APPENDIX F

STAFF ANALYSIS OF PM EMISSION REDUCTIONS AND COST-EFFECTIVENESS

ARB's methodology for determining cost-effectiveness of a regulation is to determine what costs are involved to comply with the proposed regulation over the life of the controls and to compare those costs to the emission reduction benefits to the public. Staff summarizes this cost-effectiveness as cost (in $) per pound or ton of air pollutant reduced, in this case diesel PM. The benefit to the public in terms of health expenses avoided and lost productivity are not included in the cost-effectiveness calculation, although the value of those benefits is substantial.

The proposed implementation schedule dictates a phase-in by calendar year, with the full 85 percent reduction in diesel PM by 2007 for transit agencies on the diesel path and by 2009 for transit agencies on the alternative-fuel path. Staff assumed that retrofit diesel particulate filters (DPF) would only be available for 1994 through 2002 model year engines, and that transit agencies would retire or repower older pre-1994 engines to achieve the PM reduction targets. Some transit agencies keep buses beyond the twelve year Federal minimum useful life, and therefore could comply with this regulation by retiring old buses that are past their useful life. Another strategy a transit agency could employ to reduce diesel PM emissions would be to fuel its fleet with a diesel-water emulsion, such as PuriNOx™.

Staff is only considering the cost of retrofitting buses (1994 to 2002 MY) in calculating the cost of this regulation. The Federal Transit Administration (FTA) pays 80 to 83 percent of the purchase cost of a new bus. The remaining cost is made up from local and state transportation funds. Local and regional transportation planning agencies control the allocation of federal, state, and local transportation funding in urban areas; the State Department of Transportation allocates some funds in rural areas. The ARB staff and some local air districts have encouraged transportation planning agencies to provide more funding for transit agencies that need to comply with this Fleet Rule and funding has been made available, in most cases, during the first two years of implementation of this rule. Staff expects funding to continue to be available to cover the costs of new buses.

The cost of repowering, i.e., replacing an existing engine with a new engine, may also be covered by Federal, State, and local funds. Federal funding is available for 50 to 100 percent of the cost of repower, based on an informal survey by staff. In addition, transit agencies that repower from older engines to new engines realize significant savings in fuel, from improved fuel economy, and in maintenance costs. Therefore, staff believes that the cost share of the repower is off-set over the life of the new engine by reduced fuel costs and maintenance. For example, in the case where Federal funds pay for 80 percent of the cost of a repower, over the six year lifetime of the new engine a transit agency could recoup all of its costs through avoided engine rebuild, and fuel economy and maintenance savings (Table 1).

Table 1. Example of Costs Recovered by Engine Repower, 2-Stroke to 4-Stroke

Average Cost to Repower with New Engine and Rebuilt Transmission	$80,000	
Credit Federal Cost Share 80% (50-100% Range)		-$64,000
Credit Avoided Cost of Rebuild		-$6,000
Credit Annual Fuel Savings for 6 yr Engine Life		-$12,000
(Maintenance Savings Not Quantified)		
Net Cost of Repower		-$2,000

In general, two types of costs were accounted for in the cost-effectiveness analysis, capital and operation and maintenance (O&M) costs. 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 unknown factors. The costs of technology typically decline over time. These costs have been obtained from the U.S. EPA, the Manufacturers of Emission Controls Association (MECA), and from actual quoted costs to transit agencies.

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 DPF's cost. Transit bus engines covered by this rule are heavy heavy-duty engines, so the DPF cost is on the high side. The current cost to retrofit heavy heavy-duty on-road engines and vehicles with catalyst-based DPFs is estimated to range from $4,750 to $9,500. This assumes a cost of $10 to $20 per horsepower, as reported by MECA in “Emission Control Retrofit of Diesel-Fueled Vehicles” (March 2000). The current average cost to purchase a DPF for an urban bus engine is approximately $5,500.

In contrast to the current retrofit costs, the U.S. EPA’s estimate of the future (2007) costs of applying DPFs to new on-road heavy heavy-duty engines shows a significantly lower cost, about $1,100. The U.S. EPA estimate is based on higher production volumes, and is similar to the future cost projections presented by manufacturers (MECA, March 2000). Therefore the estimated DPF capital cost ranges from $1,100 to $9,500 over the implementation of this rule (2003 to 2009). Based on current bids for retrofitting, however, staff believes a 2003 DPF cost of approximately $5,500 is a reasonable current estimate for an urban bus engine. For this rulemaking, staff has used a median cost of $3,000 as an average of current and future costs for urban bus engines (Table 2).

Table 2. Capital Costs Associated with a Passive DPF Retrofit of Urban Bus Engines

Cost Categories	Median Cost	Range
Capital Cost, inc. Installation	$3,000	$1,100 - $5,500
Annual Maintenance	$80	$0-$190

O&M costs considered by staff included the cost for maintenance, for example, periodic cleaning of the trap. Based on conversations with the manufacturers and demonstration program experience, staff determined the number of cleanings would be on average once a year or less, dependent on the device and other vehicle variables, such as oil consumption. The incremental cost of low sulfur diesel fuel is not included in this calculation, as low sulfur diesel was required to be implemented as of July 1, 2002, and its cost was figured in the original rulemaking. The cost of DPF inspection and cleanings is estimated to range from zero cost to $190 per year, with an average cost of $80. Total O&M costs per urban bus for maintenance are, therefore, an average of $80 per year.

