold of $14,300 per weighted ton of pollutants reduced. This project qualifies for $28,800, the maximum amount of grant funds requested. The applicant will take out a loan to pay the remaining $12,000 for the replacement truck.

Example 2 – Tiered Transaction

The owner of a 2000 model year, heavy heavy-duty truck wants to purchase a new 2005 model year truck meeting the optional NOx standard. He has proposed a tiered transaction where he will buy a new truck and contribute his 2000 model year truck to the owner of a 1990 truck. The owner of the old truck has agreed to scrap the old, heavy heavy-duty truck that is used exclusively to haul agricultural commodities. The old truck owner has provided conclusive documentation that for the last three years the truck operated 100 percent of the time in the Central Valley region. The replacement truck will be equipped with a Level 3 diesel emission reduction system (DECS) and an electronic monitoring unit (EMU). The replacement truck is required to continue operating in the same vocation and location for the life of the project.

a. Fleet Modernization Transaction

<u>Old Vehicle Information (Baseline Technology)</u>:
- Model: 1990 heavy heavy-duty diesel truck
- Activity: 65,000 miles/year
- Vocation: Agriculture (qualifies as a target vocation)
- Percent Operation in California: 100 percent
- Emission Rates (Table B-5): 19.72 g/mi NOx , 0.55 g/mi ROG, 0.950 g/mi PM10

<u>Replacement Truck Information (Reduced Technology)</u>:
- Model: 2000 heavy heavy-duty diesel truck
- Cost (quote provided with application): $50,000
- Emission Rates (Table B-5): 18.51 g/mi NOx, 0.21 g/mi ROG, 0.389 g/mi PM10
- DECS Cost: $19,100 (Level 3, 25 percent NOx + 85 percent PM Reduction)
- EMU Cost: $1,150 (Includes installation and monitoring for five years)

Emission Reduction Calculations:

Formula C-8: Estimated Annual Emissions Based on Mileage Using Emission Factors

1. Annual NOx baseline technology emissions
   (19.72 g/mi * 65,000 mi) / (ton/907,200 g) = 1.41 tons/yr NOx
2. Annual NOx reduced technology emissions
   (18.51 g/mi * 65,000 mi) / (ton/907,200 g) = 1.33 tons/yr NOx
3. Annual ROG baseline technology emissions
   (0.55 g/mi * 65,000 mi) / (ton/907,200 g) = 0.04 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.21 g/mi * 65,000 mi) / (ton/907,200 g) = 0.02 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.950 g/mi * 65,000 mi) / (ton/907,200 g) = 0.068 tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0.389 g/mi * 65,000 mi) / (ton/907,200 g) = 0.028 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant

- NOx Emission Benefits = (1.41 -1.33) tons/yr = 0.08 tons/yr NOx
- ROG Emission Benefits = (0.04 - 0.02) tons/yr = 0.02 tons/yr ROG
- PM10 Emission Benefits = (0.068 - 0.028) tons/yr = 0.040 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions with DECS

Emission Benefits of the Replacement Truck with the DECS providing an additional 25 percent NOx and 85 percent PM reduction

- NOx Emission Benefits = (1.33 tons/yr * 0.25) = 0.33 tons/yr NOx
- PM10 Emission Benefits = (0.028 tons/yr * 0.85) = 0.024 tons/yr PM10

Total NOx Emission Benefits
  0.08 tons/yr + 0.33 tons/yr = 0.41 tons/yr NOx

Total PM10 Emission Benefits
  0.040 tons/yr + 0.024 tons/yr = 0.064 tons/yr PM10

Formula C.2: Annual Weighted Surplus Emission Reductions
  0.41 tons/yr + 0.02 tons/yr + 20(0.064 tons/yr) = 1.71 weighted tons/yr

Annualized Cost

Project Life = 5 Years (target vocations are eligible for 5 year project life)
Capital Recovery Factor = 0.225 (Table B-1)

Incremental Cost

NADA Value of Replacement Truck: $36,000

Replacement Truck + DECS + EMU
  = $36,000 + $19,100 + $1,150 = $56,250

Formula C-12: Annualized Cost
Incremental Cost * Capital Recovery Factor
$56,250 * 0.225 = $12,656

<u>Cost-Effectiveness</u>
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions
($12,656/yr) / (1.71 weighted ton/yr)
= $7,401/ton of weighted surplus emissions reduced

b. New Vehicle Transaction

<u>Baseline Technology Information:</u>
- Baseline Technology: 2005 heavy heavy-duty diesel truck
- Cost (quote provide with application): $110,000
- Emission Rates (Table B-5): 13.21 g/mi NOx, 0.360 g/mi PM10
- Percent operation in California (application): 100 percent

<u>Reduced Technology Information (New, Low Emission, Optional Standard Truck):</u>
- Reduced technology (application): 2005 heavy-duty LNG truck certified to the 1.8 NOx + NMMC + 0.030 PM Standard
- Cost (quote provided with application): $150,000
- New LNG vehicle emission standard (Table B-2): 1.44 g/bhp-hr NOx, 0.030 g/bhp-hr PM10
- Conversion factor to convert the standard to g/mi (Table B-8): 2.6 bhp-hr/mi
- Activity: 75,000 mi/year

<u>Emission Reduction Calculations:</u>
Formula C-8: Estimated Annual Emissions Based on Mileage Using Emission Factors (used for baseline calculations)

Formula C-9: Estimated Annual Emissions Based on Mileage Using Converted Emission Standards (used for reduced calculations)

1. Annual NOx baseline technology emissions
   (13.21 g/mi * 75,000 mi/yr)(ton / 907,200 g) = 1.09 tons/yr NOx
2. Annual NOx reduced technology emissions
   (1.44 g/bhp-hr * 2.6 bhp-hr/mi * 75,000 mi/yr)(ton / 907,200 g) = 0.31 tons/yr NOx
3. Annual PM10 baseline technology emissions
   (0.360 g/mi * 75,000 mi/yr)(ton / 907,200 g) = 0.030 tons/yr PM10
4. Annual PM10 reduced technology emissions
   (0.030 g/bhp-hr * 2.6 bhp-hr/mi * 75,000 mi/yr)(ton /907,200 g) = 0.006 tons/yr PM10

ROG emission factors not available for reduced technology therefore
ROG emission reductions cannot be calculated.

Formula C-10: Annual Surplus Emission Reductions by Pollutant for New Purchases

- NOx emission benefits = 1.09 tons/yr – 0.31 tons/yr = 0.78 tons/yr NOx
- PM10 emission benefits = 0.030 tons/yr – 0.006 tons/yr = 0.024tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.78 tons/year + 20(0.024) tons/year = 1.26 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1) = 0.123

Formula C-14: Incremental Cost

$150,000 - $110,000 = $40,000

Formula C-12: Annualized Cost

$40,000 * 0.123 = $4,920/yr

Cost-Effectiveness:

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

= ($4,920/yr) / (1.26 weighted tons/yr)

= $3,904/ton of weighted surplus emissions reduced

c. Tiered Transaction Calculations

Annualized Cost of the Tiered Transaction

Fleet Mod. Project Life: 5 Years (Target vocations have 5 year project life)

CRF (Table B-1) = 0.225

New, Low NOx Truck Project Life: 10 Years

CRF (Table B-1) = 0.123

Incremental Cost of the Tiered Transaction:

(Incremental Cost Of The Fleet Mod Project from section a) + (Incremental Cost Of The New, Low NOx Project from section b)

$56,250 + $40,000 = $96,250

Annualized Cost of the Tiered Transaction

(Annualized Cost of Fleet Mod. Project from section a) + (Annualized Cost of New, Low NOx Project from section b)

$12,656 + $4,920 = $17,576

Emission Reductions
Annual Weighted Surplus Emission Reductions of the Tiered Transaction

(Weighed Emissions Reductions of the Fleet Mod Project) + (Weighed Emission Reductions of the New, Low-NOx Project)

(1.71 weighted tons/yr) + (1.26 weighted tons/yr) = 2.97 weighted tons/yr

Cost-Effectiveness of the Tiered Transaction
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
= ($17,567/yr) / (2.97 weighted tons/year)
= $5,915/year of weighted surplus emissions reduced

In this example, the cost-effectiveness is less than the threshold of $14,300 per weighted ton of pollutants reduced. Both tiered transaction project applicants qualify for the maximum amount of grant funds requested. A breakdown of the project cost follows:

- Carl Moyer Program incentives for the tiered transaction project:

Replacement truck (72 percent of $50,000 + full cost of EMU and retrofit)	$ 56,250
New truck (Incremental cost)	$ 40,000
Total Carl Moyer incentives	**$ 96,250**

- Net cost of the tiered transaction to the fleet mod. participant:

Cost of the replacement truck:	$ 50,000
Cost of EMU and retrofit	$ 20,250
Total cost of truck/EMU/retrofit	$ 70,250
Carl Moyer Incentive	-$56,250
Net cost to participant	**$14,000**

- Net cost of the tiered transaction to the new low NOx truck purchaser:

Cost of the new, low NOx truck:	$150,000
Value of the 2000 replacement truck:	$ 50,000
Carl Moyer Incentive	-$ 40,000
Payment received for replacement truck	-$ 50,000
Net cost to participant for new truck	**$110,000**

III. Heavy-Duty Truck Idle Reduction

This section provides an example calculation for determining the cost-effectiveness of surplus emission reductions for heavy-duty truck idling reducing technology projects.

A. General Criteria for Heavy-Duty Truck Idling Reducing Technologies Cost-Effectiveness Calculations

- The actual capital cost, up to $5,500, of an APU may be funded.

- The installation cost of an APU, including installation of an hour meter, up to a maximum of $1,700 per diesel APU and a maximum of $3,400 per alternative fuel, electric motor, or fuel cell APU, may be funded.

- The cost of a PM retrofit may be funded provided the overall project cost effectiveness is under the limit of $14,300

- For these calculations, PM10 refers to combustion PM10.

- The minimum project life is three years.

- Annual hours of equipment operation for determining emission reductions must be based only on readings from an installed and fully operational hour meter. A properly functioning hour meter is required to support equipment activity information included in the application for CMP funding.

- Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

- Default maximum project life:

Off-road new purchase	10 years
Off-road repower	7 years
Repower + retrofit	5 years
Retrofit	5 years

  Project life beyond the default maximum may be submitted with documentation for approval by ARB.

B. Examples

Example 1 - Diesel APU Project Repower
A truck operator proposes to purchase an APU, powered by a 2005 certified Kubota Z482B two-cylinder diesel engine, rated at 10.3 hp. The APU will be installed on a 2004 Class 8 line haul truck, to substitute for the truck's idling load. The APU will use fuel from the truck's tank.

The Kubota engine is controlled by a governor and will be set to run at a constant engine speed of 3200 RPM. This will make 2.7 kilowatts (5.33 hp) of power available from the APU while the APU engine is operating at its optimum engine efficiency of about 19.5 percent. A Level 3 PM retrofit device is installed on the main engine exhaust with the exhaust of the APU routed through the main engine exhaust.

The APU cost is $5,000 and PM retrofit costs about $6,000. The installation cost is $1,500 including an hour meter for a total cost of $12,500. The reading on the hour meter is the data item used by the operator to determine the APU's maintenance schedule. The truck operator will also use the reading on the hour meter to document the hours that the APU is used in California.

Baseline Technology Information:
- Engine: 2004 HHDV
- Annual hours of operation: 1,800
- Emission factors (From Table B-9): 191.5 g/hr NOx, 25.56 g/hr ROG, 1.50 g/hr PM10

Reduced Technology Information:
- Engine: 10.3 hp APU
- Model year: 2005
- Power requirements: 2.7 kilowatts = 1.99 hp
- APU idling substitution rate: 100 percent
- Annual hours of operation: 1,800
- Capital cost of APU: $5,000
- Capital cost of PM trap: $6,000
- Installation cost: $1,500
- Emission factors (Table B-10): 4.14g/bhp-hr NOx, 0.41g/bhp-hr ROG, 0.304 g/bhp-hr PM10

Emissions Reduction Calculations:
Formula C-4: Estimated Annual Emissions based on Hours of Operation (tons/yr):
1. Annual NOx baseline technology emissions
   (191.5 g/hr)(1,800 hr/yr)/(907,200 g/ton) = 0.38 tons/yr NOx
2. Annual NOx reduced technology emissions
   (4.14 g/bhp-hr)(1.99 hp)(1,800 hr/yr)/907,200 g/ton = 0.016 tons/yr NOx
3. Annual ROG baseline technology emissions
   (25.56 g/hr)(1,800 hr/yr)/907,200 g/ton = 0.05 tons/yr ROG

4. Annual ROG reduced technology emissions
   (0.41 g/bhp-hr)(1.99 hp)(1,800 hr/yr)/907,200 g/ton = 0.0016 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (1.50 g/hr)(1,800 hr/yr)/907,200 g/ton = 0.003 tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0.306 g/bhp-hr)(1.99 hp)(1,800 hr/yr)/907,200 g/ton = 0.00112 tons/yr PM10

Formula C-10 Annual Surplus Emission Reductions by pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 0.38 tons/yr - 0.016 tons/yr = 0.364 tons/yr NOx
- ROG emission benefits = 0.05 tons/yr - 0.0016 ton/yr = 0.048 tons/yr ROG
- PM10 emission benefits = 0.003 tons/yr - 0.0012 tons/yr = 0.0018 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits:
0.003 tons/yr PM10 *.85 = 0.0025 tons/yr

Total PM10 Emission Benefits
0.0018 + 0.0025 tons/yr = 0.0043 tons/yr

Formula C-2, Annual Weighted Surplus Emission Reductions:
(0.364 tons/yr)+(0.048 tons/yr)+20(0.0043 tons/yr) = 0.498 weighted tons/yr

<u>Annualized Cost:</u>
Project Life: 3 years
CRF (Table B-1): = 0.360

Formula C -14-Incremental Cost:
$5,000 + $6,000 + $1,500 = $12,500

Formula C- 12-Annualized Cost
0.360 * $12,500 = $4,500/yr

<u>Cost Effectiveness:</u>
Formula C-1 Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton):
($4,500/yr)/(0.498 weighted tons/yr)
=$9,036/ton of weighted surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per ton of weighted average emissions reduced and the project qualifies for the full amount requested $12,500.

IV. Transport Refrigeration Units

This section provides two examples of calculations for determining the cost-effectiveness of surplus emission reductions for TRU projects.

