CALIFORNIA ENVIRONMENTAL PROTECTION AGENCY

AIR RESOURCES BOARD

STAFF REPORT: INITIAL STATEMENT OF REASONS

SUPPLEMENTAL REPORT

PROPOSED DIESEL PARTICULATE MATTER CONTROL MEASURE FOR ON-ROAD HEAVY-DUTY RESIDENTIAL AND COMMERCIAL SOLID WASTE COLLECTION VEHICLES

Date of Release: August 8, 2003
Scheduled for Consideration: September 25-26, 2003

State of California
California Environmental Protection Agency
AIR RESOURCES BOARD

PROPOSED DIESEL PARTICULATE MATTER CONTROL MEASURE FOR ON-ROAD HEAVY-DUTY RESIDENTIAL AND COMMERCIAL SOLID WASTE COLLECTION VEHICLES

Supplemental Staff Report

Prepared by Staff of the
Mobile Source Control Division, Heavy-Duty Diesel In-Use Strategies Branch

With Assistance from Staff in the Following Branches:

Planning & Technical Support Division, Mobile Source Analysis Branch
Research Division, Health & Exposure Assessment Branch
Research Division, Research & Economic Studies Branch
Stationary Source Division, Emissions Assessment Branch

August 8, 2003

TABLE OF CONTENTS

TABLE OF TABLES

APPENDICES

APPENDIX E: REVISED SOLID WASTE COLLECTION VEHICLE EMISSIONS INVENTORY

APPENDIX F: REVISED COST-EFFECTIVENESS METHODOLOGY

EXECUTIVE SUMMARY

The Air Resources Board (ARB or "the Board") issued the Staff Report: Initial Statement of Reasons for the Proposed Diesel Particulate Matter Control Measure for On-Road Heavy-Duty Residential and Commercial Solid Waste Collection Vehicles on June 6, 2003. Subsequent to the publication of that report, the ARB determined errors existed in the calculations underlying the determination of cost-effectiveness. Staff decided the best interests of the public would be served through reissuing the economic impacts and benefits and restating the cost-effectiveness of the rule. In addition, Appendix E, the solid waste collection vehicle emissions inventory, and F, the cost-effectiveness methodology, are also reissued. In this document, tables are assigned the same numbers as in the Staff Report issued on June 6, 2003.

In the Staff Report, we estimated that cancer risk from diesel particulate matter (PM) would be reduced by a factor of ten in the highest exposure areas as a result of this rule. For this supplemental staff report, staff has analyzed the effect of diesel PM emissions reductions on premature deaths. ARB estimates that eighty premature deaths will be reduced by year 2020. Prior to 2020, cumulatively, it is estimated that three deaths would be avoided by 2006, thirty-six deaths avoided by 2010, and sixty-six by 2015.

The estimated present value of cost of control per premature death prevented, or life saved, is $900,000 based on attributing half of the cost of controls to reduce diesel PM. Compared to the present value of $4.2 million to $5.9 million using U.S. EPA's value of avoiding one death, this rule is a very cost-effective mechanism of preventing premature deaths caused by diesel PM.

The Staff Report calculated costs over a seven year period, from 2004 through 2010. For that timeframe, the revised costs associated with carrying out this proposed control measure will be about $63 million in 2002 dollars. For the supplemental staff report, staff carried out costs (and benefits) through 2020. The estimated cost for that time period is $154 million in 2002 dollars.

With the corrected estimate of emission reductions, this measure will reduce diesel particulate matter emissions by 0.28 to 0.38 tons per day (tpd) of particulate matter (PM) in 2010. This translates to as much as 84 percent reduction from the 2000 PM inventory baseline expected by 2010 and 92 percent reduction from the 2000 PM inventory baseline by 2020 of diesel PM from the solid waste collection vehicle fleet. The best available control technologies (BACT) associated with the proposed regulation are expected to reduce other pollutant emissions, including ozone precursors, as well. Between 1.30 and 1.45 tpd of hydrocarbons (HC), 3.33 and 4.29 tpd of carbon monoxide (CO) and 3.1 and 6.5 tpd of oxides of nitrogen (NOx) will be reduced as a result of this regulation in 2010. From 2004 through 2020, staff estimates that approximately

2,260,000 lbs of diesel PM will be removed from California's air as a result of this proposed rule.

Using the corrected estimates of cost and emissions reduced, therefore, the approximate cost effectiveness is now estimated to be $67 per pound ($/lb) of particulate matter reduced for the 17 year period, if all of the costs of compliance are allocated to diesel PM reduction. Since this rule will also result in significant reductions in hydrocarbons and oxides of nitrogen emissions, staff allocated half of the costs of compliance against these benefits, resulting in cost-effectiveness values of $32/lb diesel PM and $1.79/lb of HC plus NOx reduced, again for the 17 year period.

Staff expects the costs of compliance will be passed on to the solid waste collection customers. The cost per household, using the new values, is estimated to be about $5 per household over seven years, or $12 per household over 17 years. This translates into an additional cost per household for solid waste collection of less than $1.00 per year over the 17-year implementation period of this proposed rule.

Note that in the following text, only the revised sections and tables of the Staff Report are included. Original section numbers are used. For Appendices E and F, however, the entire text has been revised and reissued.

