APPENDIX F

REVISED COST EFFECTIVENESS METHODOLOGY

I. METHODOLOGY

The basic methodology ARB uses to determine cost-effectiveness of a regulation is to determine what costs are involved to comply with the proposed regulation, and to compare those costs to the emission reduction benefits to the public. Staff summarizes this cost effectiveness as cost (in $) per pound of air pollutant reduced, in this case diesel particulate matter (PM). Staff calculated cost effectiveness two ways for this regulation because although this rule is primarily a PM-reduction measure, staff also has determined that significant reductions in HC and NOx emissions will take place.

A. Implementation Schedule

The implementation schedule for the proposed regulation dictates a phase-in by fleet and engine model year group (**Table 1**). Staff assumed a best available control technology (BACT) would be available for each model year engine. Staff also assumed collection vehicle owners would choose the least expensive BACT to comply with this regulation.

Table 1. Implementation Schedule for Solid Waste Collection Vehicles, Model Years 1960 to 2006.

Group	Engine Model Years	Percentage of Group to Use BACT	Compliance Deadline
1	1988 – 2002	10	December 31, 2004
		25	December 31, 2005
		50	December 31, 2006
		100	December 31, 2007
2[a]	1960 – 1987	25	December 31, 2007
		50	December 31, 2008
		75	December 31, 2009
		100	December 31, 2010
3	2003 – 2006	50	December 31, 2009
		100	December 31, 2010

[a]Group 2: An owner of an active fleet with 15 or more solid waste collection vehicles may not use Level 1 technology as BACT.

B. Implementation Scenarios

PM emissions and exhaust temperatures dictate the type of diesel emission control strategy (DECS) that can be used on a collection vehicle (see Technical Support Document for further discussion). Based on available data on DECSs, staff created three scenarios to determine potential emission reductions and economic impacts: the first is based on use of current verified DECSs (**Table 2**), the second is based on an expansion of Level 1 verifications but no Level 2 DECS verified (potential 1) (**Table 3**), and the third is based an expansion of Level 1 verifications plus Level 2 DECS verifications (potential 2) (**Table 4**). These scenarios are slightly different from the original scenarios, reflecting less engine repowering and more use DECSs.

Table 2. Implementation Scenario (Current).

Group	Eng MY	%BACT	Implementation Date	Technology Option (By Percent Phase-In)			
				Level 1	Level 2	Level 3	Repower
1	1994-2002[a]	10%	12/31/2004	2%		8%	
		25%	12/31/2005	7%		8%	
		50%	12/31/2006	17%		8%	
		100%	12/31/2007	40%		5%	5%
1	1991-1993[b]	10%	12/31/2004	10%			
		25%	12/31/2005	15%			
		50%	12/31/2006	25%			
		100%	12/31/2007	45%			5%
1	1988-1990[c]	10%	12/31/2004				
		25%	12/31/2005				
		50%	12/31/2006				
		100%	12/31/2007				50%
		Delay	12/31/2008				50%
2	1960-1987[c]	25%	12/31/2007				22.5%
		50%	12/31/2008				22.5%
		75%	12/31/2009				22.5%
		100%	12/31/2010				22.5%
		Delay	12/31/2011				10%
3	2003-2006[d]	50%	12/31/2009	35.5%		14.5%	
		100%	12/31/2010	35.5%		14.5%	
Percent of California's Collection Vehicle Fleet Total:				53%	0%	16%	31%

Notes:
[a] Only 29% of 1994-2002 Model Year (MY) engines were considered to use passive DPFs based on verification data and the engine exhaust temperature study. The rest will apply a DOC or other Level 1 DECS, except for a small percentage (5%) that will be required to repower because of no verified technology unusual engines.
[b] All but 5% of 1991-1993 MY engines will apply Level 1 verified DECSs; the balance will repower.
[c] No verified DECSs are currently available, thus under this scenario all vehicles will have to repower.
[d] Both current Level 1 and 3 DECSs will be extended to 2003-2006 MY engines.

Table 3. Implementation Scenario (Potential 1) - no Level 2 verified.