A. General Criteria for TRU Cost-Effectiveness Calculations:

- TRU emission reduction calculations will use either fuel-based or hour-based formula for cost-effectiveness calculations.
- Annual hours of equipment operation for determining emission reductions must be based only on readings from an installed and fully operational hour meter. A properly functioning hour meter is required to support equipment activity information included in the application for CMP funding.
- TRU engine emissions increase with load. Load factors have been determined for TRU engines and have been found to vary by engine horsepower category. Table B-11 shows the default load factors assigned for use in the Carl Moyer Program.
- Baseline and reduced engine emission factors are listed in Table B-12 Appendix B.
- Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

B. Examples

Example 1 – Repower
A TRU owner proposes to purchase and install a new engine in an existing trailer TRU that uses a 1999 model year TRU Tier 1 engine rated at 37.8 hp. From records, the owner knows the existing TRU engine has operated an average of 1,300 hours per year. The owner anticipates this operating trend will continue for the next three years. He doesn't know what the TRU engine load factor is for his operations. Both the old and new operations occur 100 percent in California. The replacement engine will be a 2006 model year Tier 2 engine rated at 37.8 hp. The cost of the new certified engine will be $4,000; the cost to replace the existing engine with a remanufactured 1999 model year engine is $3200. Installation and engineering costs for the repower will be

$700 greater than replacement with a remanufactured engine due to the need to modify motor mounts.

Baseline Technology Information:

- Baseline technology (application): 1999 engine
- Emission factors (Table B-12): 5.26 g/bhp-hr NOx, 1.74 g/bhp-hr ROG, 0.480 g/bhp-hr PM10 (Tier 1)
- Engine rated HP (application): 37.8 hp
- Default load factor (Table B-11): 0.53
- Annual hours of operation (application): 1,300 hours

Reduced Technology Information:

- Reduced technology (application): 2006 engine
- Emission factors (Table B-12): 4.63 g/bhp-hr NOx, 0.29 g/bhp-hr ROG, 0.280 g/bhp-hr PM10 (Tier 2)
- Reduced engine rated HP (application): 37.8 hp
- Default load factor (Table B-11): 0.53

Emission Reduction Calculations:

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

1. Annual NOx baseline technology emissions
   (5.26 g/bhp-hr)(37.80 hp)(0.53)(1,300 hrs/yr)(1 ton/907,200 g)
   = 0.15 tons/yr NOx
2. Annual NOx reduced technology emissions
   (4.63 g/bhp-hr)(37.80 hp)(0.53)(1,300 hrs/yr)(1 ton/907,200 g)
   = 0.13 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.74 g/bhp-hr)(37.80 hp)(.53)(1,300 hrs/yr)(1ton/907,200 g)
   = 0.05 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.290 g/bhp-hr)(37.80 hp)(0.53)(1,300 hrs/yr)(1 ton/907,200 g)
   = 0.01 ton/yr ROG
5. Annual PM10 baseline technology emissions
   (0.480 g/bhp-hr)(37.8 hp)(0.530)(1,300 hrs/yr)(1 ton/907,200 g)

   = 0.014 tons/yr tons/yr PM10

6. Annual PM10 reduced technology emissions
   (0.280 g/bhp-hr)(37.80 hp)(0.530)(1,300 hrs/yr)(1 ton/907,200 g)
   = 0.008 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 0.15 tons/yr - 0.13 tons/yr = 0.01 tons/yr NOx
- ROG emission benefits = 0.05 tons/yr - 0.01 tons/yr = 0.04 tons/yr ROG
- PM10 emission benefits = 0.014 tons/yr - 0.008 tons/yr = 0.006 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions:

0.01 + 0.04 + 20(0.006) = 0.17 weighted tons/yr

Annualized Cost:

Project Life: 3 years

CRF (Table B-1): = 0.360

Formula C -14: Incremental Cost:

$4,000 + $700 - $3,200 = $1,500

Formula C-12: Annualized Cost

$1,500 * 0.360 = $540/yr

Cost Effectiveness:

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

($540yr)/(0.17 weighted ton/yr)

= $3,176/ton of weighted surplus emissions reduced

This project would qualify for a $1,500 Carl Moyer Program grant, covering all of the capital and installation costs of the project.

Example 2 – Retrofit

A TRU owner decides to retrofit a 34 hp model year 2001 TRU Tier 1 engine with a verified Level 3 active diesel particulate filter (DPF) system that uses a fuel-borne catalyst (FBC). The capital cost for the DPF system with FBC dosing unit is $2,800, including installation. The owner reports operating the TRU 2,000 hours per year. The project would commence by January 1, 2007. The applicant is willing to commit to a three year project life.

Surplus emissions from early compliance:

Model year 2001 TRU engines must comply with the TRU ATCM's LETRU In-Use Performance Standard (Level 2 – 50 percent PM reduction) by the end of 2008. Model year 2001 TRU engines must also comply with the TRU ATCM's ULETRU standard (Level 3 – 85 percent PM reduction) by the end of 2015. Therefore, all of the emission reductions in 2007 and 2008 would be surplus. And, in the third year of the project, 2009, the surplus emissions would be 35 percent (85 percent minus 50 percent) of the baseline engine emissions. The ARB test data shows ROG reductions of 55 percent from use of the DPF. For the Carl Moyer Program, the applicant may count a 50 percent ROG reduction for the cost-effectiveness calculation.

Baseline Technology Information:

- Baseline technology (application): 34 hp model year 2001 TRU engine
- Baseline engine rated HP (application): 34 hp
- Default load factor (Table B-11): 0.53 (assumed to stay constant before and after project)
- Annual hours of operation (application): 2,000 hr/yr

- Emission factors (Table B-12): 1.74 g/bhp-hr ROG, 0.480 g/bhp-hr PM10

Reduced Technology Information:

- Reduced technology (application): Level 3 active diesel particulate filter (DPF) system that uses a fuel-borne catalyst (FBC).
- Retrofit verification emission level (EO): 50 percent ROG, 85 percent PM10
- Cost (quote provided by applicant): $2,800 for DPF system with FBC dosing including installation.
- Annual hours of operation (application): 2,000 hr

Emission Reduction Calculations

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

1. Annual ROG baseline technology emissions
   (1.74 g/bhp-hr)(0.53)(2,000 hr)(1 ton/907,200 g) = 0.07 tons/yr ROG
2. Annual PM10 baseline technology emissions
   (0.480 g/bhp-hr)(34.00 hp)(0.530)(2,000 hrs/yr)(1 ton/907,200 g)
   = 0.019 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

Estimated emission reductions are:
2007: 0.07 tons/yr * 0.50 = 0.04 tons/yr ROG
2008: 0.07 tons/yr * 0.50 = 0.04 tons/yr ROG
2009: 0.07 tons/yr * 0.50 = 0.04 tons/yr ROG

2007: 0.019 tons/yr * 0.85 = 0.016 tons/yr PM10
2008: 0.019 tons/yr * 0.85 = 0.016 tons/yr PM10
2009: 0.019 tons/yr * 0.35 = 0.007 tons/yr PM10

Average PM10 Reductions = (0.016 tons/yr PM10 + 0.016 tons/yr PM10 + 0.007 tons/yr PM10)/3 = 0.013 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.04 + 20(0.013) = 0.30 weighted tons/yr

Annualized Cost:

Project Life: 3 years
CRF (Table B-1): = 0.360

Formula C-14: Incremental Cost

$2,800 – $0 = $2,800

(Note: Annual operating costs above normal (e.g., cost of FBC) cannot be paid for with Carl Moyer Program funds, but air districts may elect to pay for these with matching funds.)

Formula C-12: Annualized Cost
0.360 * $2,800 = $1,008/yr

<u>Cost-Effectiveness</u>:
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($1,008/yr)/(0.30 weighted ton/yr)
=$3,360/ ton of weighted surplus emissions reduced

The cost-effectiveness is below the $14,300 threshold. This project would therefore qualify for a $2,800 Carl Moyer Program grant covering all of the capital costs and installation costs of the project

V. Off-Road Compression-Ignition Engines

This section provides four examples of calculations for determining the cost-effectiveness of surplus emission reductions for off-road compression-ignition projects.

A. General Criteria for Off-Road Compression-Ignition Engine Cost-Effectiveness Calculations

- Off-road emission reduction calculations will use either fuel-based or hour-based formula for weighted cost-effectiveness calculations.

- Annual hours of equipment operation for determining emission reductions must be based only on readings from an installed and fully operational hour meter. A properly functioning hour meter is required to support equipment activity information included in the application for CMP funding.

- For applications or equipment not listed in Table B-13 in Appendix B, a default load factor of 0.43 must be used.

- The replacement load factor should never exceed 100 percent in cases where the replacement engine is significantly smaller than the existing engine

- Baseline and reduced engine emission factors are listed in Table B-12 of Appendix B.

- For off-road equipment capable of operation with a new certified on-road engine instead of a new off-road engine (i.e., yard hostlers, yard goats), emission benefits from the baseline engine will be based on an on-road engine. If an applicant provides sufficient documentation to show that past practices involve predominantly the use of off-road engines in yard hostlers, then an off-road engine emission factor baseline can be used.

- For new purchases of off-road equipment powered by an on-road engine, emission benefits relative to the baseline engine are calculated based on on-road engine emission factors. If an applicant provides ARB with documentation showing that in past practice, the fleet has been powered by off-road engines, then the baseline emission may be calculated using the off-road engine emission factors.

- For calculations based on fuel consumption, use the default energy consumption factor (ECF) of 18.5 bhp-hr/gallon.

- Default project life

	Default
Off-road new purchase	10 years
Off-road repower	7 years

Off-road repower and retrofit	5 years
Retrofit	5 years

Project life beyond the default project life may be submitted with documentation for approval by ARB.

- Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

B. Examples

Example 1 – Repower with a Tier 2 Engine and Retrofit with a Level 3 DECS
A construction company wants to repower an uncontrolled scraper with a Tier 2 engine. The baseline engine is a 300 hp 1987 Caterpillar 3306 that operates for 1,500 hours per year and would cost $11,500 to rebuild. The applicant is proposing to install a 300 hp 2004 Caterpillar C9 that costs $80,000. This equipment operates 100 percent of the time in California and has a project life of 5 years. A Level 3 diesel particulate filter has been verified for use on a 2004 Caterpillar C9 engine and has a cost of $15,000. Since installation of a retrofit device is required for off-road projects if available and feasible, the cost-effectiveness of the project including the installation of the DECS must be determined.

<u>Baseline Technology Information:</u>
- Engine: 1987 Caterpillar 3306
- HP(application): 300
- Hours of operation (application): 1,500
- Cost of rebuild (quote provided with application): $11,500
- Load factor (Table B-13): 0.72
- Emission factors (Table B-12): 10.23 g/bhp-hr NOx; 1.01 g/bhp-hr ROG; 0.382 g/bhp-hr PM10

<u>Reduced Technology Information:</u>
- Engine: 2004 Caterpillar C9 (Executive Order U-R-001-0247; Engine family 4CPXL08.8HSK)
- HP(application): 300
- Hours of operation (application): 1,500
- Cost of new engine (quote provided with application): $80,000
- Load factor (Table B-13): 0.72

- Emission factors (Table B-12): 3.79 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.088 g/bhp-hr PM10
- Percent operating in California (application): 100 percent
- Retrofit: Level 3 verified reductions: 85 percent PM10
- Cost of retrofit (quote provided with application): $15,000

Emission Reduction Calculations:

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

1. Annual NOx baseline technology emissions
   10.23 g/bhp-hr *300 hp*0.72*1500 hr*(ton/907,200 g) = 3.65 tons/yr NOx
2. Annual NOx reduced technology emissions
   3.79 g/bhp-hr *300 hp*0.72*1500 hr*(ton/907,200 g) = 1.35 tons/yr NOx
3. Annual ROG baseline technology emissions
   1.01 g/bhp-hr *300 hp* 0.72*1500 hr*(ton/907,200 g) = 0.36 tons/yr ROG
4. Annual ROG reduced technology emissions
   0.12 g/bhp-hr *300 hp*0.72*1500 hr*(ton/907,200 g) = 0.04 tons/yr ROG
5. Annual PM10 baseline technology emissions
   0.382 g/bhp-hr *300 hp*0.72*1500 hr*(ton/907,200 g) = 0.136 tons/yr PM10
6. Annual PM10 reduced technology emissions
   0.088 g/bhp-hr *300 hp*0.72*1500 hr*(ton/907,200 g) = 0.031 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 3.65 tons/yr - 1.35 tons/yr = 2.30 tons/yr NOx
- Emission benefits ROG = 0.36 tons/yr - 0.04 tons/yr = 0.32 tons/yr ROG
- Emission benefits PM10 = 0.136 tons/yr - 0.031 tons/yr = 0.105 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Retrofits

0.031 tons/yr PM10 * 0.85 = 0.026 tons/yr PM10

Total PM10 Emission Benefits

0.105 tons/yr + 0.026 tons/yr = 0.131 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

2.30 tons/yr + 0.32 tons/yr + 20(0.131 tons/yr) = 5.24 weighted tons/yr

Annualized Cost:

Project Life: 5 years

CRF (Table B-1): = 0.225

Formula C-14: Incremental Cost

$95,000 - $11,500 = $83,500

Formula C-12: Annualized Cost

0.225 * $83,500 = $18,788

Cost-Effectiveness:

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

($18,788/yr)/(5.24 weighted tons/yr)

= $3,585/tons of weighted surplus emissions reduced

Example 2 – New Purchase

An applicant wants to purchase a new yard tractor with an LNG 250 hp on-road engine certified to ARB's Heavy Duty Optional Standard (2004 Cummins C Gas Plus 8.3 L) at a cost of $96,800. The applicant has provided documentation that they would normally have purchased a yard tractor with a 2004 250 hp Tier 2 off-road diesel engine at a cost of $61,250. The annual hours of operation is 1,250 hours, the equipment operates 100 percent of the time in California, and has a project life of 10 years. The default load factor is 0.43.