III. Need for Reduction of Diesel Particulate Matter Emissions

E. Health Effects of Diesel Emissions and Benefits of Diesel Emissions Reductions

The following is a revision of section III.E., Health Effects of Diesel Particulate Matter, in the Staff Report issued June 6, 2003, and should be substituted for that section. This new section broadens the discussion beyond health effects of diesel PM to the health effects of the pollutants emitted by diesel engines and the health benefits of the emissions reductions that would result from the promulgation of the proposed diesel PM control measure for on-road heavy-duty solid waste collection vehicles. Health benefits would occur from diesel exhaust particulate matter reductions as well as reductions of emissions of ozone precursors, NOx and HC (or volatile organic compounds, VOC), and toxic air contaminants in diesel exhaust.

1. Diesel Exhaust

Diesel exhaust is a complex mixture of inorganic and organic compounds in both the vapor and particle phase. The composition of this mixture varies depending on engine type, operating conditions, fuel, lubricating oil, and whether or not an emission control system is present. A major component of diesel exhaust is particulate matter, which typically consists of a carbon core with a coating of organic carbon compounds, or as sulfuric acid and ash, sulfuric acid aerosols, or sulfate particles associated with organic carbon (Kittelson *et al.* 1999). Almost all of the diesel particle mass is in the range of 10 microns or less in diameter (PM_{10}). Indeed, approximately 94 percent of the mass of these particles are less than 2.5 microns in diameter. Because of their small size, the particles are readily respirable and can effectively reach the lowest airways of the lung along with the adsorbed compounds, many of which are known or suspected mutagens and carcinogens (SRP 1998).

2. Health Impacts of Exposure to Diesel PM

The U.S. Environmental Protection Agency (U.S. EPA) discussed the epidemiological and toxicological evidence of the health effects of ambient PM and diesel PM in the regulatory impact analyses for on-road and nonroad diesel engine emission standards (U.S. EPA 2000b, U.S. EPA 2003). The key health effects categories associated with ambient particulate matter include premature mortality, aggravation of respiratory and cardiovascular disease (as indicated by increased hospital admissions and emergency room visits, school absences, work loss days, and restricted activity days), aggravated asthma, acute respiratory symptoms, including aggravated coughing and difficult or painful breathing, chronic bronchitis, and decreased lung function that can be experienced as shortness of breath.

Health impacts from exposure to the fine particulate matter ($PM_{2.5}$) component of diesel exhaust have been calculated for California, using concentration-response equations from several epidemiologic studies (Lloyd & Cackette 2001). Both mortality and morbidity effects could be associated with exposure to either direct diesel $PM_{2.5}$ or indirect diesel $PM_{2.5}$, the latter of which arises from the conversion of diesel NOx emissions to $PM_{2.5}$ nitrates. In California, the average population weighted exposure to directly emitted diesel $PM_{2.5}$ is 1.8 $\mu g/m^3$. Long-term exposure to ambient concentrations of diesel $PM_{2.5}$ at this level is estimated to have led to a range of about 2,000 to 2,500 premature deaths, statewide, for the year 2000. Indirectly formed diesel $PM_{2.5}$ from NOx emissions (at 0.81 $\mu g/m^3$ concentration level) is also estimated to contribute to an additional 900 premature deaths. The mortality estimates may include some premature deaths due to cancer, because the epidemiologic studies did not identify the cause of death. Exposure to fine particulate matter, including diesel $PM_{2.5}$ can also be linked to a number of heart and lung diseases. For example, it was estimated that statewide on average, 2500 hospital admissions for chronic obstructive pulmonary disease, pneumonia, cardiovascular disease and asthma were associated with exposure to direct diesel $PM_{2.5}$. An additional 1,100 admissions were linked to exposure to indirect diesel $PM_{2.5}$.

3. Health Impacts of Exposure to Diesel Exhaust

In addition to its contribution to ambient PM levels and associated health impacts, diesel exhaust is of specific concern because it poses a lung cancer hazard for humans, as well as a hazard from noncancer respiratory effects such as pulmonary inflammation (U.S. EPA 2003). More than 30 human epidemiological studies have investigated the potential carcinogenicity of diesel exhaust. On average, these studies found that long-term occupational exposures to diesel exhaust were associated with a 40 percent increase in the relative risk of lung cancer (Cal EPA 1998). There is limited specific information, however, that addresses differing susceptibilities to the carcinogenicity of diesel exhaust within the general human population and vulnerable subgroups, such as infants, children, and people with preexisting health conditions. The carcinogenic potential of diesel exhaust was also demonstrated in numerous genotoxic and mutagenic studies on some of the organic compounds typically detected in diesel exhaust (Cal EPA 1998).

Diesel PM was listed as a toxic air contaminant (TAC) in 1998 by the Board after an extensive public review and evaluation of the scientific literature by the Office of Environmental Health Hazard Assessment (OEHHA) (CARB 1998). Using the cancer unit risk factor developed by OEHHA for the TAC program, ARB estimated that for the year 2000, exposure to 1.8 $\mu g/m^3$ of diesel exhaust could be associated with a health risk of 540 excess cancer cases per million people exposed over a 70-year lifetime. This estimated risk is currently equivalent to about 270 excess cases of cancer per year for the entire State, which is several times higher than the risk from all other identified TACs combined.