Group	Eng MY	%BACT	Implementation Date	Technology Option (By Percent Phase-In) Level 1	Level 2	Level 3	Repower
1	1994-2002[a]	10%	12/31/2004	2%		8%	
		25%	12/31/2005	7%		8%	
		50%	12/31/2006	17%		8%	
		100%	12/31/2007	40%		5%	5%
1	1991-1993[b]	10%	12/31/2004	10%			
		25%	12/31/2005	15%			
		50%	12/31/2006	25%			
		100%	12/31/2007	45%			5%
1	1988-1990[b]	10%	12/31/2004	10%			
		25%	12/31/2005	15%			
		50%	12/31/2006	25%			
		100%	12/31/2007	45%			5%
2	1960-1987[c]	25%	12/31/2007	2.5%			22.5%
		50%	12/31/2008	2.5%			22.5%
		75%	12/31/2009	2.5%			22.5%
		100%	12/31/2010	2.5%			22.5%
3	2003-2006[d]	50%	12/31/2009	21.5%		28.5%	
		100%	12/31/2010	21.5%		28.5%	
Percent of California's Collection Vehicle Fleet Total:				66%	0%	21%	14%

Notes:
[a] Same assumptions as Current scenario.
[b] Level 1 verifications will be extended for 1988-1990 MY engines; a small percentage of engines will be unable to use Level 1 DECS and will be forced to repower.
[c] Level 1 DECS verifications will be extended for 1960-1987 MY engines and will be applied to the ten percent of vehicles that are owned by companies with less than 15 vehicles; the rest will repower.
[d] A greater percentage (compared to the Current scenario) will have Level 3 verified DECS available, and thus fewer will use Level 1 DECS.

Table 4. Implementation Scenario (Potential 2) – All Levels Verified.

Group	Eng MY	%BACT	Implementation Date	Technology Option (By Percent Phase-In)			
				Level 1	Level 2	Level 3	Repower
1	1994-2002 [a]	10%	12/31/2004		2%	8%	
		25%	12/31/2005		7%	8%	
		50%	12/31/2006		17%	8%	
		100%	12/31/2007		40%	5%	5%
1	1991-1993 [b]	10%	12/31/2004		10%		
		25%	12/31/2005		15%		
		50%	12/31/2006		25%		
		100%	12/31/2007		45%		5%
1	1988-1990 [c]	10%	12/31/2004	2%	8%		
		25%	12/31/2005	2%	13%		
		50%	12/31/2006	2%	23%		
		100%	12/31/2007	2%	43%		5%
2	1960-1987 [d]	25%	12/31/2007	2%	0.5%		22.5%
		50%	12/31/2008	2%	0.5%		22.5%
		75%	12/31/2009	2%	0.5%		22.5%
		100%	12/31/2010	2%	0.5%		22.5%
3	2003-2006 [e]	50%	12/31/2009		21.5%	28.5%	
		100%	12/31/2010		21.5%	28.5%	
Percent of California's Collection Vehicle Fleet Total:				2%	64%	21%	14%

Notes:
[a] Assumes that Level 2 DECS are used in all vehicles that cannot use Level 3, except for small percentage that repower.
[b] Assumes no Level 3, and Level 2 DECS are used in all vehicles, except for small percentage that repower.
[c] Assumes that all vehicles use Level 2 DECS, except for small percentage that either use Level 1 or repower.
[d] Assumes only two percent will use Level 2 DECS; the rest will use Level 1 or repower.
[e] Moves the group that used Level 1 DECS in the previous scenario into Level 2 DECS.

C. Cost Calculations

Two types of costs were accounted for in the cost effectiveness analysis, capital costs and operation and maintenance (O & M) costs. For each cost, ARB determined the range of costs from the published literature and from estimates supplied by experts during phone inquiries. Taking the collected data, staff calculated a low, average, and high amount for each cost. It is important to note that since most of these costs are predictive, they could vary significantly depending on the state of the economy, demand, competition, and other as yet unknown factors.