Baseline Technology Information:

- Engine: 2004 Tier 2 off-road diesel engine
- HP (application): 250
- Annual hours of operation (application): 2,000
- Default load factor: 0.43
- Cost of new equipment (quote provided with application): $61,250
- Emission factors (Table B-12): 4.15 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.088 g/bhp-hr PM10

Reduced Technology Information:

- Engine (application): 2004 Cummins C Gas Plus (Executive Order A-021-0362)
- HP (application): 250
- Annual hours of operation (application): 2,000
- Default load factor: 0.43
- Cost of new equipment (quote provided with application): $96,800
- Converted emission standards (Table B-2): 1.44 g/bhp-hr NOx; 0.030 g/bhp-hr PM10
- Percent operating in California (application): 100 percent

Emission Reduction Calculations:

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

1. Annual NOx baseline technology emissions
   4.15 g/bhp-hr *250 hp*0.43*2,000 hr*(ton/907,200 g) = 0.98 tons/yr NOx
2. Annual NOx reduced technology emissions
   1.44 g/bhp-hr *250 hp*0.43*2,000 hr*(ton/907,200 g) = 0.34 tons/yr NOx
3. Annual PM10 baseline technology emissions
   0.088 g/bhp-hr *250 hp*0.43*2,000 hr*(ton/907,200 g) = 0.021 tons/yr PM10
4. Annual PM10 reduced technology emissions
   0.030 g/bhp-hr *250 hp*0.43*2,000 hr*(ton/907,200 g) = 0.007 tons/yr PM10

ROG emission factors not available for reduced technology therefore ROG emission reductions cannot be calculated.

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx =0.98 tons/yr - 0.34 tons/yr = 0.64 tons/yr NOx
- Emission benefits PM10= 0.021 tons/yr - 0.007 tons/yr = 0.014 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.64 tons/yr + 20(0.014 tons/yr) = 0.92 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost

$96,800 - $61,250 = $35,550

Formula C-12: Annualized Cost

0.123 * 35,550 = $4,373/yr

Cost-Effectiveness:

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

($4,373/yr)/ (0.92 weighted tons/yr)

= $4,753/tons of weighted surplus emissions reduced

Example 3 – Auxiliary Engine Repower

An applicant wants to repower the auxiliary engine of a street sweeper with a Tier 2 engine. The baseline engine is a Tier 1 200 hp engine that consumes an estimated 4,500 gallons fuel per year and would cost $7,000 to rebuild. The applicant is proposing to install a 200 hp Tier 2 engine that costs $35,000. This equipment operates 100 percent of the time in California and has a project life of 7 years. No retrofit device has been verified for this engine or equipment.

Baseline Technology Information:

- Engine (application): Tier 1 off-road diesel engine
- HP (application): 200 (not used for calculation, but used to determine appropriate emission factors)
- Annual fuel consumption (application): 4,500
- Cost of rebuild (quote provided with application): $7,000
- Energy consumption factor: 18.5 bhp-hr/gal
- Emission factors (Table B-12): 5.93 g/bhp-hr NOx; 0.38 g/bhp-hr ROG; 0.120 g/bhp-hr PM10

Reduced Technology Information:

- Engine (application): Tier 2 off-road diesel engine

- HP (application): 200 (not used for calculation, but used to determine appropriate emission factors)
- Annual fuel consumption (application): 4,500 gallons
- Cost of new equipment (quote provided with application): $35,000
- Energy consumption factor: 18.5 bhp-hr/gal
- Emission factors (Table B-12): 4.15 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.088 g/bhp-hr PM10
- Percent operating in California (application): 100 percent

<u>Emission Reduction Calculations:</u>

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr)

1. Annual NOx baseline technology emissions
   5.93 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.54 tons/yr NOx
2. Annual NOx reduced technology emissions
   4.15 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.38 tons/yr NOx
3. Annual ROG baseline technology emissions
   0.38 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.03 tons/yr ROG
4. Annual ROG reduced technology emissions
   0.12 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.01 tons/yr ROG
5. Annual PM10 baseline technology emissions
   0.120 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.011 tons/yr PM10
6. Annual PM10 reduced technology emissions
   0.088 g/bhp-hr *18.5 bhp-hr/gal *4,500 gal*(ton/907,200 g) = 0.008 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 0.54 tons/yr - 0.38 tons/yr = 0.16 tons/yr NOx
- Emission benefits ROG = 0.03 tons/yr - 0.01tons/yr = 0.02 tons/yr ROG
- Emission benefits PM10 = 0.011 tons/yr -0.008 tons/yr = 0.003 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.16 tons/yr + 0.02 tons/yr + 20(0.003 tons/yr) = 0.24 weighted tons/yr

<u>Annualized Cost:</u>

Project Life: 7 years

CRF (Table B-1): = 0.167

Formula C-14: Incremental Cost

$35,000 - $7,000 = $28,000

Formula C-12: Annualized Cost

0.167 * $28,000 = $4,676

Cost-Effectiveness:

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

($4,676/yr/ (0.24 weighted tons/yr)

= $19,483/tons of weighted surplus emissions reduced

The cost-effectiveness for this example is greater than the $14,300 per weighted ton cost-effectiveness requirement. In order to meet the $14,300 per weighted ton cost-effectiveness requirement, this project would only qualify for a fraction of the incremental cost $20,551. This amount is determined by multiplying the maximum allowed cost --effectiveness by the estimated annual emission reductions and divided by the capital recovery factor:

($14,300 * 0.24)/0.167 = $20,551

Example 4 – Retrofit of a Tier 1 Engine with a Level 2 DECS

A Level 2 diesel oxidation catalyst with emulsified fuel has been verified for use on a yard tractor with a Tier 1 110 hp 2002 Case 4TA-390 engine. The cost of installing the retrofit is $2,000 and is verified for 50 percent reductions of PM10 and 15 percent reductions of NOx. The yard tractor consumes 5,000 gallons of fuel per year. There is an incremental cost for the fuel of $0.20/ gallon that is eligible for funding with match funds by the district. The incremental cost was calculated with information provided from the applicant (i.e. quote from distributor). Retrofit projects have a maximum project life of 5 years.

Baseline Technology Information:

- Engine: 2002 Case 4TA-390
- Gallons consumed (application): 5,000 gal/yr
- Cost: $0
- Energy consumption factor: 18.5 bhp-hr/gal
- Emission factors (Table B-12): 6.54 g/bhp-hr NOx; 0.304 g/bhp-hr PM10

Reduced Technology Information:

- Level 2 verified reductions: 15 percent NOx; 50 percent PM10
- Cost of retrofit (quote provided with application): $2,000
- Percent operating in California (application): 100 percent

Emission Reduction Calculations:

Formula C-6: Estimated Annual Emissions based on Fuel Consumption using Emission Factors or Converted Emission Standard (tons/yr)

1. Annual NOx baseline technology emissions
   6.54 g/bhp-hr * 5,000 gal* 18.5 bhp-hr/gal *(ton/907,200 g) = 0.67 tons/yr NOx
2. Annual PM10 baseline technology emissions
   0.304 g/bhp-hr * 5,000 gal * 18.5 bhp-hr/gal *(ton/907,200 g) = 0.031 tons/yr PM10

Formula C-11: Annual Surplus Emission Reductions by Pollutant (tons/yr) for retrofits

- 0.67 tons/yr * 0.15 = 0.10 tons/yr NOx
- 0.031 tons/yr * 0.50 = 0.016 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions
0.10 tons/yr + 0 tons/yr + 20(0.016 tons/yr) = 0.42 weighted tons/yr

<u>Annualized Cost:</u>
Project Life: 5 years
CRF (Table B-1): = 0.225

Formula C-14: Incremental Cost
$2,000 - $0 = $2,000

Formula C-12: Annualized Cost
0.225 * $2,000 = $450

<u>Cost-Effectiveness:</u>
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($450/yr)/(0.42 weighted tons/yr)
= $1,071/tons of weighted surplus emissions reduced

Calculations with incremental cost of fuel paid for with district funds (if district chooses to provide funding for increased fuel cost)

5,000 gal/ yr * 5 years project life * $0.20/gal = $5,000

District may pay up to $5,000 for incremental cost of fuel.

<u>Annualized Cost:</u>
Project Life: 5 years
CRF (Table B-1): = 0.225

Formula C-14: Incremental Cost
($2,000 + $5,000) - $0 = $7,000

Formula C-12: Annualized Cost
0.225 * $7,000 = $1,575

<u>Cost-Effectiveness:</u>
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($1,575/yr)/(0.34 weighted tons/yr)
= $4,632/tons of weighted surplus emissions reduced

VI. Large Spark-Ignition Off-Road Equipment

Example calculations will be included once project criteria are developed.

VII. Ground Support Equipment

Sample calculations will be added once project criteria are developed.

VIII. Locomotives

This section provides four examples of calculations for determining cost-effectiveness of surplus emission reductions for locomotive projects.

A. General Criteria for Locomotive Cost-Effectiveness Calculations

- Baseline emissions for a locomotive engine repower are based upon federal emission requirements for engine remanufacture (see Chapter VIII, Section III) and the corresponding emission rates in Table B-16. Baseline costs for a locomotive engine repower equal the actual remanufacture cost or $50,000, whichever is greater.

- For the purposes of the Carl Moyer Program, an alternative technology switcher is defined as a hybrid (e.g., Green Goat) or multiple engine switcher in which an existing locomotive chassis is significantly refurbished with a new engine, brakes, electronic controls, and/or other equipment. An alternative technology switcher must meet Tier 2 locomotive emission standards and achieve a NOx emission rate of no greater than 5.67 g/bhp-hr. An alternative technology switcher project is considered a new locomotive purchase.

- Baseline emissions for an alternative technology switcher project reflect Tier 0 emission rates for Class I locomotives and uncontrolled emission rates for Class III locomotives. The cost of an alternative technology switcher eligible for Carl Moyer Program funding shall not exceed 60 percent of the total cost of the new switcher for Class I locomotives, and 80 percent of the total cost of the new switcher for Class III locomotives.

- Baseline emissions and costs for a new locomotive purchase project which is not an alternative technology switcher reflect Tier 2 emission rates and the cost of a new Tier 2 locomotive, respectively.

- Locomotive repower or ILD projects must achieve a 15 percent NOx reduction beyond existing emission levels.

- All locomotive purchase and repower projects (except alternative technology switchers) must include purchase and installation of an automatic engine start-stop (AESS) ILD to reduce unnecessary engine idling if the locomotive is not already equipped with such a device and AESS installation is technically feasible.

- If not already required by a rule, regulation, MOU, or other legal mandate, the purchase and installation cost of an AESS is eligible for Carl Moyer Program funding, subject to the following limitations:

  - The Carl Moyer Program may provide actual equipment costs up to a maximum of $8,000 for a locomotive-specific AESS.

  - The Carl Moyer Program may provide the lower amount of actual installation costs of the AESS, up to a maximum of $3,400.
  - AESS emission reductions are calculated by applying the ILD emission reduction factors in Table B-17 to the reduced engine emissions.

- Because of uncertainty in locomotive load factors, locomotive project activity must be based upon annual fuel consumption.

- The energy consumption rate for a locomotive engine is 20.8 bhp-hr per gallon. The energy consumption rate for an on- or off-road engine used in a locomotive application is 18.5 bhp-hr per gallon.

- Class I freight locomotive projects must have a minimum project life of ten years. All other locomotive projects have a minimum project life of three years.

- The maximum project life for a locomotive project is 20 years.

- The baseline emission rates used to determine emission reductions and cost-effectiveness for locomotives subject to the South Coast MOU reflect the Tier 2 locomotive emission factors for line-haul and switch locomotives identified in Table B-16.

- Baseline activity for a new locomotive purchase should reflect fuel consumption of an existing locomotive or locomotives with similar functions and characteristics. For example, if the new switch locomotive is intended to replace the activity of an existing switch locomotive in the same rail yard, annual fuel consumption is based upon that of the existing switcher. For alternative technology locomotive projects, if the baseline locomotive activity derives from locomotives without a functioning ILD, the ILD emission reduction factor is applied to the new locomotive emission calculations. The ILD emission reduction factor is found in Table B-17. Examples 3 and 4 utilize estimated locomotive activity for a new locomotive purchase.

- The ILD factor is applied to locomotive activity in order to reflect the benefits of reduced idling. The ILD factor is also applied under certain circumstances to reflect the reduced engine idling associated with advanced locomotive technology projects (See previous bullet). Finally, the ILD factor is applied to Class I locomotive baseline emission calculations, if the baseline locomotive does not have a functioning ILD and baseline fuel consumption does not reflect ILD usage. Use of the ILD factor is necessary in this final circumstance because, as signatories to the Statewide Locomotive MOU, Class I railroads will be required to install an ILD on virtually all their locomotives.