Another highly significant health effect of diesel exhaust exposure is its apparent ability to act as an adjuvant in allergic responses and possibly asthma (Diaz-Sanchez *et al.* 1996, Takano *et al.* 1998, Diaz-Sanchez *et al.* 1999). However, additional research is needed at diesel exhaust concentrations that more closely approximate current ambient levels before the role of diesel exhaust exposure in the increasing allergy and asthma rates is established.

4. Health Impacts of Exposure to Ozone

Ozone is formed by the reaction of VOCs and NOx in the atmosphere in the presence of heat and sunlight. The highest levels of ozone are produced when both VOC and NOx emissions are present in significant quantities on clear summer days. Ozone is a powerful oxidant that can damage the respiratory tract, causing inflammation and irritation, which can result in breathing difficulties.

Studies have shown qualitatively that there are impacts on public health and welfare from ozone at moderate levels that do not exceed the California 1-hour ozone standard. Short-term exposures to high ambient ozone concentrations have been linked to increased hospital admissions and emergency visits for respiratory problems (U.S. EPA 2000). Repeated exposure to ozone can make people more susceptible to respiratory infection and lung inflammation and can aggravate preexisting respiratory diseases, such as asthma. Prolonged (6 to 8 hours), repeated exposure to ozone can cause inflammation of the lung, impairment of lung defense mechanisms, and possibly irreversible changes in lung structure, which over time could lead to premature aging of the lungs and/or chronic respiratory illnesses such as emphysema and chronic bronchitis.

The subgroups most susceptible to ozone health effects include individuals exercising outdoors, children and people with preexisting lung disease such as asthma, and chronic pulmonary lung disease. Children are more at risk from ozone exposure because they typically are active outdoors, during the summer when ozone levels are highest. Also, children are more at risk than adults from ozone exposure because their respiratory systems are still developing. Adults who are outdoors and moderately active during the summer months, such as construction workers and other outdoor workers, also are among those most at risk. These individuals, as well as people with respiratory illnesses such as asthma, especially asthmatic children, can experience reduced lung function and increased respiratory symptoms, such as chest pain and cough, when exposed to relatively low ozone levels during prolonged periods of moderate exertion.

5. Health Benefits of Reductions of Diesel PM Emissions

This section examines the health benefits of reducing diesel PM emissions differently than section III. F. Risk Assessment. The following analysis estimates premature deaths prevented from reducing diesel PM and also the costs, or savings, to society for each prevented premature death. In addition, a brief discussion of the health benefits of reducing ozone precursors is included.

a. Reduced Ambient PM Levels

The emission reductions obtained from this regulation will result in lower ambient PM levels and significant reductions of exposure to primary and secondary diesel PM. Lower ambient PM levels and reduced exposure, in turn, mean reduction of the prevalence of the diseases attributed to diesel PM, reduced incidences of hospitalizations and prevention of premature deaths.

Primary Diesel PM**.** Lloyd and Cackette (2001) estimated that, based on the Krewski *et al.* (2000) study[1], diesel $PM_{2.5}$ exposures at level of 1.8 $\mu g/m^3$ resulted

[1] Although there are two mortality estimates in the report by Lloyd and Cackette (2001) – one based on work by Pope *et al.* (1995) and the other based on Krewski *et al.* (2000), we selected the estimate based on the Krewski's work. For Krewski *et al.,* an independent team of scientific experts commissioned by the Health Effects Institute conducted an extensive reexamination and reanalysis of the health effect data and studies, including Pope *et al*. The reanalysis resulted in the relative risk being based on changes in mean levels of $PM_{2.5}$, as opposed to the median levels from the original Pope *et al.* study. The Krewski *et al*. reanalysis includes broader geographic areas than the original study (63 cities vs. 50 cities). Further, the U.S. EPA has been using Krewski's study for its regulatory impact analyses since 2000.

in a mean estimate of 1,985 cases of premature deaths per year in California. The diesel PM emissions corresponding to the direct diesel ambient population-weighted PM concentration of 1.8 $\mu g/m^3$ is 28,000 tons per year (CARB 2000). Based on this information, we estimate that reducing 14.11 tons of diesel PM emissions would result in one fewer premature death (28,000 tons/1,985 deaths). Comparing the $PM_{2.5}$ emission before and after this regulation, the proposed regulation is expected to reduce emissions by 2,260,000 lbs (or 1,130 tons) at the end of year 2020, and therefore prevent an estimated eighty premature deaths by year 2020. Prior to 2020, cumulatively, it is estimated that three deaths would be avoided by 2006, thirty-six deaths avoided by 2010, and sixty-six by 2015.