1. Capital Costs

As an example of how costs will likely decrease over time, staff compared future predicted and current capital costs for a passive diesel particulate filter (DPF). Capital costs for a passive DPF include the cost of the device, an engine backpressure monitor, and its installation. In general, the horsepower of the engine determines a passive DPF's cost. **Table 5** provides an estimate of the current cost to retrofit on-road engines and vehicles with catalyst-based DPFs. This information assumes a cost of $10 to $20 per horsepower, as reported by the Manufacturers of Emission Controls Association (MECA 2000). Based on an ARB survey, the average horsepower of a collection vehicle engine is 245, falling around the medium heavy-duty (MHD) categories' costs of $2,500 to $5,000.

Table 5. Capital Costs Associated with a Passive DPF Retrofit of On-Road Engines

Vehicle Class	LHD	MHD	HHD
Average Horsepower[1]	**190 hp**	**250 hp**	**475 hp**
Passive DPF	$1,900 - $3,800	$2,500 - $5,000	$4,750 - $9,500

In contrast to the retrofit costs presented in **Table 5**, **Table 6** presents the United States Environmental Protection Agency's (U.S. EPA) estimate of the future (2007) costs of applying passive DPFs to new on-road engines and vehicles (U. S. EPA 2000). The U.S. EPA estimates are based on higher production volumes, and they are similar to the future cost projections presented by manufacturers (MECA 2000).

Table 6. Future (2007) Catalyst-Based DPF Costs for On-Road Engines

Vehicle Class	LHD	MHD	HHD
Average Horsepower[2]	**190 hp**	**250 hp**	**475 hp**
Catalyst-Based DPF Costs[3]	$670	$890	$1,100

Based on the costs from these two tables and the average horsepower for a collection vehicle, the estimated average passive DPF capital costs could be a

[1] The average horsepower was derived from the U.S. EPA's engine certification database for LHDD, MHDD, and HHDD engines for model years 1999 and 2000.

[2] The engine horsepower ranges were derived from the U.S. EPA's engine certification database for LHDD, MHDD, and HHDD engines for model years 1999 and 2000.

[3] The U.S. EPA Catalyst Based-DPF cost estimates include both fixed costs (e.g., tooling, research and development, and certification) and variable costs (e.g., hardware, assembly and markup).

high of $5,000 currently to a low of $890 in 2007. The current cost is consistent with those City of Los Angeles recently paid for an order of passive DPF, $4,900, which included the cost of backpressure monitors (ARB 2003). A stark contrast therefore exists between the current costs associated with retrofitting existing engines and the future costs associated with applying DPFs to new engines and vehicles.

Staff expects, however, these costs will decline as production volumes and experience increase, and that, over the next five years, the current retrofit costs (**Table 5**) will approach the new engine DPF costs (**Table 6**).

The cost of installation and an engine backpressure monitor were not factored into these current and projected costs. Staff interviewed heavy-duty diesel repair shop personnel for the cost of a muffler installation to estimate the time needed for installation and the cost associated with the mechanic's time. Installation takes between two and a half to five hours of time for installation, and labor costs ranged from $160 to $480. This was also consistent with a recent fleet purchase experience. The City of Los Angeles paid $475 per unit installed (ARB 2003). Staff assumed this cost would be applicable to all hardware DECS, i.e., DPFs and diesel oxidation catalysts (DOCs). An engine backpressure monitor costs between $1000 and $1200 currently. Therefore, the current average capital cost for a passive DPF would be approximately $5400.

Also, the current costs are not representative of the higher end of the range of capital costs associated with a passive DPF. Additional sources quote costs upwards of $9000 (Cal-infopool 2002) and $8000 (Fuelstar 2000). Factoring these higher costs into the capital cost provides a high capital cost of $10,700. These high-end costs for passive DPF are reflective of the current costs associated with the capital costs associated with active DPF. No capital active DPF costs were discovered in the literature, but from meetings with manufacturers and quotes for demonstration devices, ARB staff found the range of capital costs to be from $6200 to $16,700 with an average cost of $11,800.