B. Examples

Example 1 – Switch Locomotive Engine Repower (Class III Railroad)
A Class III railroad operator opts to replace an existing 1971 model year switch locomotive engine with a 2006 model year locomotive engine. The existing locomotive consumes 40,000 gallons of fuel per year. The cost to rebuild the existing engine is $48,000, while the cost to purchase and install the new engine is $350,000. The cost to purchase an automatic engine start-stop ILD is $8,000, while installation of the device costs $3,000. The railroad company will commit to a 10 year project life. Emission reductions are calculated as follows:

<u>Baseline Technology Information:</u>

- Locomotive model year (application): 1971
- Locomotive emission rate (Table B-16): 15.66 g/bhp-hr NOx, 0.99 g/bhp-hr ROG, 0.396 g/bhp-hr PM10
- Activity (application): 40,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal

<u>Reduced Technology Information:</u>

- Engine model year (application): 2006
- Emission rate (Table B-16): 6.57 g/bhp-hr NOx, 0.51 g/bhp-hr ROG, 0.189 g/bhp-hr PM10
- Activity (application): 40,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal
- ILD emission reduction factor (Table B-17): 0.90

<u>Emission Reduction Calculations:</u>
Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
(15.66 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g)
= 14.36 ton/yr NOx
2. Annual NOx reduced technology emissions
(6.57 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal*0.90)*(ton/907,200g)
= 5.42 ton/yr NOx
3. Annual ROG baseline technology emissions
(0.99 g/bhp-hr *40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g)
= 0.91 ton/yr ROG
4. Annual ROG reduced technology emissions
(0.51 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal *0.90)*(ton/907,200g)
= 0.42 ton/yr ROG
5. Annual combustion PM10 baseline technology
(0.396 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal)*(ton/907,200g)
= 0.363 ton/yr PM10

6. Annual combustion PM10 reduced technology emissions
(0.189 g/bhp-hr*40,000 gal/yr*20.8 bhp-hr/gal *0.90)*(ton/907,200g)
= 0.156 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 14.36 tons/yr – 5.42 tons/yr = 8.94 tons/yr NOx
- ROG emission benefits = 0.91 tons/yr - 0.42 tons/yr = 0.49 tons/yr ROG
- PM10 emission benefits= 0.363 tons/yr - 0.156 tons/yr = 0.207 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions
8.94 tons/yr + 0.49 tons/yr + 20(0.207 tons/yr) = 13.57 weighted tons/yr

Annualized Cost:
Project Life: 10 years
CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost
($350,000 + $11,000) - $50,000 = $311,000

Formula C-12: Annualized Cost
0.123 * $311,000 = $38,253/yr

Cost-Effectiveness:
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($38,253/yr)/(13.57 weighted tons/yr)
= $2,819/tons of weighted surplus emissions reduced

Example 2 – Line-Haul Locomotive Engine Repower (Class I Railroad)
A Class I railroad operator opts to replace his existing 1976 line-haul locomotive engine with a 2006 model year locomotive engine. Based on the fuel receipts, it is determined that the existing and new locomotive engines will consume 75,000 gallons of fuel per year. The cost to rebuild the existing engine is $65,000, while the cost of the new engine plus installation is $390,000. The locomotive is not equipped with an ILD. The railroad will have to install an ILD as a signatory to the Statewide MOU; this aspect of the project is therefore not eligible for Carl Moyer Program funding. The railroad will commit to a 20 year project life. Emission reductions are calculated as follows:

Baseline Technology Information:

- Locomotive model year (application): 1976
- Emission rate (Table B-16): 7.74 g/bhp-hr NOx, 0.47 g/bhp-hr ROG, 0.288 g/bhp-hr PM10
- Activity (application): 75,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal
- ILD emission reduction factor(Table B-17): 0.97

Reduced Technology Information:

- Engine model year (application): 2006
- Emission rate (Table B-16): 4.50 g/bhp-hr NOx, 0.26 g/bhp-hr ROG, 0.153 g/bhp-hr PM10
- Activity (application): 75,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal
- ILD emission reduction factor (Table B-17): 0.97

Emission Reduction Calculations:

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
   (7.74 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr * 0.97) *(ton/907,200g)
   = 12.91 ton/yr NOx
2. Annual NOx reduced technology emissions
   (4.50 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr* 0.97) *(ton/907,200g)
   = 7.51 ton/yr NOx
3. Annual ROG baseline technology emissions
   (0.47 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr * 0.97) *(ton/907,200g)
   = 0.78 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.26 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr* 0.97) *(ton/907,200g)
   = 0.43 ton/yr ROG
5. Annual combustion PM10 baseline technology
   (0.288 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr * 0.97) *(ton/907,200g)
   = 0.480 ton/yr PM10
6. Annual combustion PM10 reduced technology emissions
   (0.153 g/bhp-hr * 20.8 bhp-hr/gal * 75,000 gal/yr* 0.97) *(ton/907,200g)
   = 0.255 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 12.91 tons/yr - 7.51 tons/yr = 5.40 tons/yr NOx
- Emission benefits ROG = 0.78 tons/yr - 0.43 tons/yr = 0.35 tons/yr ROG
- Emission benefits PM10 = 0.480 tons/yr - 0.255 tons/yr = 0.225 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

5.40 tons/yr + 0.35 tons/yr + 20(0.225 tons/yr) = 10.25 weighted tons/yr

Annualized Cost:

Project Life: 20 years

CRF (Table B-1): = 0.074

Formula C-14: Incremental Cost

$390,000 - $65,000 = $325,000

Formula C-12: Annualized Cost

0.074 * $325,000 = $24,050/yr

<u>Cost-Effectiveness:</u>

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

($24,050/yr)/(10.25 weighted tons/yr)

= $2,346/tons of weighted surplus emissions reduced

Example 3 – Hybrid Switch Locomotive Purchase (Class I Railroad)

A Class I railroad has the opportunity to purchase a locomotive frame refurbished with an 800 horsepower Tier 2 certified off-road engine. Because the project is a hybrid locomotive project, involves significantly refurbishing the existing locomotive frame with a new battery and other equipment, meets Tier 2 locomotive emission standards and emits NOx at a rate over 30 percent below the Tier 2 locomotive emission standard, the project is considered a new locomotive purchase. Based on fuel consumption data from other switchers at the rail yard where the locomotive is to be deployed, the locomotive is projected to consume 45,000 gallons per year. The cost of the locomotive project is $1.1 million. The project life is 10 years. Emission reductions are calculated as follows:

<u>Baseline Technology Information:</u>

- Baseline locomotive model year: none
- Baseline emission rates (reflect locomotive Tier 0 emission factors, Table B-16): 11.34 g/bhp-hr NOx, 0.99 g/bhp-hr ROG, 0.396 g/bhp-hr PM
- Activity (application): 45,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal
- ILD emission reduction factor (Table B-17): 0.90

<u>Reduced Technology Information:</u>

- Engine model year: 2006
- Reduced emission rates (reflect off-road Tier 2 emission factors, Table B-12): 3.87 g/bhp-hr NOx, 0.12 g/bhp-hr ROG, 0.088 g/bhp-hr PM10
- Activity (application): 45,000 gal/year
- Energy consumption factor = 18.5 bhp-hr/gal
- ILD emission reduction factor (Table B-17): 0.90

<u>Emission Reduction Calculations:</u>

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
   (11.34 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 10.53 ton/yr NOx
2. Annual NOx reduced technology emissions
   (3.87 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 3.20 ton/yr NOx

3. Annual ROG baseline technology emissions
   (0.99 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.92 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.12 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.10 ton/yr ROG
5. Annual combustion PM10 baseline technology
   (0.396 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.368 ton/yr PM10
6. Annual combustion PM10 reduced technology emissions
   (0.088 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.073 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 10.53 tons/yr – 3.20 tons/yr = 7.33 tons/yr NOx
- Emission benefits ROG = 0.92 tons/yr - 0.10 tons/yr = 0.82 tons/yr ROG
- Emission benefits PM10 = 0.368 tons/yr - 0.073 tons/yr = 0.295 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

7.33 tons/yr + 0.82 tons/yr + 20(0.295 tons/yr) = 14.05 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1): = 0.123

Formula C-14: Incremental Cost

$1,100,000 * 0.60 = $660,000

Formula C-12: Annualized Cost

0.123 * $660,000 = $81,180/yr

Cost-Effectiveness:

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

($81,180/yr)/(14.05 weighted tons/yr)

= $5,778/tons of weighted surplus emissions reduced

Example 4 – Multiple Engine Switcher Purchase (Class III Railroad)

A Class III railroad operator has the opportunity to purchase a switch locomotive with three Tier 3 certified 700 horsepower off-road engines. Because this is a switcher with new electronics, a new battery, and other components, which meets Tier 2 locomotive emission standards and which emits NOx at a level at least 30 percent below the Tier 2 locomotive emission standard, the project is evaluated as a new locomotive purchase. Fuel receipts indicate switch locomotives in the rail yard not equipped with an ILD consume 45,000 gallons of fuel per year. The cost of the new multiple engine switcher is $975,000. The project life is 5 years. Emission reductions are calculated as follows:

Baseline Technology Information:

- Locomotive model year: none
- Locomotive emission rate (uncontrolled, Table B-16): 15.66 g/bhp-hr NOx, 0.99 g/bhp-hr ROG, 0.396 g/bhp-hr PM10
- Activity (application): 45,000 gal/year
- Energy consumption factor = 20.8 bhp-hr/gal

Reduced Technology Information:

- Engine model year: 2006
- Emission rates (reflect off-road Tier 3 emission factors, Table B-12): 2.32 g/bhp-hr NOx, 0.12 g/bhp-hr ROG, 0.088 g/bhp-hr PM10
- Activity (application): 45,000 gal/year
- Energy consumption factor = 18.5 bhp-hr/gal
- ILD emission reduction factor (Table B-17): 0.90

Emission Reduction Calculations:

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr):

1. Annual NOx baseline technology emissions
   (15.66 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g)
   = 16.16 ton/yr NOx
2. Annual NOx reduced technology emissions
   (2.32 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 1.92 ton/yr NOx
3. Annual ROG baseline technology emissions
   (0.99 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g)
   = 1.02 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.12 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.10 ton/yr ROG
5. Annual combustion PM10 baseline technology
   (0.396 g/bhp-hr * 45,000 gal/yr * 20.8 bhp-hr/gal) *(ton/907,200g)
   = 0.409 ton/yr PM10
6. Annual combustion PM10 reduced technology emissions
   (0.088 g/bhp-hr * 45,000 gal/yr * 18.5 bhp-hr/gal * 0.90) *(ton/907,200g)
   = 0.073 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOx = 16.16 tons/yr – 1.92 tons/yr = 14.24 tons/yr NOx
- Emission benefits ROG = 1.02 tons/yr – 0.10 tons/yr = 0.92 tons/yr ROG
- Emission benefits PM10 = 0.409 tons/yr – 0.073 tons/yr = 0.336 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

14.24 tons/yr + 0.92 tons/yr + 20(0.336 tons/yr) = 21.88 weighted tons/yr

Annualized Cost:
Project Life: 5 years
CRF (Table B-1): = 0.225

Formula C-14: Incremental Cost
$975,000 * 0.80 = $780,000

Formula C-12: Annualized Cost
0.225 * $780,000 = $175,500/yr

Cost-Effectiveness:
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($175,500/yr)/(21.88 weighted tons/yr)
= $8,021/tons of weighted surplus emissions reduced

IX. Marine Vessels

This section provides three examples of calculations for determining the cost-effectiveness of surplus emission reductions for marine vessel projects.

A. General Criteria for Marine Vessel Cost-Effectiveness Calculations

- Engines on marine vessels with wet exhaust systems are eligible for Carl Moyer Program funding if the project vessel meets all other applicable program requirements. The wet exhaust systems themselves are not eligible for Carl Moyer Program funding. A wet exhaust factor of 0.80 must be applied to the baseline and reduced emission propulsion and auxiliary engine emission calculations for all projects on vessels with wet exhaust systems.

- Projects must have a minimum project life of three years.

- The maximum project life for marine vessel projects (equivalent to the average engine life reported by U.S. EPA) is as follows:
  Engine displacement ≤5.0 liter/cyl. 16 years
  Engine displacement >5.0 liter/cyl. 23 years
  Auxiliary engines 17 years

B. Examples

Example 1 – Tugboat Propulsion Engine Repower
A tugboat operator wishes to replace a 1975 model year 1,200 horsepower tugboat propulsion engine during the normal overhaul period with a 2006 model year 1,200 horsepower engine. Both engines have a displacement of 7.0 liters per cylinder. The operator documents that the vessel consumes 95,000 gallons of fuel annually within California Coastal Waters. The cost to rebuild the old engine is $100,000. The cost to purchase and install the new engine and new GPS unit on the vessel are $250,000 and $2,500, respectively. The operator commits to a 5 year project life. Emission reductions are calculated as follows:

<u>Baseline Technology Information:</u>
- Baseline technology (application): 1975
- Engine horsepower (application): 1,200 hp
- Engine emission rate (Table B-18): 11.16 g/bhp-hr NOx, 1.14 g/bhp-hr ROG, 0.382 g/bhp-hr PM10
- Activity (application): 95,000 gal/yr
- Engine displacement (application): 7.0 liters/cylinder
- Fuel consumption rate (Table B-20): 20.8 bhp-hr/gal

<u>Reduced Technology Information:</u>
- Reduced technology (application): 2005
- Engine horsepower (application) = 1,200 hp

- Engine emission rate (Table B-18): 7.60 g/bhp-hr NOx, 0.82 g/bhp-hr ROG, 0.274 g/bhp-hr PM10
- Activity (application): 95,000 gal/yr
- Fuel consumption rate (Table B-20): 20.8 bhp-hr/gal

<u>Emission Reduction Calculations:</u>

Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standards (tons/yr)

1. Annual NOx baseline technology emissions
   (11.16 g/bhp-hr)(95,000 gal/yr)(20.8 bhp-hr/gal)(ton/907,200 g)
   = 24.31 ton/yr NOx
2. Annual NOx reduced technology emissions
   (7.60 g/bhp-hr * 95,000 gal/yr * 20.8 bhp-hr/gal)(ton/907,200 g)
   = 16.55 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.14 g/bhp-hr * 95,000 gal/yr * 20.8 bhp-hr/gal)(ton/907,200 g)
   = 2.48 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.82 g/bhp-hr * 95,000 gal/yr * 20.8 bhp-hr/gal)(ton/907,200 g)
   = 1.79 ton/yr ROG
5. Annual PM10 baseline technology emissions
   (0.382 g/bhp-hr * 95,000 gal/yr * 20.8 bhp-hr/gal)(ton/907,200 g)
   = 0.832 ton/yr PM10
6. Annual PM10 reduced technology emissions
   (0.274 g/bhp-hr * 95,000 gal/yr * 20.8 bhp-hr/gal)(ton/907,200 g)
   = 0.597 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission reductions = 24.31 tons/yr – 16.55 tons/yr = 7.76 tons/yr NOx
- ROG emission reductions = 2.48 tons/yr – 1.79 tons/yr = 0.69 tons/yr ROG
- PM10 emission reductions = 0.832 tons/yr – 0.597 tons/yr= 0.235 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

7.76 + 0.69 +20(0.235) = 13.15 weighted tons/yr

<u>Annualized Cost:</u>

Project life = 5 years

CRF (Table B-1) = 0.225

Formula C-14: Incremental Cost

($250,000 + $2,500) - $100,000 = $152,500

Formula C-12: Annualized Cost

($152,500 * 0.225) = $34,312/yr

Cost-Effectiveness:

Formula C-1: Cost-Effectiveness of Surplus Emission Reductions

($34,312/year)/(13.15 weighted tons/yr)

= $2,609/ton of weighted surplus emissions reduced

Example 2 – Fishing Vessel Auxiliary Engine Repower

A charter fishing vessel owner wishes to repower a 125 horsepower 1985 auxiliary engine with a new 2005 model year 200 horsepower engine. The new engine has a displacement 1.3 liters per cylinder. The vessel owner has documented that the vessel auxiliary engine operates for 900 hours annually in California waters. The cost to rebuild the existing engine is $2,600. The cost to purchase and install a new engine and GPS unit is $52,500. The applicant will commit to a 10 year project life. Emission reductions are calculated as follows:

Baseline Technology Information:

- Baseline technology (application): 1985
- Engine horsepower (application): 125 hp
- Engine emission rate (Table B-18): 10.23 g/bhp-hr NOx, 1.06 g/bhp-hr ROG, 0.396 g/bhp-hr PM10
- Activity (application): 900 hr/yr
- Engine load factor (Table B-19): 0.43

Reduced Technology Information:

- Reduced technology (application): 2005
- Engine horsepower (application) = 200 hp
- Emission rate (Table B-18): 4.17 g/bhp-hr NOx, 0.39 g/bhp-hr ROG, 0.160 g/bhp-hr PM10
- Activity (application): 900 hr/yr
- Engine displacement (application) = 1.3 liters per cylinder
- Load adjustment (*Formula C-5: Replacement Load Factor*):
  = 0.43*(125 hp/200 hp) = 0.27

Emission Reduction Calculations:

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

1. Annual NOx baseline technology emissions
   (10.23 g/bhp-hr * 900 hr/yr * 125 hp * 0.43)(ton/907,200 g)
   = 0.55 ton/yr NOx
2. Annual NOx reduced technology emissions
   (4.17 g/bhp-hr * 900 hr/yr * 200 hp * 0.27)(ton/907,200 g)
   = 0.22 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.06 g/bhp-hr * 900 hr/yr * 125 hp * 0.43)(ton/907,200 g)
   = 0.06 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.39 g/bhp-hr * 900 hr/yr * 200 hp * 0.27)(ton/907,200 g)
   = 0.02 ton/yr ROG

5. Annual PM10 baseline technology emissions
   (0.396 g/bhp-hr * 900 hr/yr * 125 hp * 0.43)(ton/907,200 g
   = 0.021 ton/yr PM10
6. Annual PM10 reduced technology emissions
   (0.14 g/bhp-hr * 900 hrs/year * 200 hp * 0.27)(ton/907,200 g)
   = 0.008 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission reductions = 0.55 tons/yr – 0.22 tons/yr = 0.33 tons/yr NOx
- ROG emission reductions = 0.06 tons/yr – 0.02 tons/yr = 0.04 tons/yr ROG
- PM10 emission reductions = 0.021 tons/yr – 0.008 tons/yr= 0.013 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.33 tons/yr + 0.04 tons/yr + 20(0.013 tons/yr) = 0.63 weighted tons/yr

Annualized Cost:

Project life = 10 years

CRF (Table B-1) = 0.123

Formula C-14: Incremental Cost

$52,500 - $2,600 = $49,900

Formula C-12: Annualized Cost

($49,900 * 0.123) = $6,137/yr

Cost-Effectiveness:

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

($6,137/year)/ (0.63 weighted tons/yr)

= $9,741/ton of weighted surplus emissions reduced

Example 3 – Fishing Vessel Propulsion Engine Repower (Wet Exhaust System)

A commercial fishing vessel owner wishes to repower a 1973 250 horsepower propulsion engine with a new 2006 model year 250 horsepower engine. The existing and replacement engines both have a displacement of 1.4 liters per cylinder. The vessel has a wet exhaust system. The vessel owner has documented that the vessel propulsion engine consumes 24,000 gallons of fuel annually in California waters. The cost to rebuild the existing engine is $3,250. The cost to purchase and install a new engine is $51,300. The vessel will be outfitted with a new GPS unit for $2,300. The applicant will commit to a 5 year project life. Emission reductions are calculated as follows:

Baseline Technology Information:

- Baseline technology (application): 1973
- Engine horsepower (application): 250 hp

- Engine emission rate (Table B-18): 11.16 g/bhp-hr NOx, 1.14 g/bhp-hr ROG, 0.396 g/bhp-hr PM10
- Activity (application): 24,000 gal/yr
- Engine displacement (application): 1.4 liters/cylinder
- Fuel consumption rate (Table B-20): 18.5 bhp-hr/gal
- Wet exhaust emission factor (default): 0.80

<u>Reduced-Emission Technology Information:</u>
- Reduced technology (application): 2006
- Engine horsepower (application): 250 hp
- Emission rate (Table B-18): 4.17 g/bhp-hr NOx, 0.39 g/bhp-hr ROG, 0.160 g/bhp-hr PM10
- Activity (application): 24,000 gal/yr
- Engine displacement (application): 1.4 liters per cylinder
- Fuel consumption rate (Table B-20): 18.5 bhp-hr/gal
- Wet exhaust emission factor (default) = 0.80

<u>Emission Reduction Calculations:</u>
Formula C-6: Estimated Annual Emissions based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr)
1. Annual NOx baseline technology emissions
   (11.16 g/bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 4.30 ton/yr NOx
2. Annual NOx reduced technology emissions
   (4.17 g/bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 1.63 ton/yr NOx
3. Annual ROG baseline technology emissions
   (1.14 g/bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 0.45 ton/yr ROG
4. Annual ROG reduced technology emissions
   (0.39 g.bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 0.15 ton/yr ROG
5. Annual PM10 baseline technology emissions
   (0.396 g/bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 0.155 ton/yr PM10
6. Annual PM10 reduced technology emissions
   (0.160 g/bhp-hr * 24,000 gal/yr * 18.5 bhp-hr/gal * 0.80)(ton/907,200 g)
   = 0.063 ton/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant for Repowers and New Purchases
- NOx Emission Reductions = 4.30 tons/yr – 1.63 tons/yr = 2.67 tons/yr NOx
- ROG Emission Reductions = 0.45 tons/yr – 0.15 tons/yr = 0.30 tons/yr ROG
- PM10 Emission Reductions = 0.155 tons/yr – 0.063 tons/yr
  = 0.092 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

2.67 + 0.30 +20(0.092) = 4.81 weighted tons/yr

<u>Annualized Cost:</u>

Project life = 5 years

CRF (Table B-1) = 0.225

Formula C-14:   Incremental Cost

($51,300 + 2,300) - $3,250 = $50,350

Formula C-12:   Annualized Cost

$50,350 * 0.225 = $11,328/yr

<u>Cost Effectiveness:</u>

Formula C-1: Cost-Effectiveness of Surplus Emission Reductions

($11,328/year)/(4.81 weighted tons/yr) =

$2,355/ ton of weighted surplus emissions reduced

X. Agricultural Sources

This section provides three examples of calculations for determining the cost-effectiveness of surplus emission reductions for agricultural source projects.

A. General Criteria for Agricultural Source Cost-Effectiveness Calculations

- Projects must have a minimum project life of three years. ARB may approve a shorter project life on a case-by-case basis. Projects with shorter lives have be subject to additional funding restrictions, such as a lower cost-effectiveness limit or a project cost cap.

- The default project life when determining project benefits for new purchases to repowers shall be ten years for electric motors and for engines with documentation. The default project life for engines without documentation shall be seven years. A longer project life may be used with approval by ARB staff, however, sufficient documentation must be provided to ARB that supports the selected project life based on actual remaining useful life.

- In these calculations PM10 refers to combustion particulate matter.

- Emission reduction calculations may be based on hours of operation or on fuel usage.

- Baseline and reduced technology emission factors are listed in Table B-12 and B-14 of Appendix B.

- Load factors for selected equipment categories are in Table B-13 of Appendix B.

- For emission reduction calculations based on fuel usage, an energy consumption factor must be used. The default energy consumption factor for stationary agricultural irrigation pump engines greater than 50 hp is 17.56 bhp-hr/gal. An energy consumption factor may be calculated: 1) by dividing the horsepower rating of the engine by its fuel economy expressed in units of gallons per hour (gal/hr), or 2) by dividing the energy density of the fuel (in units of BTU/gal) by the brake-specific fuel consumption of the engine.

B. Examples

Example 1 - Repower (diesel to diesel) Based on Hours

<u>Baseline Technology Information:</u>
- Baseline technology (application): 1977 John Deere JD6466A
- Engine horsepower (application): 182 hp
- Activity (application): 3,000 hours per year

- Load factor (Table B-13): 0.65
- Emission factors (Table B-12): 11.16 g/bhp-hr NOx; 1.14 g/bhp-hr ROG; 0.396 g/bhp-hr PM10
- Baseline rebuild cost (quote provided with application): $3,500

Reduced Technology Information:

- Reduced technology (application): 2005 John Deere 6068HF275-225
- Engine horsepower (application): 184 hp
- Activity (application): 3,000 hr/yr
- Load factor (Table B-13): 0.65
- Emission factors (Table B-12): 4.15 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.088 g/bhp-hr PM10
- New engine cost (quote provided with application): $20,320 (includes hour meter)

Emission Reduction Calculations:

Formula C-4: Estimated Annual Emissions Based on Hours of Operation (tons/yr)

1. Annual NOx baseline technology emissions
   (11.16 g/bhp-hr * 182 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 4.37 tons/yr NOx
2. Annual NOx reduced technology emissions
   (4.15 g/bhp-hr * 184 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 1.64 tons/yr NOx
3. Annual ROG baseline technology emissions
   (1.14 g/bhp-hr * 182 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 0.45 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.12 g/bhp-hr * 184 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 0.05 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.396 g/bhp-hr * 182 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 0.155 tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0.088 g/bhp-hr * 184 hp * 0.65 * 3,000 hrs)(ton/907,200 g) = 0.035 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 4.37 tons/yr – 1.64 tons/yr = 2.73 tons/yr NOx
- ROG emission benefits = 0.45 tons/yr – 0.05 tons/yr = 0.40 tons/yr ROG
- PM10 emission benefits = 0.155 tons/yr – 0.035 tons/yr = 0.120 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

2.73 tons/yr + 0.40 tons/yr + 20(0.120 tons/yr) = 5.53 weighted tons/yr

Annualized Cost:

Project life: 7 years

CRF (Table B-1): 0.167

Formula C-14: Incremental Cost

$20,320 - $3,500 = $16,820

Formula C-12: Annualized Cost

0.167 * $16,820 = $2,809/yr

Cost-Effectiveness:

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions

($2,809/yr)/(5.53 weighted tons/yr)

= $508/tons of weighted surplus emissions reduced

The cost-effectiveness for this project is less than $14,300 per weighted ton of emissions reduced. This project qualifies for the maximum amount of grant funds requested.

Example 2 - Repower (diesel to diesel) Based on Fuel Use

Baseline Technology information:

- Baseline Technology (application): 1979 Cummins NTC 220
- Engine horsepower (application): 220 hp
- Annual fuel consumption (application): 8,000 gal/yr
- Energy consumption factor (default): 17.56 bhp-hr/gal
- Emission Factors (Table B-12): 11.16 g/bhp-hr NOx; 1.20 g/bhp-hr ROG; 0.396 g/bhp-hr PM1010
- Rebuild cost (quote provided with application): $2,500

Reduced Technology information:

- Reduced Technology (application): 2005 Case I-H PX190
- Engine horsepower (application): 190 hp
- Energy consumption factor (supplied by manufacturer): 20 bhp-hr/gal
- Annual fuel consumption (equation in bullets above): (17.56/20)bhp-hr/gal * 8,000 gal/yr = 7,024 gal/yr
- Emission Factors (Table B-12): 4.15 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.088 g/bhp-hr PM1010
- New engine cost (quote provided with application): $16,500 (includes hour meter)

Emission Reduction Calculations:

Formula C-6: Estimated Annual Emissions Based on Fuel Consumed using Emission Factors or Converted Emission Standard (tons/yr)

1. Annual NOx baseline technology emissions
   (11.16 g/bhp-hr * 17.56 bhp-hr/gal * 8,000 gal)(ton/907,200 g) = 1.73 tons/yr NOx
2. Annual NOx reduced technology emissions
   (4.15 g/bhp-hr * 20 bhp-hr/gal * 7,024 gal/yr)(ton/907,200 g) = 0.64 tons/yr NOx
3. Annual ROG baseline technology emissions
   (1.20 g/bhp-hr * 17.56 bhp-hr/gal * 8,000 gal)(ton/907,200 g) = 0.19 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.12 g/bhp-hr * 20 bhp-hr/gal * 7,024 gal/yr)(ton/907,200 g) = 0.02 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.396 g/bhp-hr * 17.56 bhp-hr/gal * 8,000 gal)(ton/907,200 g) = 0.061 tons/yr PM10

6. Annual PM10 reduced technology emissions
   (0.088 g/bhp-hr * 20 bhp-hr/gal * 7,024 gal/yr)(ton/907,200 g) = 0.014 tons/yr PM10

Formula C-9: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 1.73 tons/yr – 0.64 tons/yr = 1.09 tons/yr NOx
- ROG emission benefits = 0.19 tons/yr – 0.02 tons/yr = 0.17 tons/yr ROG
- PM10 emission benefits = 0.061 tons/yr – 0.014 tons/yr = 0.047 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

1.09 tons/yr + 0.17 tons/yr + 20(0.047 tons/yr) = 2.20 weighted tons/yr

<u>Annualized Cost:</u>
Project life: 7 years
CRF (Table B-1): 0.167

Formula C-14: Incremental Cost

$16,500 - $2,500 = $14,000

Formula C-12: Annualized Cost

0.167 * $14,000 = $2,338/yr

<u>Cost-Effectiveness:</u>
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions

($2,338/yr)/(2.20 weighted tons/yr)
= $1,063/tons of weighted surplus emissions reduced

The cost-effectiveness for this project is less than $14,300 per weighted ton of emissions reduced. This project qualifies for the maximum amount of grant funds requested.