If we multiply 14.11 tons of diesel PM emissions by the average present value of cost-effectiveness of $32 per pound (or $64,000 per ton), the estimated cost of control per premature death prevented is about $900,000 in 2002 dollars. The U. S. EPA has established $6.3 million (in year 2000 dollars) for a 1990 income level as the mean value of avoiding one death (U.S. EPA 2003). As real income increases, the value of a life may rise. U.S. EPA further adjusted the $6.3 million value to $8 million (in 2000 dollars) for a 2020 income level. Assuming that real income grew at a constant rate from 1990 and will continue at the same rate to 2020, we adjusted the value of avoiding one death for the income growth. Since the control cost is expressed in 2002 discounted value, accordingly, we discounted values of avoiding a death in the future back to the year 2002. In U.S. EPA's guidance of social discounting, it recommends using both three and seven percent discount rates (U.S. EPA, 2000a). Using these rates, and using the annual avoided deaths as weights, the weighted value of reducing a premature future death discounted back to year 2002 is $4.2 million at seven percent discount rate, and $5.9 million at three percent. The cost per death avoided because of this proposed regulation is 4.7 to 6.6 times lower than the U.S. EPA's benchmark for value of avoided death. This rule is, therefore, a cost-effective mechanism to reduce premature deaths that would otherwise be caused by diesel PM emissions without this regulation.

The benefits of reducing diesel emission based on a statewide average diesel emission value, such as Lloyd and Cackette (2001), contain off-road emissions from a number of categories that occur well away from population centers. Waste collection trucks, and their diesel emissions, are more concentrated in urban areas, thus a greater reduction of the emissions as a result of the regulation are expected to occur in urban areas, as compared to rural areas. Emission reductions are therefore likely to have greater benefits than those estimated by Lloyd and Cackette (2001). Thus the proposed rule is likely more cost-effective than the above estimate would suggest.

<u>Secondary Diesel PM</u>. Lloyd and Cackette (2001) also estimated that indirect diesel $PM_{2.5}$ exposures at level of 0.81 $\mu g/m^3$ resulted in a mean estimate of 895 additional premature deaths per year in California, above those caused by

directly formed diesel PM. The NOx emissions level corresponding to the indirect diesel ambient PM concentration of 0.81 $\mu g/m^3$ is 1,641 tpd (598,965 tpy). Following the same approach as above, we estimate that reducing 669 tons of NOx emissions would result in one fewer premature death (598,965 tons/895 deaths).

If we multiply 669 tons of NOx emissions by the average present value of cost-effectiveness of $1.29/lb ($2,580 per ton) (see Section IX), the estimated cost of control per premature death prevented is about $1.7 million. This value is again lower than the U.S. EPA's present value of a life by 2.5 to 3.5 times.

b. Reduced Ambient Ozone Levels

Emissions of NOx and VOC are precursors to the formation of ozone in the lower atmosphere. Exhaust from heavy-duty vehicles contributes a substantial fraction of ozone precursors in any metropolitan area. Therefore, reduction of heavy-duty diesel vehicle emissions of NOx and VOCs would make a considerable contribution to reducing exposures to ambient ozone. Controlling emissions of ozone precursors would reduce the prevalence of the types of respiratory problems associated with ozone exposure and would reduce hospital admissions and emergency visits for respiratory problems.

VIII. Revised Economic Impact

After publishing the staff report on June 6, 2003, staff determined a formula error existed in calculating the capital recovery factor (CRF) for best available control technologies. In order to present a more accurate estimate of cost-effectiveness, at the same time that staff revised the CRF, we also revised additional assumptions associated with the costs of the proposed regulation. The changes made are summarized below:

- The CRF was reported to be 0.07, with an interest rate of 0.07 and a five-year lifetime for each control technology. The CRF should have been 0.24. For the revised analysis, staff used a CRF of 0.14, corresponding to an interest rate of 0.07 and a ten-year lifetime.
- In this analysis, because the lifetime for each control technology is ten years, only one installation of a diesel particulate filter (DPF), diesel oxidation catalyst (DOC) or engine repower is assumed.
- Net annual savings in fuel ($700) and maintenance ($200) costs of $900 for a repowered engine is assumed in the revised analysis. Most of these savings result from repowering from an old engine to a 1994 model year or newer engine. The original analysis assumed no fuel and maintenance cost savings.

- For Level 2 BACT, staff used the cost associated with PuriNOx™. As staff assumed there are no capital costs for this technology, no CRF was applicable to this cost.
- All costs are now figured in 2002 dollars, not 2003 dollars, as per standard economics analysis, because the year is not yet complete.
- Staff reduced the number of expected engine repowers to include only those expected to be forced by the rule; the original scenarios included the costs of a certain amount of "voluntary" repowers, or those performed by owners who preferred to repower rather than installing a lower-cost diesel emission control strategy (DECS).

C. Revised Estimated Costs to Collection Vehicle Owners

1. Implementation Scenarios

The scenarios used to calculate costs and benefits for this analysis are slightly different from the original scenarios in that they assume a lower use of engine repowering and higher use of DECSs (**Tables 14 – 16**), as discussed above. Both scenario sets are valid. The set of scenarios presented here is based solely of the impact of the regulation to force use of a certain technology. The scenarios used on the original staff report placed more emphasis on "voluntary" engine repowers, based on assumptions about owner behaviors.

Table 14 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 15 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 16 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.

2. Revised Implementation Costs

Capital costs per vehicle and technology for various DECS options are listed in **Table 17**. The total costs for passive and active diesel particulate filters have increased slightly because of a slightly higher assumed cost of the engine backpressure monitor.