On the other hand, the current capital costs of DOCs are nearer the low-end of the range of costs associated with passive DPF. The costs for these devices range from $700 to $6500 with an average of $3100 (MECA 2000, Clean Air Counts 2002, Fuelstar 2000, Worldbank 2001).

2. Operation and Maintenance Costs

O & M costs considered by staff included the cost for cleaning the trap, the incremental fuel cost to convert to diesel fuel with a sulfur content of 15 parts per million by weight or less (low sulfur diesel fuel), and the incremental cost associated with transportation of this fuel. Based on conversations with the DECS manufacturers and personnel involved with demonstration programs, staff determined the number of cleanings would be on the average once a year or less, dependent on the DECS and other vehicle variables, such as oil consumption.

The incremental cost of producing low sulfur diesel fuel is expected to be somewhat higher than CARB diesel. Until low sulfur diesel fuel is used on a statewide basis for all diesel fleets, beginning with the federal diesel fuel rule in mid-2006, fuel will likely not be transported through the existing pipeline but by delivery trucks. Staff assumed an incremental fuel transportation cost for fiscal years (FY) 2004 and 2005 would vary depending on the distance from the refinery rack to the tank. In phone conversations with fuel transporters, staff calculated a range of transportation costs in dollars per gallon for transportation from zero to 50 miles, 50 to 100, 100-200, and 200-300, the assumed maximum distance needed to travel from the rack to any location requiring the low sulfur diesel fuel in California. Total O & M costs per vehicle ranged from $220 to $910 with an average cost of $510 per year before the mid-2006 low sulfur diesel fuel federal rule begins.

Those who do opt to use an ARB-verified fuel DECS in lieu of low sulfur diesel fuel may do so. The only option currently available, but not ARB verified, is Lubrizol's PuriNOx™, a fuel-water emulsion. PuriNOx™ costs are based solely on incremental O & M costs of approximately 25 cents per gallon.

After the U.S. EPA low sulfur diesel fuel rule is implemented in mid-2006, no additional fuel or fuel transportation costs would apply, since all on-road heavy-duty diesel trucks would be expected to use this fuel regardless of our regulation, and, therefore, the volume would be sufficient to transport the fuel the normal method, which is via the pipeline and then fuel tanker trucks, not just fuel tanker trucks, as discussed above. The only additional cost to owners for O & M would then be the cost of increased inspection and DECS cleanings, which ranged from zero cost to $190 per year, with an average cost of $80.

The costs for various DECS staff believes might be used as options to meet the requirements of this regulation, therefore, might vary substantially between the strategies (**Table 7**). The option that is most cost effective (i.e., the least cost option responsible for the greatest decrease in diesel PM emissions) is the passive DPF. Since this option will likely not be available to all, staff have accounted for the other technologies that might be used in the cost effectiveness of this regulation.

Table 7. Average Costs Associated with Possible DECS used for Collection Vehicles.

Cost	Passive DPF	Active DPF	PuriNOx™, a	DOC
Capital				
Hardware	$3,980	$10,500	N/A	$2,830
Installation	$290	$290	N/A	$290
Engine Backpressure Monitor	$1,100	$1,000	N/A	N/A
Total	**$5,370**	**$11,790**	**N/A**	**$3,120**
Annual O & M				
Increased Maintenance	$80	$80	N/A	$80
Incremental Fuel	$200[b]	$200	$2,750	$200
Incremental Transportation of Fuel	$230	$230	Included	$230
Total	**$510**	**$510**	**$2,750**	**$510**

[a] In order to verify PuriNOx™ as a Level 2 DECS, it will likely need to use a DOC.

[b] This is the fuel cost for 15 ppmw or less sulfur diesel fuel.

D. Repower Costs

The cost to repower an engine to meet a 0.01 g/bhp-hr PM emission standard (2007 or later model years) will vary according to the engine model year and vehicle type from which it is being converted. Replacing an electronically-controlled fuel injection engine (1994 and newer model years) with a 2007 or later model year engine is expected to cost less than replacing a mechanically-controlled fuel injection engine of earlier vintage due to the challenges associated with conversion of mechanical to electronic systems. In some instances it may not be possible to upgrade engines because of space constraints in the engine compartment of the vehicle. An owner would, therefore, need to consider using a DECS or replacing the entire vehicle. In other cases it may be more cost effective to comply by replacing a pre-1994 model year engine with a 1994 to 2006 model year engine and installing a diesel particulate filter.