Example 3 – Natural Gas Repower Based on Hours

<u>Baseline Technology information:</u>

- Baseline Technology (application): 1980 Detroit Diesel 8V71
- Engine horsepower (application): 220 hp
- Activity (application): 2,000 hours per year
- Load factor (Table B-13): 0.65
- Emission Factors (Table B-12): 10.23 g/bhp-hr NOx; 1.08 g/bhp-hr ROG; 0.396 g/bhp-hr PM10
- Rebuild cost (quote provided with application): $6,000

<u>Reduced Technology information:</u>

- Reduced Technology (application): 2005 Cummins GTA 8.3
- Engine horsepower (application): 200 hp
- Activity (application): 2,000 hr/yr

- Load factor (Table B-13): 0.65
- Emission Factors (Table B-14): 1.58 g/bhp-hr NOx; 0.13 g/bhp-hr ROG; 0.060 g/bhp-hr PM10
- New engine cost (quote provided with application): $29,000 (includes hour meter)

Emission Reduction Calculations:

Formula C-4: Estimated Annual Emissions Based on Hours of Operation (tons/yr)

1. Annual NOx baseline technology emissions
   (10.23 g/bhp-hr * 220 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 3.23 tons/yr NOx
2. Annual NOx reduced technology emissions
   (1.58 g/bhp-hr * 200 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 0.45 tons/yr NOx
3. Annual ROG baseline technology emissions
   (1.08 g/bhp-hr * 220 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 0.34 tons/yr ROG
4. Annual ROG reduced technology emissions
   (0.13 g/bhp-hr * 200 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 0.04 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.396 g/bhp-hr * 220 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 0.125 tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0.060 g/bhp-hr * 200 hp * 0.65 * 2,000 hrs)(ton/907,200 g) = 0.017 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 3.23 tons/yr – 0.45 tons/yr = 2.78 tons/yr NOx
- ROG emission benefits = 0.34 tons/yr – 0.04 tons/yr = 0.30 tons/yr ROG
- PM10 emission benefits = 0.125 tons/yr – 0.017 tons/yr = 0.108 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

2.78 tons/yr + 0.30 tons/yr + 20(0.108 tons/yr) = 5.24 weighted tons/yr

Annualized Cost:

Project life: 7 years

CRF (Table B-1): 0.167

Formula C-14: Incremental Cost

$29,000 - $6,000 = $23,000

Formula C-12: Annualized Cost

0.167 * $23,000 = $3,841/yr

Cost-Effectiveness:

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions

($3,841/yr)/(5.24 weighted tons/yr)

= $733/tons of weighted surplus emissions reduced

The cost-effectiveness for this project is less than $14,300 per weighted ton of emissions reduced. This project qualifies for the maximum amount of grant funds requested.

XI. Light-Duty Vehicles

This section provides an example calculation for determining the cost-effectiveness of surplus emission reductions for light-duty vehicle projects.

A. General Criteria for Light-Duty Vehicle Cost-Effectiveness Calculations

- Emission reductions from VAVR programs shall be calculated in accordance with the methodology specified in the ARB's VAVR regulations. Emission reductions, by model year of vehicle retired, are shown in Table 11-2. (The table is also included in Appendix B, Tables for Emission-Reduction and Cost-Effectiveness Calculations, at Table B-21.)

- The project life for a vehicle retirement project is three years as specified in the ARB's VAVR regulation.

- In calculating cost-effectiveness, the total cost is the full cost paid by the district using State funds (i.e, the total paid to the enterprise operator to retire a vehicle, not just the amount paid to the vehicle owner).

- Cost-effectiveness is calculated without interim rounding to the annualized cost or the annual weighted surplus emission reduction.

- For these calculations, PM10 refers to combustion PM10.

B. Examples

Example 1 - Voluntary Accelerated Vehicle Retirement Project
A district pays $750 to retire a 1980 model year light-duty vehicle during calendar year 2006. Please note that the cost of $750 is the total cost paid by the district with Carl Moyer Program or AB 923 funds to the enterprise operator to retire the vehicle, not just the amount paid to the vehicle owner.

<u>Emissions Reduction Calculations:</u>

Table B-21 lists the emission reductions over the 3 year project life in pounds.

- NOx emission benefit
  = 85 pounds over 3 years (from Table B-21)
  = (85 lb)/[(3 yrs)*(2000 lb/ton)] = 0.0142 tons/yr NOx

- ROG emission benefit
  = 129 pounds over 3 years (from Table B-21)
  = (129 lb)/[(3 yrs)*(2000 lb/ton)] = 0.0215 tons/yr ROG

- PM10 emission benefit
  = 1.13 pounds over 3 years (from Table B-21)
  = (1.13 lb)/[(3 yrs)*(2000 lb/ton)] = 0.000188 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions
0.0142 + 0.0215 + 20*(0.000188) = 0.0394 weighted tons/yr

<u>Annualized Cost:</u>

Project life: 3 years
CRF (Table B-1) = 0.360

Total cost: $750

Formula C-12: Annualized cost
0.360 * $750 = $270/yr

<u>Cost-Effectiveness:</u>

Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/ton)
($270/yr)/(0.0394 weighted tons/yr)
= $6,850/weighted ton of surplus emissions reduced

XII. Zero-Emission Technologies

This section provides several examples of calculations for determining the cost-effectiveness of surplus emission reductions for zero-emission projects.

A. General Criteria for Zero-Emission Technology Cost-Effectiveness Calculations

<u>Electrically Driven Agricultural Pumps</u>

- Agricultural pumps that use an electric motor may use a 10 year project life for calculating cost effectiveness.

- All electric-driven agricultural pumps must have a functioning kilowatt-hour meter, or other method approved by the local air district, to monitor usage.

- Participants in the PG&E/SCE rate incentive programs must use Tier 3 engine emission factors for calculating reduced technology emissions.

- Participants in the PG&E/SCE rate incentive programs may use one-half the rebuild cost for calculating incremental cost.

- Participants in the PG&E/SCE rate incentive programs that are replacing a baseline Tier 2 engine still under contract with the Carl Moyer Program may use zero rebuild cost for calculating incremental cost.

- For these calculations, PM10 refers to combustion PM10.

- The minimum project life is three years.

<u>Electric Idle Reduction</u>

- The actual capital cost, up to $5,500, of an APU may be funded.

- The installation cost of an APU, including installation of an hour meter, up to a maximum of $3,400 per electric motor or fuel cell APU may be funded.

B. Examples

Example 1 – Replacing a Diesel Pump Engine with a Electric Pump Motor: Not Participating in PG&E/SCE Incentive Program

An applicant wants to purchase a 2005 GE 5K445FT328, 100 hp (75 kW) electric pump motor to replace a 1991 Caterpillar 3116, 155 hp diesel pump engine with uncontrolled emissions. The motor costs $26,700; otherwise the applicant would have to rebuild the diesel engine at a cost of $7,000. On average, the applicant currently operates the diesel pump engine at 65 percent of the maximum load rating for 2,000 hours each year. The pump operates 100 percent of the time in California.

Baseline Technology Information:
- Engine (application): 1991 Caterpillar 3116, diesel off-road engine (uncontrolled)
- Engine HP (application): 155 hp
- Load factor (default for agricultural pumps): 0.65
- Activity (application): 2,000 hours per year
- Cost rebuild (quote provided with application): $7,000
- Emission factors (Table B-12): 7.60 g/bhp-hr NOx; 0.82 g/bhp-hr ROG; 0.274 g/bhp-hr PM10

Reduced Technology Information:
- Engine (application): 2005 GE 5K445FT328, electric motor
- Engine HP (application):   100 hp (75 kW)
- Activity (application): 2,000 hours per year
- Percent operate in California (application): 100 percent
- Cost of new equipment (quote provided with application): $26,700
- Emissions: 0 g/bhp-hr NOx; 0 g/bhp-hr ROG; 0 g/bhp-hr PM10

Emission Reduction Calculations:
Formula C-4: Estimated Annual Emissions Based on Hours of Operation
1. Annual NOx baseline technology emissions
   (7.60 g/hp-hr *155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 1.69 tons/yr NOx
2. Annual NOx reduced technology emissions = 0 tons/yr
3. Annual ROG baseline technology emissions
   (0.82 g/hp-hr *155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.18 tons/yr ROG
4. Annual ROG reduced technology emissions = 0 tons/yr
5. Annual PM10 baseline technology emissions
   (0.274 g/hp-hr *155 hp *0.65 * 2,000 hrs)/(907,200 g/ton) = 0.061 tons/yr PM
6. Annual PM10 reduced technology emissions = 0 tons/yr

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases
- Emission benefits NOx = 1.69 tons/yr - 0 tons/yr = 1.69 tons/yr NOx
- Emission benefits ROG = 0.18 tons/yr - 0 tons/yr = 0.18 tons/yr ROG
- Emission benefits PM10 = 0.061 tons/yr - 0 tons/yr = 0.013 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions
1.69 + 0.18 + 20(0.061) = 3.09 weighted tons/yr

Annualized Cost:
Project Life: 10 years
CRF (Table B-1) =   0.123

Formula C-14: Incremental Cost
$26,700 – $7,000 = $19,700

Formula C-12: Annualized Cost
$19,700 * 0.123 = $2,423/yr

Cost-Effectiveness:
Formula C-1: Cost-Effectiveness of Weighted Surplus Emission Reductions ($/weighted ton)
($2,423/yr)/(3.09 weighted ton/yr)
= $784/weighted ton of surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per weighted ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 2 – Replacing a Diesel Pump Engine with a Electric Pump Motor: Applicant Is Participating in PG&E/SCE Incentive Program

An applicant wants to purchase a 2005 GE 5K445FT328, 100 hp (75 kW) electric pump motor to replace a 1991 Caterpillar 3116, 155 hp diesel pump engine with uncontrolled emissions. The motor costs $26,700; otherwise the applicant would have to rebuild the diesel engine at a cost of $7,000. On average, the applicant currently operates the diesel pump engine at 65 percent of the maximum load rating for 2,000 hours each year. The pump operates 100 percent of the time in California. The applicant is eligible and has been accepted in the PG&E/SCE rate incentive program.

Baseline Technology Information:

- Engine (application): 1991 Caterpillar 3116, diesel off-road (uncontrolled)
- Engine HP (Application): 155 hp
- Load factor (default for agricultural pumps): 0.65
- Activity (application): 2,000 hours per year
- Cost to rebuild (quote provided with application): $7,000
- Emission factors (Table B-12): 7.60 g/bhp-hr NOx; 0.82 g/bhp-hr ROG; 0.274 g/bhp-hr PM10

Reduced Technology Information:

- Engine (application): 2005 GE 5K445FT328, electric
- Engine HP (application): 100 hp (75 kW)
- Activity (application): 2,000 hours per year
- Percent operate in California (application): 100 percent
- Cost of new equipment (quote provided with application): $26,700
- *Emissions: Applicant can only claim emission benefit from baseline to a comparable Tier III engine*.

Electric motor: 0 g/bhp-hr NOx; 0 g/bhp-hr ROG; 0 g/bhp-hr PM
Tier III 155 hp diesel engine (Table B-12): 2.32 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.112g/bhp-hr PM10

Emission Reduction Calculations:

Formula C-4: Estimated Annual Emissions Based on Hours of Operation

1. Annual NOx baseline technology emissions
   (7.60 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 1.69 tons/yr NOx
2. Annual NOx Tier III technology emissions
   (2.32 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.52 tons/yr NOx
3. Annual ROG baseline technology emissions
   (0.82 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.18 tons/yr ROG
4. Annual ROG Tier III technology emissions
   (0.12 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.03 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.274 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.061 tons/yr PM10
6. Annual PM10 Tier III technology emissions
   (0.112 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.025 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOX = 1.69 tons/yr- 0.52 tons/yr = 1.17 tons/yr NOx
- Emission benefits ROG = 0.18 tons/yr - 0.03 tons/yr = 0.15 tons/yr ROG
- Emission benefits PM10 = 0.061 tons/yr - 0.025 tons/yr = 0.036 tons/yr PM10

Formula C.2 – Annual Weighted Surplus Emission Reductions

1.17 + 0.15 + 20(0.036) = 2.04 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1) = 0.123

Formula C-14: Incremental Cost

$26,700 – ($7,000/2) = $23,200 *Applicant may use one-half rebuild cost for baseline, as per criteria

Formula C-12: Annualized Cost

$23,200 * 0.123 = $2,854/yr

Cost-Effectiveness:

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

($2,854/yr)/(2.04 weighted ton/yr)

= $1,399/weighted ton of surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per weighted ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 3 – Replacing a Diesel Pump Engine with a Electric Pump Motor: Applicant Is Participating in PG&E/SCE Incentive Program and Replaced Engine Is a CMP-Funded Tier II Engine

An applicant wants to purchase a 2005 GE 5K445FT328, 100 hp (75 kW) electric pump motor to replace a Tier 2 155 hp diesel pump engine. The motor costs $26,700. On average, the applicant currently operates the diesel pump engine at 65 percent of the maximum load rating for 2,000 hours each year. The pump operates 100 percent of the time in California. The Tier 2 engine was purchased with Carl Moyer Program funds three years ago, and is still under contract. The engine has not reached its rebuild interval. The applicant is eligible and has been accepted in the PG&E/SCE rate incentive program.

Baseline Technology Information:
- Engine (application): 2004 Tier 2 diesel off-road
- Engine HP (application): 155 hp
- Load factor(default for agricultural pumps): 0.65
- Activity (application): 2,000 hours per year
- Cost rebuild (quote provided with application): $0

Tier II 155 hp diesel engine (Table B-12): 4.17 g/bhp-hr NOx; 0.19 g/bhp-hr ROG; 0.128 g/bhp-hr PM10

Reduced Technology Information:
- Engine (application): 2005 GE 5K445FT328, electric
- Engine HP (application): 100 hp (75 kW)
- Activity (application): 2,000 hours per year
- Percent operate in California (application): 100 percent
- Cost of new equipment (quote provided with application): $26,700
- *Emissions: Applicant can only claim emission benefit from baseline to a comparable Tier III engine.*
  Tier III 155 hp diesel engine (Table B-12): 2.32 g/bhp-hr NOx; 0.12 g/bhp-hr ROG; 0.112g/bhp-hr PM10

Emission Reduction Calculations:
Formula C-4 - Estimated Annual Emissions based on Hours of Operation
1. Annual NOx baseline technology emissions
   (4.17 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.93 tons/yr NOx
2. Annual NOx Tier III technology emissions
   (2.32 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.52 tons/yr NOx
3. Annual ROG baseline technology emissions
   (0.19 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.04 tons/yr ROG

4. Annual ROG Tier III technology emissions
   (0.12 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton) = 0.03 tons/yr ROG
5. Annual PM10 baseline technology emissions
   (0.128 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton)= 0.028 tons/yr PM10
6. Annual PM10 Tier III technology emissions
   (0.112 g/hp-hr * 155 hp * 0.65 * 2,000 hrs)/(907,200 g/ton)= 0.025 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOX = 0.93 tons/yr- 0.52 tons/yr = 0.41 tons/yr NOx
- Emission benefits ROG = 0.04 tons/yr - 0.03 tons/yr = 0.01 tons/yr ROG
- Emission benefits PM10= 0.028 tons/yr - 0.025 tons/yr = 0.003 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.41 tons/yr + 0.01 tons/yr + 20(0.003 tons/yr) = 0.480 weighted tons/yr

Annualized Cost:

Project Life: 10 years

CRF (Table B-1) = 0.123

Formula C-14: Incremental Cost

$26,700 – $0* = $26,700 *Applicant may use a rebuild cost of $0 since they are still under Moyer contract and are not to their rebuild interval.