Table 17 Average Capital Costs for Diesel Emission Control Strategies.

	Average Cost ($)		
Cost Description	**Passive Diesel Particulate Filter** [a, b]	**Active Diesel Particulate Filter** [e,f]	**Diesel Oxidation Catalyst** [g,h,I,j]
Device	$3,980	$10,500	$2,830
Installation [c, d]	$290	$290	$290
Engine Backpressure Monitor [k]	$1,100	$1,100	$0
Total Cost:	$5,360	$11,890	$3,120

Note: Costs and how they are derived are described in detail in Appendix F.
[a]MECA, November 2000, Study of DECS costs. 100-500 hp for varying production costs.
[b] U.S. EPA, May 2000, Draft RIA. Cost in 2007, pg. V-9.
[c]U.S. EPA, May 2000, Draft RIA. Includes trap cost, labor, warranty and muffler removal savings.
[d]ARB, June 2001. Installation cost for a muffler through phone conversations with Cummins, Golden State Ford Truck Sales, Caterpillar, and Performance Truck and Diesel.
[e]ARB, 2002. Cost to ARB demonstration program (device plus regeneration unit)
[f] ARB, October 2001. Cost quoted to ARB at Oct. 2001 meeting with active diesel particulate filters providers from Europe
[g]MECA, March 2000. Emission Control Retrofit of Diesel-Fueled Vehicles.
[h]Clean Air Counts, 2002.
[i]Fuelstar, 2000.
[j]Parsons, February 2001.
[k]Cost given at September 4-5, 2001 workshop by MECA members.

The estimated cost to repower an engine to meet a 0.01 g/bhp-hr PM emission standard (2007 or later MY) has not changed from the Staff Report. Staff did, however, quantify two benefits that offset the initial cost of repowering an engine, increased fuel economy and decreased maintenance costs. The staff analysis determined than an average annual savings of $900 was representative of the benefit of repowering to a new engine.

D. Revised Potential Impact on Small Businesses

Using the revised values discussed above, staff recalculated the average cost for a small fleet of ten vehicles, which is a typical size fleet of collection vehicles in California. Staff assumed 80 percent of the vehicles would fall under Group 1 (MY 1988 – 2002), and 20 percent of the vehicles would fall under Group 2 (MY 1960 – 1987) implementation phase-in. For comparison, staff also calculated the average cost for a large fleet of 100 collection vehicles. For the large company staff assumed 80 percent of the vehicles would fall under Group 1, and 20 percent under Group 3 (MY 2003 – 2006) implementation phase-in, because larger companies are assumed to only keep vehicles for five to ten years. As described in the cost effectiveness methodology (Appendix F), in order to translate the capital costs into annualized capital costs, staff used the cost recovery factor of 0.14.[2] Including both annualized capital, such as the DECS, and Operations and Maintenance (O & M) costs and savings, the average total estimated costs for a large and small private company to implement this regulation between fiscal years 2004 and 2020[3] are $761,000 and $178,000, respectively (**Table 20**). The cost analysis accounts for variability found in implementing a full range of BACT as discussed and is based on an average of the current, potential 1, and potential 2 implementation scenarios (**Tables 14 – 16**). Note that much of the increased costs to implement, relative to the original Staff Report, are to be found in the additional years, 2011 through 2020, included in this revised analysis.

---

[2] Capital recovery factor is r(1+r)^N/[(1+r)^N-1] (Linsley, 1977), where r = 0.07 discount rate, and N = 10 years.

[3] Assumes costs paid for during the year leading up to December 31st implementation.

Table 20 Estimated Average Cost to a Small or Large Collection Vehicle Owner Based on the Average of Three Implementation Scenarios.

Fleet Type	Number of Vehicles Retrofit	Calendar Year	Discounted Annual Capital Costs [a]	Average Annual O&M Costs [b]	Total Average Annual Cost
Small					
	Varies	2004	$0	$1,601	$1,601
	Varies	2005	$362	$3,405	$3,767
	Varies	2006	$677	$4,312	$4,988
	Varies	2007	$9,596	$4,367	$13,963
	Varies	2008	$12,134	$3,682	$15,816
	Varies	2009	$15,779	$2,880	$18,659
	Varies	2010	$17,512	$2,343	$19,855
	-	2011	$16,366	$2,189	$18,556
	-	2012	$15,296	$2,046	$17,342
	-	2013	$14,295	$1,912	$16,207
	-	2014	$13,360	$973	$14,333
	-	2015	$12,302	$117	$12,419
	-	2016	$11,325	-$631	$10,694
	-	2017	$6,027	-$761	$5,266
	-	2018	$4,024	-$508	$3,516
	-	2019	$1,504	-$190	$1,314
	-	2020	$0	$0	$0
	10	**Total:**	**$150,559**	**$27,737**	**$178,296**
Large					
	Varies	2004	$4,676	$5,809	$10,485
	Varies	2005	$9,705	$14,949	$24,654
	Varies	2006	$15,861	$19,710	$35,571
	Varies	2007	$44,077	$38,758	$82,834
	Varies	2008	$41,193	$36,222	$77,415
	Varies	2009	$41,818	$37,358	$79,176
	Varies	2010	$42,184	$38,190	$80,374
	-	2011	$39,424	$35,692	$75,116
	-	2012	$36,845	$33,357	$70,202
	-	2013	$34,435	$31,175	$65,609
	-	2014	$29,805	$27,602	$57,407
	-	2015	$25,143	$22,757	$47,900
	-	2016	$20,046	$15,428	$35,474
	-	2017	$3,864	$4,081	$7,944
	-	2018	$3,611	$3,814	$7,424
	-	2019	$1,687	$1,782	$3,469
	-	2020	$0	$0	$0
	100	**Total**	**$394,374**	**$366,682**	**$761,056**