Another option available to control diesel PM emissions, which may be verified in the future to Level 2 (50% reduction), is an emulsified fuel, Lubrizol's PuriNOx™. PuriNOx™ costs approximately 25 cents per gallon over conventional diesel fuel, based solely on incremental operation and maintenance costs. This option is not considered in the cost-effectiveness calculation because the technology is not yet verified for use as a diesel emission control strategy.

Staff determined the amount of PM, in tons, reduced per year based on the implementation of this proposed regulation (Table 3). Utilizing the EMFAC modeling program, implementation of these proposed rule changes is expected to result in a reduction of 24.1 tons of PM in 2004. For 2006, the total PM reduced is estimated to be 36.3 tons. By 2008, the proposed regulation would realize an estimated 38.5 tons of PM reduction.

In order to arrive at the discounted capital costs for the regulation, staff multiplied the capital costs by the capital recovery factor[1], and assumed a lifetime of the DPF based on the minimum warranty period of five years with an annual interest rate of seven percent[2]. It is quite likely a DPF will last much longer than five years in a well-maintained vehicle, as some DPFs have been operating for over five years in Europe.

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[1] 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).
[2] USEPA uses the factor to calculate costs of environmental programs.

Five years was used in an effort to make a conservative estimate. Clearly, the cost effectiveness would be lower if the DPF has a longer lifetime.

The average costs of implementing the program from 2003 to 2009 were included in the cost effectiveness calculation (Table 3). Based on the median cost scenario, the cost effectiveness would be approximately $50,460 per ton ($25.23/lb) diesel PM reduced. Staff also calculated a low cost scenario, based on the future cost of $1,100 per DPF, of $21,824 per ton diesel PM reduced and a high cost scenario, based on the current cost of $5,500 per DPF, of $89,021 per ton reduced. The staff predicts the cost will fall toward the low to average end of the cost effectiveness scale, based on past experience and because engine manufacturers already are required to install DPFs on new urban bus engines produced after October 1, 2002 to comply with the PM emission standard of 0.01 g/bhp-hr. The federal PM emission standard declines to 0.01 g/bhp-hr for all heavy-duty diesel engines beginning with the 2007 MY.

Table 3. Average Cost Effectiveness of Proposed Regulation

Year	Diesel PM Reduced (tons/year)	Total Annual Cost ($)	Total Cost ($) per Ton PM Reduced
2003	24.1	658,800	27,347
2004	29.2	1,133,400	38,815
2005	36.3	1,580,000	43,502
2006	37.1	2,026,600	54,699
2007	38.5	2,445,200	63,495
2008	36.0	2,356,460	65,548
2009	33.4	1,997,860	59,816
TOTAL:	**234.6**	**12,198,320**	**50,460**

The costs accounted for above do not include administrative costs. Reporting and additional administrative costs are not expected to result in any significant cost to transit agencies. Under the existing rule, transit agencies must already make annual reports, and the reporting required by this proposed amendment substitutes for reporting that has been deleted from the original rule.

The cost of maintenance training is not included in the analysis. From discussions with trap manufacturers, ARB staff concluded that the DPF manufacturer would provide maintenance training at no additional charge.

Staff assumed no fuel economy penalty would exist from the use of a DPF. This is based on staff experience with the verification procedure and the inability of studies to determine a consistently significant impact, either positive or negative. It is possible a slight penalty or benefit might exist, but until more conclusive data are available, staff assumed either would be negligible.

Waste ash generated by cleaning a DPF may be a hazardous waste in California because of high zinc content. The source of the zinc is the lubricating oil. Staff assumed the fee for disposal of ash from a DPF would be negligible, based on the following analysis. From experience gained during demonstration and testing programs, ARB staff estimated the weight of ash generated per DPF to be approximately 10 to 20 grams, which is dependent upon oil consumption. The quantity of ash would be greater with more than average oil consumption. Based on conversations with the manufacturers and demonstration program experience, staff determined the number of cleanings would be on the average once a year or less, dependent on the device and other vehicle variables, such as oil consumption. Using these values staff determined the quantity of ash that might be generated by a fleet of ten, 100, or 1000 transit buses (Table 4).

Table 4. Ash Disposal Analysis

Number of Buses	Ash Accumulation (kilograms per year)		Years to Accumulate 100 kg of Ash
	Low	High	
10	0.1	0.2	500-1000
100	1	2	50-100
1000	10	20	5-10

Considering only waste ash generation, a transit agency could qualify as a small quantity generator. According to the Department for Toxic Substances Control, a hazardous waste may be stored on-site for 180 days or less, after the site has accumulated 100 kilograms of waste. Staff did not include the cost of ash disposal in the cost effectiveness analysis because of the long length of time to accumulate sufficient ash for disposal, the uncertainty that ash will be a hazardous waste in all fleets, and the variability in ash quantity generated per vehicle and fleet.