Formula C-12: Annualized Cost

$26,700 * 0.123 = $3,284/yr

Cost-Effectiveness:

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

($3,284/yr)/(0.480 weighted ton/yr)

= $6,842/weighted ton of surplus emissions reduced

The cost-effectiveness for the example is less than $14,300 per weighted ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 4 – Electric Idle Reduction Package Replaces Main Diesel Engine Idling

An applicant wants to purchase an electric package that includes an electric HVAC, a large alternator, and inverter/charger and a lead acid battery pack. These units will replace all idling that uses the truck's main propulsion engine. The package costs $10,000 and another $2,000 for installation. The applicant currently idles his 1999 MY truck engine an average of 1,250 hours each year.

Baseline Technology Information:

- Main engine model year (application): 1999
- Annual hours of idling (application): 1,250
- Main Engine idling emission rate (Table B-9): 171.00 g/hr NOx, 34.28 g/hr ROG, g/hr 2.28 PM10

Reduced Technology Information:

- 110 VAC, 60 Hz HVAC (8300 BTU) ; 270 A alternator; lead acid battery pack; inverter/charger (application)
- Annual hours of idling (application): 1,250
- Percent operate in California (application): 100 percent
- Cost of new equipment (quote provided with application): $10,000
- Cost of installation (quote provided with application): $2,000
- Electric emission rates: 0 g/bhp-hr NOx; 0 g/bhp-hr ROG; 0 g/bhp-hr PM10

Emission Reduction Calculations:

Formula C-4: Estimated Annual Emissions based on Hours of Operation

1. Annual NOx baseline technology emissions
   (171.00 g/hr * 1,250 hrs)/(907,200 g/ton) = 0.24 tons/yr NOx
2. Annual NOx reduced technology emissions = 0 tons/yr NOx
3. Annual ROG baseline technology emissions
   (34.28 g/hr * 1,250 hrs)/(907,200 g/ton) = 0.05 tons/yr ROG
4. Annual ROG reduced technology emissions = 0 tons/yr ROG
5. Annual combustion PM10 baseline technology emissions
   (2.28 g/hr * 1,250 hrs)/(907,200 g/ton) = 0.003 tons/yr PM10
6. Annual combustion PM10 reduced technology emissions = 0 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by Pollutant (tons/yr) for Repowers and New Purchases

- Emission benefits NOX = 0.24 tons/yr - 0 tons/yr = 0.24 tons/yr NOx
- Emission benefits ROG = 0.05 tons/yr - 0 tons/yr = 0.05 tons/yr ROG
- Emission benefits PM10 = 0.003 tons/yr - 0 tons/yr = 0.003 tons/yr PM10

Formula C-2: Annual Weighted Surplus Emission Reductions

0.24 tons/yr + 0.05 tons/yr + 20(0.003 tons/yr) = 0.350 weighted tons/yr

Annualized Cost:

Project Life: 5 years

CRF (Table B-1) = 0.225

Formula C-14: Incremental Cost

Capital cost: $10,000 CMP will pay up to $5,500, as per guideline criteria
Installation cost: $2,000
$5,500 + $2,000= $7,500

Formula C-12: Annualized Cost

$7,500 * 0.225 = $1,688/yr

Cost-Effectiveness:

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

($1,688/yr)/(0.350 weighted ton/yr)

= **$4,823/weighted ton of surplus emissions reduced**

The cost-effectiveness for the example is less than $14,300 per weighted ton of pollutants reduced. This project qualifies for the maximum amount of grant funds requested.

Example 5 – Purchase of TRU with Electric Standby Option

The TRU owner proposes to purchase a TRU that is equipped with electric standby in lieu of one without this option. This would virtually eliminate TRU engine operation while the TRU is at the facility. The TRU owner has submitted records that show his fleet of facility-controlled TRUs has operated an average of three hours per day of TRU engine run time while at the facility. The incremental cost of the E/S option is $2,000. Facility infrastructure would cost $5,000. TRUs operate at the facility 360 days per year. The new TRU would be equipped with a 2006 engine rated at 36.2 hp to maintain cooling when the truck is not at the facility.

Baseline Technology

- Engine rating = 36.2 hp
- Model year = 2006
- Default load factor = 0.53
- Emission factors (Table B-12): 4.63 g/bhp-hr NOx, 0.29 g/bhp-hr ROG, 0.280 g/bhp-hr PM10

Reduced Technology

- Electric standby = zero emissions
- Annual TRU engine activity replaced with electric standby =
  (3 hrs/day)(360 days/yr) = 1,080hr/yr

Emission Reduction Calculations:

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

1. Annual NOx baseline technology emissions
   (4.63 g/bhp-hp)(36.2 hp)(0.53)(1,080 hrs/yr)(1 ton/907,200g)
   = 0.10 tons/yr NOx
2. Annual NOx reduced technology emissions
   (0 g/bhp-hr)(36.2hp)(0.53)(1,080hrs)(1 ton/907,200g)
   = 0 ton/yr NOx
3. Annual ROG baseline technology emissions
   (0.29 g/bhp-hr)(36.20hp)(.53)(1,080 hrs/yr)(1ton/907,200g)
   = 0.007 tons/yr ROG

4. Annual ROG reduced technology emissions
   (0 g/bhp-hr)(36.2hp)(0.53)(1,080hrs)(1 ton/907,200g)
   = 0 ton/yr ROG
5. Annual PM10 baseline technology emissions
   (0.280 g/bhp-hp)(36.2 hp)(0.530)(1,080 hrs/yr)(1 ton/907,200g)
   = 0.006 tons/yr tons/yr PM10
6. Annual PM10 reduced technology emissions
   (0 g/bhp-hp)(36.2 hp)(0.530)(1,080 hrs/yr)(1 ton/907,200g)
   = 0 tons/yr PM10

Formula C-10: Annual Surplus Emission Reductions by pollutant (tons/yr) for Repowers and New Purchases

- NOx emission benefits = 0.10 tons/yr - 0 tons/yr = 0.10 tons/yr NOx
- ROG emission benefits = 0.007 tons/yr - 0 tons/yr = 0.007 tons/yr ROG
- PM10emission benefits = 0.006 tons/yr - 0 tons/yr = 0.006 tons/yr PM10

Formula C-2, Annual Weighted Surplus Emission Reductions:

0.10 tons/yr + 0.007 tons/yr + 20(0.006 tons/yr) = 0.227 weighted tons/yr

<u>Annualized Cost:</u>

Project Life: 3 years

CRF (Table B-1): =0.360

Incremental Cost: =$2,000

Formula C- 12-Annualized Cost

0.360 * $2,000 = $720/yr

<u>Cost Effectiveness:</u>

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

($720/yr)/(0.227 weighted tons/yr)

= $3,172/ton of weighted surplus emissions reduced

The $5,000 cost for electric power plugs cannot be funded by Carl Moyer Program because it is considered infrastructure. The air district may pay for this with district match funds.

This project qualifies for the $2,000 cost of the E/S option.

APPENDIX E

DESCRIPTION OF CERTIFICATION AND VERIFICATION EXECUTIVE ORDERS

APPENDIX E

DESCRIPTION OF CERTIFICATION AND VERIFICATION

I. New Engine Certification

The Air Resources Board (ARB) certifies engines destined for sale in California and provides the engine manufacturers with an Executive Order (EO) for each certified engine family. An example of an EO is shown in Figure E-1. The EO includes general information about the certified engine such as engine family, displacement, horsepower rating(s), intended service class, and emission control systems. It also shows the applicable certification emission standards as well as the average emission levels measured during the actual certification test procedure. For the purpose of the Carl Moyer Program, the certification emission standards are used to calculate emission reductions. The certification emission standards are shown in the row titled “(DIRECT) STD” under the respective “FTP” column headings for each pollutant. For instance, the Cummins 8.3 liter natural gas engine illustrated in Figure E-1 was certified to a combined oxides of nitrogen plus non-methane hydrocarbon (NOx+NMHC) emission standard of 1.8 g/bhp-hr, a carbon monoxide (CO) emission standard of 15.5 g/bhp-hr, and a particulate matter (PM) emission standard of 0.03 g/bhp-hr.

In the case where an EO shows emission values in the rows labeled “AVERAGE STD” and/or “FEL”, the engine is certified for participation in an averaging, banking, and trading (AB&T) program. AB&T engines (i.e., all FEL-certified engines) are not eligible to participate in the CMP for new vehicle purchase projects since emission benefits from an engine certified to an FEL level are not surplus emissions.

Figure E-1
Sample Executive Order

ARB Executive Order
for Heavy-Duty On-Road Engines

California Environmental Protection Agency AIR RESOURCES BOARD	CUMMINS INC.	EXECUTIVE ORDER A-021-0340 New On-Road Heavy-Duty Engines

Pursuant to the authority vested in the Air Resources Board (ARB) by Health and Safety Code (HSC) Division 26 Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by HSC Sections 39515 and 39516 and Executive Order (EO) G-02-003; and

Pursuant to the December 15, 1998 Settlement Agreement (SA) between ARB and the manufacturer, and any modifications thereof to the Settlement Agreement;

IT IS ORDERED AND RESOLVED: That the engine and emission control systems produced by the manufacturer are certified as described below for use in on-road motor vehicles with a manufacturer's GVWR over 14,000 pounds. Production engines shall be in all material respects the same as those for which certification is granted.

MODEL YEAR	ENGINE FAMILY	ENGINE SIZE (liter)	FUEL TYPE (CNG/LNG=compressed/liquefied natural gas; LPG=liquefied petroleum gas)	STANDARDS & TEST PROCEDURE	INTENDED SERVICE CLASS (L/M/H HDD=light/medium/heavy heavy-duty [HD] diesel; UB=urban bus; HDO=HD Otto)
2003	3CEXH0505CBK	8.3	CNG / LNG	Diesel	UB

SPECIAL FEATURES & EMISSION CONTROL SYSTEMS	ENGINE MODELS / CODES (rated power in horsepower, hp)
TBI, OC, HO2S, TC, CAC, PCM	CG-280 / 8012 (280 hp), CG-275 / 8009 (275 hp), CG-250 / 8006 (250 hp), CG-250 / 8003 (250 hp)

GVWR=gross vehicle weight rating TWC/OC=three-way/oxidizing catalyst WU (prefix) =warm-up cat. O2S=oxygen sensor HO2S=heated O2S TBI=throttle body fuel injection MFI=multi port fuel injection SFI=sequentialMFI DDI/IDI=direct /indirect diesel injection TC/SC=turbo/super charger CAC=charge air cooler EGR=exhaust gas recirculation AIR=secondary air injection PAIR=pulsed AIR SPL=smoke puff limiter ECM/PCM=engine /powertrain control module EM=engine modification 2 (prefix)=parallel (2) (suffix)=in series HC=hydrocarbon NMHC=non-methane HC NOx=oxides of nitrogen CO=carbon monoxide PM=particulate matter HCHO=formaldehyde g/bhp-hr=grams per brake horsepower-hour

The following are the exhaust emission standards (STD), or family emission limit(s) (FEL) as applicable, and certification levels (CERT) for this engine family under the "Federal Test Procedure" (FTP) (Title 13, California Code of Regulations, (13 CCR) Section 1956.1 (urban bus) or 1956.8 (other than urban bus)), and under the "Euro III Test Procedure" (EURO) in the Settlement Agreement, including EURO's "Not-to-Exceed" standard(s). "Diesel" CO certification compliance may have been demonstrated pursuant to Code of Federal Regulations, Title 40, Part 86, Subpart A, Section 86.091-23(c)(2)(i) in lieu of testing. (For flexible- and dual-fueled engines, the CERT values in brackets [ ] are those when tested on conventional test fuel. For multi-fueled engines, the STD and CERT values for default operation permitted in 13 CCR Section 1956.1 or 1956.8 are in parentheses.)

			EURO'S NOT-TO-EXCEED STD				NMHC: *		NOx: *		NMHC+NOx: 2.25		PM: 0.0375	
* = not applicable	HC		NMHC		NOx		NMHC+NOx		CO		PM		HCHO	
	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO	FTP	EURO
(DIRECT) STD	*	*	*	*	*	*	1.8	1.8	15.5	15.5	0.03	0.03	*	*
AVERAGE STD	*	*	*	*	*	*	*	*	*	*	*	*	*	*
FEL	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CERT	*	*	*	*	*	*	1.7	1.4	2.0	1.3	0.01	0.005	*	*

BE IT FURTHER RESOLVED: That certification to the FEL(s) listed above, as applicable, is subject to the following terms, limitations and conditions. The FEL(s) is the emission level declared by the manufacturer and serves in lieu of an emission standard for certification purposes in any averaging, banking, or trading (ABT) programs. It will be used for determining compliance of any engine in this family and compliance with such ABT programs.

BE IT FURTHER RESOLVED: That the listed engine models have been certified to the FTP optional NOx, or NMHC+NOx as applicable, and PM emission standard(s) listed above pursuant to 13 CCR Section 1956.1 or 1956.8.

BE IT FURTHER RESOLVED: That for the listed engine models, the manufacturer has submitted the materials to demonstrate certification compliance with 13 CCR Sections 1965 (emission control labels), and 2035 et seq. (emission control warranty).

BE IT FURTHER RESOLVED: That the listed engine models are conditionally certified subject to the following conditions: (**1**) The SA is in effect; (**2**) The manufacturer is in compliance with all applicable California emission regulations, and all SA's applicable requirements and any modifications thereof; (**3**) This EO is void with respect to any engine within this family determined to have a defeat device as that term is defined in the test procedures and SA. Any engine produced under the voided EO remains subject to stipulated penalties under the SA. Such penalties would begin to accrue upon manufacture of the first engine under this EO; (**4**) This EO expires at midnight on December 31, 2002; (**5**) Production of any engine within this family under this EO is acceptance of all conditions in this EO; and (**6**) ARB reserves the right to disapprove certification of this family, or any families using the same or similar auxiliary emission control device (AECD) strategies as this family is employing, based on all available information.

The Bureau of Automotive Repair will be notified by copy of this Executive Order.
Executed at El Monte, California on this 2ND day of October 2002.

Allen Lyons, Chief
Mobile Source Operations Division

II. Retrofit System Verification

The ARB's verification procedures provide a way to thoroughly evaluate the emission reduction capabilities and durability of a variety of emission control strategies as part of a retrofit in-use program. It ensures that emission reductions achieved by a control strategy are both real and durable and that production units in the field are achieving emission reductions which are consistent with their verification.