[a] Derived from capital costs using A = (Net Present Value)*(Capital Recovery Factor of 0.07).
[b] Discounted average annual O&M costs for fiscal years 2004 and 2005, include incremental fuel and fuel transportation costs for those vehicle using DECS requiring low sulfur diesel fuel.

I. Revised Potential Costs to Local and State Agencies

As with the above analysis, staff recalculated the costs to public agencies statewide that contract with or own solid waste collection fleets. The total estimated statewide cost for local government agencies with solid waste collection fleets would be an average total cost of about $9,300,000 (**Table 21**) from 2004 to 2020 for the three implementation scenarios based on current, potential 1, and potential 2 verification scenarios (**Tables 14 – 16**).

Table 21 Total Estimated Statewide Cost for Local Government Agencies Based on the Average of Three Implementation Scenarios.

Calendar Year	Discounted Annual Capital Costs [a]	Average Annual O&M Costs [b]	Total Average Annual Cost
2004	$56,951	$70,752	$127,703
2005	$118,210	$182,081	$300,291
2006	$193,192	$240,065	$433,258
2007	$536,857	$472,067	$1,008,924
2008	$501,736	$441,184	$942,919
2009	$509,340	$455,019	$964,359
2010	$513,801	$465,156	$978,958
2011	$480,188	$434,726	$914,914
2012	$448,774	$406,286	$855,060
2013	$419,415	$379,706	$799,121
2014	$363,026	$336,188	$699,214
2015	$306,241	$277,186	$583,427
2016	$244,158	$187,916	$432,075
2017	$47,059	$49,701	$96,760
2018	$43,980	$46,450	$90,430
2019	$20,551	$21,706	$42,257
2020	$0	$0	$0
TOTAL	**$4,803,479**	**$4,466,189**	**$9,269,668**

J. Revised Cost to the Average Household Receiving Waste Collection Service

Municipalities, or collection vehicle owners directly, are expected to pass through the cost to implement the proposed regulation to ratepayers. Staff derived the annual expected increased cost of solid waste collection services per household by dividing the total statewide dollar costs that businesses and individuals may incur from this proposed regulation over its lifetime, about $154 million, by the number of estimated households in California, or 12,335,400 households as of 2005 (Center for Continuing Study of the California Economy 2001). The total revised cost per household in California, over the implementation period of fiscal years 2004 to 2020, would therefore be approximately $12, or $0.70 annually. This estimated cost per household includes residential and commercial solid waste and recycling services.

IX. Revised Environmental Impacts and Cost-Effectiveness

The proposed regulation would provide significant cost-effective diesel PM emission reductions throughout California, especially at the neighborhood level. The air quality benefits statewide would be not only from reduction of diesel PM emissions, but also from reduction of NO_x, HC, and CO emissions as well. Following the publication of the Staff Report on June 6, 2003, staff determined that there was an error in the method used to calculate the survival rate, or turnover, of solid waste collection vehicles. Vehicles were previously assumed to last longer in the population than staff now believes is realistic. The increased turnover rate used in recalculating emission benefits results in lower emission benefits than previously assumed.

A. Revised Benefits

1. Revised Statewide Benefits

Using the revised vehicle turnover rate, ARB staff now estimates that the proposed diesel PM control measure would result in the reduction of between 0.28 and 0.38 tpd of diesel PM emissions in 2010 and between 0.07 and 0.09 tpd diesel PM reduced in 2020 (**Table 22**). The reduction of diesel PM emissions attributed to this regulation peaks around 2010 because all collection vehicles are expected to meet the diesel PM control measure by 2010. After 2010 the benefits attributed to this regulation decline to between 0.07 and 0.09 tpd in 2020 as vehicles are retired and replaced with new engines that meet the federal 2007 0.01 g/bhp-hr PM standard. From 2004 through 2020, staff estimates that approximately 2,260,000 lbs., or 1,130 tons, of diesel PM will be removed from California's air as a result of this proposed rule.

Table 22 Statewide Diesel PM Emission Reduction Benefits.

Calendar Year	Baseline Inventory (tpd)	Diesel PM Reduction (tpd)		
		Current	Potential 1	Potential 2
2005	0.94	0.03	0.04	0.06
2010	0.56	0.38	0.28	0.36
2015	0.31	0.17	0.13	0.18
2020	0.17	0.07	0.07	0.09

Other air quality benefits also exist as a result of the use of the various BACT, including reduced emissions of CO, HC, and NO_x. The reductions in HC are also accounted for in the State Implementation Plan. Based on expected reduction capabilities from the various DECS that might be used (**Table 23**), reductions of up to 4.29 tons of CO per day (**Table 24**), up to 1.45 tons of HC per day (**Table 25**), and 6.5 tons of NO_x per day (**Table 26**) are predicted.