1. Capital Costs

To determine the costs associated with repowering an engine to meet the 0.01 g/bhp-hr PM emission standard, ARB staff surveyed engine providers. While engine providers could not predict the cost of a 2007 engine, they could supply ARB staff with current cost of repowering an older model year engine to a newer model year engine to meet current particulate emission standards. Staff found the cost to repower to a pre-2007 model year engine ranged from $21,000 to $90,000, according to the original and the new makes and model years of the engines. Since these engines would still require additional diesel emission control to meet the best available control technology requirement for this regulation, staff included the average cost of a DPF. Based on the data, the average total cost used in this analysis is $50,000 (**Table 8**)

Table 8. Engine Repower Capital Costs.

New Engine (pre-2007) Plus Installation	Capital Cost
Average Total Cost	$45,000
Average Cost of DPF	$5,000
Total Repower Capital Costs	**$50,000**

2. Operations and Maintenance Savings

Staff quantified two benefits that offset the cost of repowering an engine, increased fuel economy and decreased maintenance costs. The fuel economy benefit appears to vary depending on the engine model year and its duty cycle. Mechanical (pre-1991) engines, in general, achieve much lower miles per gallon than electronically fuel-injected engines, two to three miles versus 3.5 to four miles per gallon. Staff used the actual fuel economy data reported to ARB during its engine survey (see Technical Support Document) for the current fuel economy. For future fuel economy, staff assumed that new 2007 engines would have similar fuel economy to a current model year engine. On average, the fuel economy saving was $xxx per year.

To determine if vehicle owners would achieve maintenance cost savings, staff surveyed owners for the costs of preventative maintenance by engine model year. Again, staff assumed that maintenance for the new, 2007 engines would be the same cost as current engines. Maintenance cost savings were therefore estimated to be $xx per year. Staff did not attempt to quantify the value of increased time on the road and fewer repairs from a new engine.

The annual operations and maintenance savings assumed for new, repowered engines, was therefore $900 per year.

E. Cost-Effectiveness Calculation

Staff determined the amount of PM, HC, and NOx reduced per year based on the implementation of this proposed regulation. Using one method, staff determined cost-effectiveness by dividing the total discounted capital costs plus annual O & M costs by the annual tons of diesel PM reduced. Using the second method, staff allocated half of the costs to PM reduced and half of the costs to HC and NOx reduced.

In order to arrive at the discounted capital costs for the regulation, staff multiplied the capital costs by the capital recovery factor[4], and assumed a lifetime of the

[4] Capital Recovery Rate Factor: 480r(1+r)^N/[(1+r)^N-1], where r = the annual interest rate, and N = lifetime of project (in years) (Linsley 1977).

DECS based on an expected minimum lifetime of ten years per technology with an annual interest rate of seven percent.[5] Certain technologies, such as a DPF, will likely last much longer than ten years in a well-maintained vehicle, as some DPFs have been operating for over 300,000 miles in the U.S. Average collection vehicle mileage is 15,635 miles per year[6]. Ten years life for DECSs was used in an effort to make a conservative estimate. The cost-effectiveness would be lower if a DECS has a longer lifetime than estimated here.

1. All Costs Allocated to PM Reduction

The average costs of implementing the program from December 31, 2004, to December 31, 2020, were used to calculate cost-effectiveness (**Tables 9, 10, & 11**). The average cost effectiveness of the program, considering the range of costs and implementation scenarios, is about $60 per pound diesel PM reduced between 2004 and 2010 and $67 per pound diesel PM reduced between 2004 and 2020.

In comparing the three implementation scenarios, the current (**Table 9**) and potential 1 (**Table 10**) implementation scenarios are the most cost-effective due to their low operation and maintenance costs. The Level 2 DECS used in the calculation for potential 2 implementation scenario is the fuel-water emulsion strategy (**Table 11**). It is also possible the flow through filter will be verified (see Technical Support Document). This would bring the costs down closer to the current (**Table 9**) or potential 1 (**Table 10**) values.