The ARB has a verification procedure for in-use strategies to control emissions from diesel engines (diesel emission control systems or DECS). The verification procedure requires a minimum PM reduction of at least 25 percent. If a diesel emission control strategy also reduces NOx emissions by at least 15 percent, that reduction can also be verified. Emission control strategies for diesel engines are verified based on a tiered verification classification shown in Table E-1 below. It is the responsibility of the diesel emission control strategies manufacturer to provide data to verify emission reduction claims. The ARB issues Executive Orders for verified emission control strategies destined for sale in California. An example of an EO for a retrofit emission control system for diesel engines is shown in Figure E-2.

Applicants may claim ROG emission reductions from DECS if hydrocarbon emission reductions for that technology are obtained from the ARB's retrofit website at: http://www.arb.ca.gov/diesel/verdev/verdev.htm. For the Carl Moyer Program, ROG emission reductions will be credited at the 25 percent, 50 percent, and 85 percent reduction levels. To calculate emission reductions of ROG for the Carl Moyer Program, applicants should use the percentage reduction of hydrocarbons from the ARB's retrofit website to determine the appropriate "level" of emission reductions. For example, a technology that provides a 40 percent emission reduction of hydrocarbons would be permitted to apply a 25 percent reduction in ROG emissions for determining eligibility and grant amount in the Carl Moyer Program.

ARB staff has also developed an interim retrofit verification procedure for large spark-ignition engines. This interim procedure can be used to verify retrofit systems to reduce NOx and HC emissions from spark-ignition engines until the interim procedure is formally adopted by the ARB.

Table E-1
Verification Levels for Diesel Emission Control Strategies

Pollutant	Emission Reduction	Classification
PM	< 25%	Not Verified
	≥ 25%	Level 1
	≥ 50%	Level 2
	≥ 85%, or ≤ 0.01 g/bhp-hr	Level 3
NOx	< 15%	Not Verified
	≥ 15%	Verified in 5% Increments

Figure E-2
Example of an EO for a Retrofit Emission Control System

State of California
AIR RESOURCES BOARD

EXECUTIVE ORDER DE-04-006-05

Pursuant to the authority vested in the Air Resources Board (ARB) by Health and Safety Code, Division 26, Part 5, Chapter 2; and pursuant to the authority vested in the undersigned by Health and Safety Code Section 39515 and 39616 and Executive Order G-02-003;

Relating to Exemptions under Section 27156 of the Vehicle Code, and Verification under Sections 2700 through 2710 of Title 13 of the California Code of Regulations

Johnson Matthey, Inc.
Continuously Regenerating Technology (CRT®) Particulate Filter

ARB has reviewed Johnson Matthey, Inc.'s request for verification of the CRT® Particulate Filter. Based on an evaluation of the data provided, and pursuant to the terms and conditions specified below, the Executive Officer of ARB hereby finds that the CRT® Particulate Filter reduces emissions of diesel particulate matter (PM) consistent with a Level 3 device (greater than or equal to 85 percent reductions) (Title 13 California Code of Regulations (CCR) Sections 2702 (f) and (g) and Section 2708). Accordingly, the Executive Officer determines that the system merits verification and, subject to the terms and conditions specified below, classifies the CRT® Particulate Filter as a Level 3 system, for the applications listed in Table 1 and engine families listed in Attachment 1.

Table 1: Appropriate Applications for the CRT® Particulate Filter

Diesel Emission Control Strategy	Application
CRT® Particulate Filter	All On-Road Applications only

The aforementioned verification is subject to the following terms and conditions:

- The engines are originally manufactured from model year 1994 through 2006 having the engine family numbers listed in Attachment 1.
- The engines do not employ exhaust gas recirculation, except for those engine families specified in Table 2 of Attachment 1.
- The engines are not used in a hybrid (e.g., diesel/electric) configuration.
- The application must have a duty cycle with an average temperature profile greater than 260 degrees Celsius for 40 percent of the operating cycle.
- The engine may or may not have a pre-existing original equipment manufacturer oxidation catalyst.
- The engine must not have a pre-existing diesel particulate filter.

- The engine must be certified in California for on-road applications.
- The engine must be certified at a PM emission level of at most 0.1 grams per brake horsepower-hour (g/bhp-hr), and greater than 0.01 g/bhp-hr.
- The engine must be four-stroke.
- The engine must be turbocharged.
- The engine can be mechanically or electronically injected.
- The engine should be well maintained and not consume lubricating oil at a rate greater than that specified by the engine manufacturer.
- Lube oil, or other oil, should not be mixed with the fuel.
- The engine must be operated on:
  - diesel fuel (e.g. not alternative diesel fuels) with a sulfur content of no more than 15 parts per million by weight or
  - B20 defined, based on volume, as a mixture of 20 percent neat biodiesel (B100) that complies with ASTM D6751 and 80 percent diesel (e.g. not alternative diesel fuels) with a sulfur content of no more than 15 parts per million by weight.
- The other terms and conditions specified below.

IT IS ALSO ORDERED AND RESOLVED: That installation of the CRT® Particulate Filter, manufactured by Johnson Matthey, Inc. of 380 Lapp Road, Malvern, Pennsylvania 19355, has been found not to reduce the effectiveness of the applicable vehicle pollution control system, and therefore, the CRT® Particulate Filter is exempt from the prohibitions in Section 27156 of the Vehicle Code for installation on heavy-duty on-road vehicles listed in Attachment 1.

This exemption is only valid provided the engines meet the aforementioned conditions.

The CRT® Particulate Filter basic design is a diesel oxidation catalyst followed by a diesel particulate filter and a backpressure monitor. The major components of the CRT® Particulate Filter are identified in Attachment 2.

This Executive Order is valid provided that installation instructions for the CRT® Particulate Filter do not recommend tuning the vehicle to specifications different from those of the vehicle manufacturer.

Changes made to the design or operating conditions of the CRT® Particulate Filter, as exempted by ARB, which adversely affect the performance of the vehicle's pollution control system, shall invalidate this Executive Order.

No changes are permitted to the device. The ARB must be notified in writing of any changes to any part of the CRT® Particulate Filter. Any changes to the device must be evaluated and approved by ARB. Failure to do so shall invalidate this Executive Order.

Marketing of the CRT® Particulate Filter using identification other than that shown in this Executive Order or for an application other than that listed in this Executive Order shall be prohibited unless prior approval is obtained from ARB.

This Executive Order shall not apply to any CRT® Particulate Filter advertised, offered for sale, sold with, or installed on a motor vehicle prior to or concurrent with transfer to an ultimate purchaser.

As specified in the Diesel Emission Control Strategy Verification Procedure (Title 13 CCR Section 2706 (g)), the ARB assigns each Diesel Emission Control Strategy a family name. The designated family name for the verification as outlined above is: CA/JMI/2001/PM3/N00/ON/DPF01.

Additionally, as stated in the Diesel Emission Control Strategy Verification Procedure, Johnson Matthey, Inc. is responsible for honoring the required warranty (Section 2707) and conducting in-use compliance testing (Section 2709).

In addition to the foregoing, ARB reserves the right in the future to review this Executive Order and the exemption and verification provided herein to assure that the exempted and verified add-on or modified part continues to meet the standards and procedures of CCR, Title 13, Section 2222, et seq and CCR, Title 13, Sections 2700 through 2710.

Systems verified under this Executive Order shall conform to all applicable California emissions regulations.

This Executive Order does not release Johnson Matthey from complying with all other applicable regulations.

Violation of any of the above conditions shall be grounds for revocation of this Executive Order.

Executed at El Monte, California, this 15th day of August 2005.

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Robert H. Cross, Chief
Mobile Source Control Division

Attachment 1: ARB Approved Model Year 1994 to 2006 Engine Families for the CRT® Particulate Filter

Attachment 2: Part Numbers and Model Numbers of the CRT® Particulate Filter and Standard Part Numbers of Backpressure Monitor

APPENDIX F

RETROFIT EMISSION CONTROL STRATEGIES

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All retrofit systems must be verified by ARB in order to qualify for Carl Moyer Program funding. Potential compression-ignited (diesel) engine retrofits include diesel oxidation catalysts, diesel particulate filters, flow though filters and fuel additives. Potential spark-ignited engines include closed-loop fuel control, three-way catalyst, fuel injection, or any combination thereof.

I. Compression-Ignited (Diesel) Engines

A. Diesel Oxidation Catalysts

A diesel oxidation catalyst (DOC) reduces carbon monoxide (CO), hydrocarbons (HC), and the soluble organic fraction (SOF) of diesel PM through catalytic oxidation. Negligible reductions of the solid particle portion of PM also occur. Exhaust gases are not filtered, as with a diesel particulate filter (DPF) so the solid particles escape. A DOC reduces total PM emissions up to 30 percent. PM emission reductions at this higher end are typically associated with engines that emit "wet" PM (i.e., particles that have a higher percentage of SOF, unburned or partially burned fuel, adsorbed onto the particle surface). Older engines or engines that have less efficient fuel combustion typically produce PM with higher SOF. Engines that more efficiently combust the fuel would have less SOF adsorbed on the soot particle, so the PM emission reductions would be less on a percentage basis.

B. Passive Diesel Particulate Filters

A DPF uses a porous substrate to filter out PM particles from the exhaust. DPFs must "regenerate" or be cleaned periodically to remove the collected particulate matter. A passive DPF has a catalyst coating on the filter surfaces that lowers the PM ignition temperature, allowing the collected PM to burn off. Emissions of HC and CO are also reduced by catalytic oxidation. This approach is called "passive" regeneration because no outside source of energy or intervention is required for regeneration, making it very attractive due to its simplicity.

C. Active Diesel Particulate Filters

Active DPFs use an external source of energy or external intervention to increase the exhaust temperature to the point where PM oxidation can occur, achieving a regeneration. Additional heat may be added to the exhaust using electrical power, microwaves, or injecting fuel. Another approach uses periodic, short-duration use of an intake throttle to reduce the amount of excess air, so the exhaust temperature rises as a result of not having to heat the excess air. The temperature of the filter and collected PM increases until the PM burns off, at which point the throttle re-opens. Active DPFs systems can initiate regeneration when the backpressure on the filter reaches a specified level or the operator can initiate a regeneration when a warning light indicates backpressure has exceeded a set point. For applications where the engine-out PM is relatively high, or the exhaust temperature is relatively cool, active regeneration systems may be more effective than a passive DPF. Emission reductions of HC and CO can also occur in active DPFs, and to a greater extent if the DPF system uses lightly catalyzed surfaces or fuel-borne catalysts to assist in achieving regenerations.

D. Flow-Through Filters

Unlike the DPF, in which only the exhaust gases can pass through the substrate, the flow-though filter (FTF) does not physically "trap" and accumulate PM. Instead, exhaust flows through a medium (such as a wire mesh or metal foils) that has a high density of tortuous flow channels, thus giving rise to turbulent flow conditions that favor PM oxidation. The medium is typically treated with an oxidizing catalyst that is able to reduce emissions of PM, HC, and CO, or the FTF is used in conjunction with a fuel borne catalyst (FBC). The filtration efficiency of the FTF is typically lower than that of a DPF because unburned PM is not "trapped", but the FTF is less likely to plug under unfavorable conditions, such as high PM emissions or low exhaust temperature.

E. Fuel Additives

A fuel additive is designed to be added to fuel or fuel systems so that it is present in-cylinder during combustion. Fuel additives can reduce the total mass of PM emissions, with variable effects on CO, NOx and gaseous HC production. A fuel-borne catalyst (FBC) is an additive that is used with diesel fuel to aid in soot removal by decreasing the ignition temperature of the carbonaceous exhaust. FBCs can be used with passive and active filter systems to improve fuel economy, aid system performance, and decrease mass PM emissions. FBC/DPF systems have been verified for on-road use in California in medium duty and heavy-duty engines. In addition, FBC/DPF systems are in wide spread use in Europe in both on-road and off-road, mobile and stationary applications. Use of FBCs with DOCs or FTFs may not be verified for use in California since catalytic particle emissions occur and the consequences of such emissions are unknown.

II. Spark-Ignition Engines

Retrofit refers to modifications or additions made to an engine and/or fuel system such that the specifications of the retrofitted engine are not the same as the original engine. Retrofits for LSI equipment will likely incorporate advanced automotive-inspired emission control technologies that dramatically reduce emissions while still meeting operational requirements. These have already been in use on a variety of LSI equipment for about 10 years. To qualify for Carl Moyer Program funding, the retrofit technology must be verified for sale in California and must comply with established durability and warranty requirements.

A. Three-Way Catalyst

Three-way catalytic converters have helped manufacturers to meet progressively lower-emissions standards. Manufacturers have installed three-way catalysts on automobiles for more than 25 years. Advanced three-way catalysts will likely be components in new LSI retrofit kit, and have been shown to be robust in research demonstrations for the 2001 LSI regulation.

LSI catalyst volumes are much lower than light duty vehicles - between 40 to 60 percent of engine displacement. Precious metal loading of the catalytic converter in a current LSI application is typically half of that in automotive applications. LSI catalysts in retrofits will likely use multi-layered wash coats that increase precious metals performance to achieve lower emissions. Due to confined space on forklifts, the three-way catalysts are made such that they can be a direct fit replacement of the original vehicle silencer. Other LSI equipment will most likely be adaptable to catalyst additions.

B. Closed-Loop Fuel Control System

Central to automotive emission control systems is the closed-loop fuel control system. Since 1980, automotive emission control systems have used a closed-loop fuel control system to help reduce emissions. This technology has increasingly been applied to LSI retrofit technology in the last 10 years. A closed-loop fuel control system uses sensors to monitor exhaust gas concentrations, and feed this information back to an electronic control module, which in turn keeps the air to fuel mixture at an optimum level. The sensors (usually oxygen sensors) deteriorate over time, causing the system to lose emissions reduction ability, but equipment with sensors have indicator lights that can alert the operator of an sensor failure so that they can replace the oxygen sensors as needed.

C. Fuel-Injection System

To help ensure more precise metering of fuel and optimum combustion, carburetors will likely be replaced by sequential fuel injection or a more sophisticated regulator/mixer. Today's advanced systems must maintain an extremely tight stoichmetric air to fuel balance during nearly all engine operations because wide fluctuations from the stoichiometric position will result in less ability to reduce NOx and hydrocarbons.