Table 23 Other Pollutant Potential Reductions from Diesel Emission Control Strategies.

Diesel Emission Control Strategy	Emission Reduction (Percent)			
	PM	**CO**	**HC**	**NO_x**
Passive Diesel Particulate Filter	85[a]	90[b]	95[b]	0[c]
Fuel-Water Emulsion[h]	50[a]	35[d]	60[d]	15
Average Diesel Oxidation Catalyst	25[a]	47[e, f]	76[e, f]	0[c]

[a]Verified Level Reduction Goals for ARB. Strategies will not be verified without meeting this standard at a minimum.
[b]Allansson, R, et al. 2001, European Experience of High Mileage Durability of Continuously Regenerating Diesel Particulate Filter Technology. SAE. 2001-01-0480.
[c]Majewski, W. Addy, 2001, Diesel Net Technology Guide: Diesel Particulate Traps. www.dieselnet.com.
[d]Diesel Net Technology Guide: Emission Control Technologies, 1998. www.dieselnet.com.
[e]Diesel Net Technology Guide: Diesel Oxidation Catalyst, 1999. www.dieselnet.com.
[f]Khair, Magdi; McKinnon, Dale L. Performance Evaluation of Advanced Emission Control Technologies for Diesel Heavy-Duty Engines. SAE. 1999-01-3564.
[h]Fuel-water emulsion increases CO and HC emissions. Although can be verified alone for the purposes of simplifying calculations, assumed it would be used in conjunction with a diesel oxidation catalyst to decrease impact of increase. Choose least decrease to account for offset of increase from fuel-water emulsion.

Table 24 Statewide Diesel Carbon Monoxide Emission Reduction Benefits.

Calendar Year	Baseline Inventory (tpd)	Diesel CO Reduction (tpd)		
		Current	**Potential 1**	**Potential 2**
2005	8.95	0.41	0.64	0.51
2010	6.02	4.29	4.07	3.33
2015	3.79	2.31	2.24	1.78
2020	2.57	1.20	1.24	1.01

Table 25 Statewide Diesel Hydrocarbon Emission Reduction Benefits.

Calendar Year	Baseline Inventory (tpd)	Diesel HC Reduction (tpd)		
		Current	Potential 1	Potential 2
2005	2.93	0.15	0.24	0.22
2010	1.76	1.45	1.42	1.30
2015	0.95	0.72	0.70	0.62
2020	0.54	0.34	0.34	0.30

Table 26 Statewide Diesel Oxides of Nitrogen Emission Reduction Benefits.

Calendar Year	Baseline Inventory (tpd)	Diesel NOx Reduction (tpd)		
		Current	Potential 1	Potential 2
2005	27.0	0	0	0.4
2010	20.9	6.5	3.1	5.1
2015	14.1	2.3	1.1	2.5
2020	7.99	0.6	0.3	1.0

2. Impacts on the State Implementation Plan for PM_{10}

The anticipated benefits of this proposed rule are included in the draft State Implementation Plan (SIP) for PM_{10} in the San Joaquin Valley. That plan was adopted in June 2003, with attainment of the federal PM_{10} standard projected by 2010. As a “serious” nonattainment area, the San Joaquin Valley must use best available control measures for all sources of PM_{10} in its district and must also achieve five percent annual emission reductions in PM_{10} and its precursors. The San Joaquin Valley has seven percent of the statewide solid waste collection vehicles and will see a benefit of up to 0.03 tpd of PM reduced by 2010. In addition, the NOx and volatile organic carbon (VOC) benefits of the proposed rule are contained in the plan, as they are precursors to secondary PM formation.

The South Coast air basin is also classified as a “serious” nonattainment area for PM_{10} but its attainment deadline is 2006, before most of the benefits of the proposed rule will be achieved. Nonetheless, the proposed rule will help that District maintain compliance with the federal PM_{10} standard. The rule also serves as a down payment on future plans to achieve the federal $PM_{2.5}$ standards and California’s own, more stringent standards. Thirty-five percent of California’s solid waste collection vehicles are in the South Coast region. By

2010, the proposed rule will reduce emissions from those vehicles by up to 0.13 tpd.

All other PM_{10} nonattainment areas in California will benefit from the proposed rule in a general way. Every district, except Lake County, is nonattainment for the California PM_{10} standard. In addition, four other areas in California are nonattainment for the federal PM_{10} standards: Owens Valley, Searles Valley, Coachella Valley, and Imperial Valley.

For ozone SIPs there is a similar situation. The South Coast and San Joaquin Valley have new federal ozone plans under development, with adoption tentatively scheduled for September 2003 and December 2003, respectively. Both districts have an attainment deadline of 2010 for the federal one-hour ozone standard. The overall NOx and VOC benefits of ARB's planned diesel in-use PM reduction rules are contained in the draft South Coast ozone plan and will be included in the San Joaquin Valley ozone plan once it is released for public review. The Sacramento Metropolitan region is considering an ozone plan update and would include ARB's diesel in-use PM reduction control measures if its attainment deadline ultimately shifts from 2005 to 2010.