[5] USEPA uses the factor to calculate costs of environmental programs.
[6] ARB. 2001. Averages of survey of three solid waste collection vehicle companies.

Table 9. Average Cost Effectiveness Current Implementation Scenario: All Costs Allocated to PM Reduction.

Fiscal Year	Diesel PM Reduced (lb/yr)	Total Annual Cost ($/yr)	Cost per Pound PM Reduced
2004	10950	$722,664	
2005	19710	$1,605,293	
2006	35040	$1,764,773	
2007	179580	$10,180,773	
2008	278130	$15,028,439	
2009	286890	$15,590,376	
2010	276670	$16,014,070	
2011	245718	$17,180,009	
2012	214766	$16,056,084	
2013	183814	$15,005,686	
2014	152862	$13,782,624	
2015	121910	$13,327,613	
2016	107456	$11,351,988	
2017	93002	$6,272,377	
2018	78548	$3,059,150	
2019	64094	$2,073,565	
2020	49640	$1,204,046	
TOTAL	**2,398,780**	**$160,219,530**	**$67**

Table 10. Average Cost Effectiveness of Potential 1 Implementation Scenario: All Costs Allocated to PM Reduction.

Fiscal Year	Diesel PM Reduced (lb/yr)	Total Annual Cost ($/yr)	Cost per Pound PM Reduced
2004	14600	$900,415	
2005	29930	$2,014,920	
2006	54020	$2,180,173	
2007	151840	$7,253,515	
2008	178850	$8,126,175	
2009	197830	$9,091,450	
2010	203670	$9,689,158	
2011	182354	$11,264,953	
2012	161038	$10,527,994	
2013	139722	$9,839,246	
2014	118406	$8,904,459	
2015	97090	$8,865,348	
2016	87454	$6,923,466	
2017	77818	$3,818,995	
2018	68182	$2,884,311	
2019	58546	$1,934,673	
2020	48910	$1,201,912	
TOTAL	**1,870,260**	**$105,421,163**	**$56**

Table 11. Average Cost Effectiveness of Potential 2 Implementation Scenario: All Costs Allocated to PM Reduction.

Fiscal Year	Diesel PM Reduced (lb/yr)	Total Annual Cost ($/yr)	Cost per Pound PM Reduced
2004	21170	$1,625,225	
2005	44530	$4,003,373	
2006	87600	$7,462,044	
2007	213890	$17,923,695	
2008	240170	$18,108,932	
2009	259150	$19,005,914	
2010	263530	$19,499,349	
2011	237250	$18,300,305	
2012	210970	$17,103,089	
2013	184690	$15,984,195	
2014	158410	$14,754,240	
2015	132130	$13,646,558	
2016	118698	$12,566,268	
2017	105266	$6,177,841	
2018	91834	$5,083,439	
2019	78402	$3,291,169	
2020	64970	$1,467,203	
TOTAL	**2,512,660**	**$196,002,837**	**$78**

2. Costs Split Between PM and HC+NOx Reductions

Along with reducing diesel PM, each control technology also reduces HC emissions, and some, such as a new engine, also reduce NOx emissions. Staff therefore has calculated cost-effectiveness by allocating half of the costs to HC and NOx reductions and the other half to PM reductions. Using this method, the average cost-effectiveness over the implementation of this rule is $1.79/lb HC+NOx to 2020 and $1.67 to 2010, and $32/lb PM reduced to 2020 and $30/lb to 2010 (**Tables 12, 13, & 14**).

Table 12. Average Cost-Effectiveness of Current Implementation Scenario: Costs Split Between PM and HC+NOX.