As with PM_{10}, all other ozone nonattainment areas in California will benefit from the proposed rule in a general way as it reduces the precursors to ozone formation (see **Tables 25 and 26**).

3. Revised Cost-Effectiveness of Proposed Regulation

The estimated average cost-effectiveness of this proposed diesel PM emission reduction regulation, considering only the benefits of reducing diesel PM, is approximately $67/lb of PM reduced annually from fiscal years 2004 to 2020. This rule will also result in significant emission reductions of HC and NOx, however, thus it is valid to allocate half of the cost of compliance to the benefits of HC and NOx reduction. The cost-effectiveness for reducing HC and NOx, which are ozone precursors and contributors to secondary PM formation, is $1.79/lb of HC plus NOx. Since NOx emissions account for, on average, 72 percent of the total HC and NOx emissions, the cost-effectiveness of NOx and HC would be approximately 1.29/lb of NOx and 0.50/lb of HC, respectively. The cost-effectiveness of PM reduction is $32/lb, when half of the cost of compliance is allocated to HC and NOx reduction in this way. The costs and emission reductions associated with this regulation and how they were derived are discussed in further detail in Appendix F.

As discussed earlier in section III.E.5.a., this rule is also estimated to cost $900,000 per premature death prevented, or life saved. Staff estimates that, on average, the reduction in diesel PM emissions because of this rule will result in the prevention of eighty premature deaths by year 2020. Compared to present value of the U.S. EPA's value of avoiding one death at $4.2 million to $5.9

million, this rule is a very cost-effective mechanism of preventing premature deaths caused by diesel PM.

XII. References to This Supplemental Staff Report

California Air Resources Board. *Resolution 98–35: Identification of Particulate Emissions from Diesel-Fueled Engines as a Toxic Air Contaminant*; California Air Resources Board: Sacramento, CA, 1998, http://www.arb.ca.gov/regact/diesltac/res98-35.pdf.

California Air Resources Board. *Risk Reduction Plan to Reduce PM Emissions from Diesel-Fueled Engines and Vehicles*, Sacramento, CA, October 2000.

California Environmental Protection Agency. *Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant: Health Risk Assessment for Diesel Exhaust; Appendix III, Part B*; Office of Environmental Health Hazard Assessment: Sacramento, CA, 1998.

Diaz-Sanchez, D.; Tsien, A.; Casillas, A.; Dotson, A.R.; Saxon, A. Enhanced Nasal Cytokine Production in Human Beings after in vivo Challenge with Diesel Exhaust Particles; *J. Allergy Clin. Immunol.* 1996, *98*, 114-123.

Diaz-Sanchez, D.; Garcia, M.P.; Wang, M.; Jyrala, M.; Saxon, A. Nasal Challenge with Diesel Exhaust Particles Can Induce Sensitization to a Neoallergen in the Human Mucosa; *J. Allergy Clin. Immunol.* 1999*, 104*, 1183-1188.

Kittelson, D.B.; Arnold, M.; Watts, W.F. (1999) Review of Diesel Particulate Matter Sampling Methods. Final Report. University of Minnesota www.me.umn.edu/centers/cdr/Proj_EPA.html.

Krewski D.; Burnett R.; Goldberg M.; Hoover K.; Stemiatychi J.; Jerrett M.; Abrahamovicz M.; White W. Reanalysis of the Harvard Six Cities Study and the American Cancer Society Study of Particulate Air Pollution and Mortality. Health Effects Institute, Cambridge MA. 2000.

Lloyd, A.C.; Cackette, T.A. Diesel Engines: Environmental Impact and Control; *J Air Waste Manage. Assoc.* 2001, 51: 809-847.

Pope C.A.; Thun M.J.; Namboodiri M.M.; Dockery D.W.; Evans J.S.; Speizer F.E.; Heath C.W. Particulate Air Pollution as a Predictor of Mortality in Prospective Study of U.S. Adults. *Am. J. Respir. Crit. Care Med.* 1995, *151*:669-674.

Scientific Review Panel. Report to the Air Resources Board on the Proposed Identification of Diesel Exhaust as a Toxic Air Contaminant. Part A.

Exposure Assessment. As Approved by the Scientific Review Panel on April 22, 1998.

Takano, H.; Ichinose, T.; Miyabara, Y.; Shibuya, T.; Lim, H.B.; Yoshikawa, T.; Sagai, M. Inhalation of Diesel Exhaust Enhances Allergen-related Eosinophil Recruitment and Airway Hyperresponsiveness in Mice; *Toxicol. Appl. Pharmacol.* 1998, *150*, 328-337.

United States Environmental Protection Agency, 2000a, *Guidelines for Preparing Economic Analyses.* September 2000.

United States Environmental Protection Agency, 2000b, Assessment and Standards Division, Office of Transportation and Air Quality. *Regulatory Impact Analysis: Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements*. EPA420-R-00-026, December 2000.

United States Environmental Protection Agency, Assessment and Standards Division, Office of Transportation and Air Quality, *Draft Regulatory Impact Analysis: Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel*. EPA420-R-03-008, April 2003.