Fiscal Year	Diesel PM Reduced (lb/yr)	HC+NOX Reduced (lb/yr)	Half of Annual Costs ($/yr)	Cost per Pound Reduced	
				PM	HC+NOx
2004	10,950	22	$361,332		
2005	20,440	55	$802,646		
2006	35,040	106	$882,386		
2007	197,830	2,573	$7,035,272		
2008	294,190	3,765	$9,283,197		
2009	310,980	3,900	$10,315,761		
2010	306,600	3,865	$11,172,612		
2011	274,772	3,468	$11,662,971		
2012	242,944	3,071	$10,899,973		
2013	211,116	2,674	$10,186,891		
2014	179,288	2,277	$9,399,768		
2015	147,460	1,880	$8,901,282		
2016	131,838	1,676	$7,866,977		
2017	116,216	1,472	$4,195,155		
2018	100,594	1,269	$2,544,005		
2019	84,972	1,065	$1,543,946		
2020	69,350	861	$664,294		
TOTAL	**2,734,580**	**34,000**	**$107,718,467**	**$39.39/lb**	**$1.58/lb**

Table 13. Average Cost-Effectiveness of Potential 1 Implementation Scenario: Costs Split Between PM and HC+NOX.

Fiscal Year	Diesel PM Reduced (lb/yr)	HC+NOX Reduced (lb/yr)	Half of Annual Costs ($/yr)	Cost per Pound Reduced	
				PM	HC+NOx
2004	14600	37	$449,714		
2005	29930	88	$1,006,538		
2006	54020	172	$1,088,795		
2007	183960	2,124	$6,259,221		
2008	210970	2,395	$6,530,131		
2009	233600	2,645	$7,724,256		
2010	239440	2,759	$8,629,273		
2011	215934	2,508	$8,964,407		
2012	192428	2,258	$8,377,950		
2013	168922	2,008	$7,829,860		
2014	145416	1,758	$7,172,328		
2015	121910	1,507	$6,882,130		
2016	110376	1,363	$5,838,010		
2017	98842	1,218	$2,791,492		
2018	87308	1,074	$2,262,995		
2019	75774	929	$1,290,746		
2020	64240	785	$489,358		
TOTAL	**2,247,670**	**25,628**	**$83,587,205**	**$37.19/lb**	**$1.63/lb**

Table 14. Average Cost-Effectiveness of Potential 2 Implementation Scenario: Costs Split Between PM and HC+NOX.

Fiscal Year	Diesel PM Reduced (lb/yr)	HC+NOX Reduced (lb/yr)	Half of Annual Costs ($/yr)	Cost per Pound Reduced	
				PM	HC+NOx
2004	21170	69	$812,613		
2005	45260	226	$2,001,686		
2006	87600	511	$3,731,022		
2007	236520	2,705	$10,566,236		
2008	262800	3,012	$10,558,035		
2009	283970	3,226	$11,724,838		
2010	289080	3,340	$12,588,278		
2011	261340	3,050	$11,803,053		
2012	233600	2,759	$11,030,891		
2013	205860	2,468	$10,309,244		
2014	178120	2,178	$9,542,677		
2015	150380	1,887	$8,847,164		
2016	135780	1,707	$8,174,615		
2017	121180	1,526	$4,041,071		
2018	106580	1,346	$3,429,475		
2019	91980	1,166	$2,060,105		
2020	77380	986	$733,602		
TOTAL	**2,788,600**	**32,162**	**$121,954,605**	**$43.79/lb**	**$1.90/lb**

II. OTHER FACTORS

Any calculation of the cost of a rule is based on certain assumptions and is rendered less accurate when certain variables are unable to be quantified. In this revised cost estimate, certain assumptions have changed since the June 6, 2003, Staff Report was published. In addition, staff has uncovered additional data, such as savings in operations and maintenance, that were not quantified in the first report. Finally, as this rule allows vehicle owners to choose from a menu of options for compliance, it is impossible to predict emission benefits and costs with certainty. Staff has used its best judgement, backed up by research, to develop the scenarios on which the costs and benefits are based. Other scenarios would yield different results that those presented here.

A. Changes in Assumptions from June 6, 2003 Staff Report

A number of assumptions were updated from the Staff Report published on June 6, 2003, to reflect additional data collection. The majority of these assumptions are discussed above, but are summarized again below:

- The CRF was reported to be 0.07, with r = 0.07 interest rate and n = 5 years lifetime. With these input, the CRF should have been 0.24. For this revised analysis, staff use a CRF of 0.14, with r = 0.07 interest rate and n = 10 years lifetime.

- Only one installation of the DPF, repower or DOC is assumed. While a replacement may need to occur after ten years, these costs are not factored into the calculation.
- A net savings in fuel and maintenance is assumed to be $900 for repowered engines and BACT options, versus no savings in the staff report.
- Only O & M costs for Level 2 PuriNOx are assumed, therefore, no CRF was applicable to this BACT.
- All costs are in 2002 dollars, not 2003 dollars because the year is not complete yet. For example, annual costs in 2004 are multiplied by a net present value factor (NPV) of 0.87 based on the equation where, NPV = 1/(1+r)^n = 1/(1+0.07)^2).
- Emission reductions for 2011 to 2014 are based on a fitted curve between 2010 and 2015 data points. Likewise, benefits for 2016 to 2019 are based on a fitted curve between 2015 and 2020 data points.

B. Variables Unknown or Not Quantified

A number of costs are not factored into the cost-effectiveness analysis because of lack of available information. The costs accounted for above do not include administrative costs (see form 399 attachment for these). From discussions with trap manufacturers, ARB staff assumed the DECS manufacturer would provide maintenance training at no additional charge. Finally, staff did not include the costs of purchasing a new vehicle in its calculations. Based on discussions with manufacturers, dealers, and owners, staff determined that a new engine is a valid option for compliance and thus chose this as the lowest cost option for the analysis.

C. Additional Assumptions

Staff also assumed incremental fuel transportation cost would disappear for those collection vehicles using DECS requiring the use of low sulfur diesel fuel after July 1, 2006, when, for on-road vehicles nationwide, diesel fuel will all be low sulfur. The incremental fuel transportation cost is based on the assumption that the cost to transport the low sulfur diesel fuel will be higher than after the fuel is required nationwide. With low throughput of the fuel would come a greater transmix between gasoline and diesel grade fuel, increasing the cost to the fuel providers. Staff assumes the 2006 fuel rule full conversion of the fleet would be the maximum required to return to use of the pipeline. The possibility exists that the pipeline could be used earlier, making our calculation of cost high for this item.

Staff assumed no fuel economy penalty would exist from the use of a DECS. This is based on staff experience with the verification procedure and the inability of studies to determine an impact, either positive or negative (LeTavec *et al* 2000, LeTavec *et al* 2002). A slight penalty or benefit may exist, but until more conclusive data is available staff assumed either would be negligible.

Staff also assumed the fee for disposal of ash from a DPF would be negligible. From cleaning of the DPF during the ARB demonstration and testing program, ARB staff estimated the weight of weight ash to be approximately ten to 15 grams per disposal, which is dependent upon oil consumption. The quantity of ash would be greater with more than average oil consumption. Based on conversations with the DECS manufacturers and demonstration program experience, staff determined the number of cleanings would be one to two times a year or less, dependent on the DECS and other vehicle variables, such as oil consumption.

Staff determined the quantity of ash that might be generated by a fleet of ten, 100, or 1000 collection vehicles (**Table 15**). Since the quantity was so low, the collection vehicle owner would qualify as a conditionally exempt small quantity generator. According to the Department for Toxic Substances Control, no permit is required for less than 55 gallons of hazardous waste accumulation (DTSC 2001). Typically, a hazardous waste may be stored on-site for 180 days or less, after the site has accumulated 100 kilograms of waste. In order to accumulate 100 kg of ash for this scenario, it would take between three and ten years. Due to the length of time to accumulate ash and to the variability in ash quantity, staff did not include this cost in the cost effectiveness analysis. The cost to dispose of a 55-gallon drum of ash would cost about $200 (Girstenson 2001).

Table 15. Ash Disposal Analysis

Number of Trucks	Ash Accumulation (in grams per year)			Years to Accumulate 100 kg of Ash
	Low	Average	High	
10	100	200	300	10
100	1000	2000	3000	5
1000	10,000	20,000	30,000	3

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