APPENDIX D

COST ANALYSIS METHODOLOGY

I. Methodology

A. Implementation Scenarios

1. Vehicle Population

To determine the number of vehicles affected by the regulation, staff established that the 2003 transit fleet vehicle (TFV) population is 5411, of which 4054 vehicles were vehicles fueled by diesel or alternative fuel (See Appendix B). The 2003 population was categorized by engine model year and gross vehicle weight rating (GVWR) for both trucks and buses.

Staff developed an implementation scenario based on the population characteristics. Numbers and types of vehicles were identified in the survey data, then staff adjusted the numbers affected to the number reflected in the 2003 estimated population. For the implementation scenarios trucks and buses were treated separately because trucks do not receive federal transportation funding, whereas federal funding is received for purchases of buses. Staff assumed that trucks do not turnover and were still present in each implementation year. Buses are replaced based on their Federal Transportation Administration useful service life determination. Staff evaluated each transit agency that submitted data as a separate entity and calculated individual NOx fleet averages and diesel PM emission totals for each implementation date. Since the emissions benefits provided by fleet turnover are already occurring, the number of vehicles affected were determined by first applying the NOx fleet average requirements, then by diesel PM total requirements.

2. NOx Fleet Average Requirements

To determine the number of affected vehicles to meet the December 31, 2007, NOx fleet average of 3.2 grams per brake horsepower-hour (g/bhp-hr), staff calculated each transit agency's NOx fleet average based on engine certification standards on December 31, 2007.

To obtain the model year distribution for this date, staff applied a useful service life value to each bus in a transit agency's fleet. FTA bases funding availability on the number of years and mileage of the vehicle that funding is sought for. Buses are rated as 4, 5, 7, 10 and 12 -year vehicles (FTA 2004, Dave Avery Per. Comm., Dan Mundy Per. Comm.). Since mileage was not always available, staff used an average number of years based on the survey information within GVWR category and FTA funding guidelines Staff also took into consideration the time it takes transit agencies to obtain funding and the state transit funding issues. The useful life values used were 7 years for vehicles less than 14,000 pounds GVWR, 10 years for vehicles 14,000 to 33,000 pounds GVWR, and 15 years for greater than 33,000 pounds GVWR. Staff identified the oldest vehicle requiring replacement in order to meet the NOx fleet average.

If a bus was near the end of its useful service life, only a portion of the bus equivalent to the remaining useful life was used. For example, in Table 1, the bus equivalent number is a sum of the portion of useful service life left for a vehicle times the number of vehicles. In 2010, the value of 0.21 is shown. This number represents a fraction of the useful service life for one vehicle adjusted for population.

For the December 31, 2010 deadline, staff used the same methodology as above. Because the deadline was further out, which allows transit agencies to plan for funding requests, staff used the useful life values of 5 years for vehicles less than 14,000 pounds GVWR, 7 years for vehicles 14,000 to 17,000 pounds GVWR, 10 years for 17, 000 to 33,000 pounds GVWR, and 12 years for greater than 33,000 pound GVWR.

Table 1 provides the number of repowers required to meet the 2007 and 2010 requirements. Staff differentiated between the model years used for the NOx and PM requirements. For the NOx requirements, costs were set based on repowering with a 2002 MY engine because in 2010 transit agencies have an option of retiring all 2001 or earlier MY engines instead of meeting the strict NOx average value.

3. Diesel Particulate Matter Emissions Requirements

Staff calculated each transit agency's 2005 diesel PM baseline using the 2003 survey information and determined the 40 and 80 percent goals for each transit agency for the 2007 and 2010 requirements. Staff determined the fleet make-up for 2007 and 2010 and adjusted each fleet MY population for modification required for achieving the fleet NOx average. Using this information, staff calculated each transit agency's diesel PM emissions total for December 31, 2007, and December 31, 2010.

Staff determined the number of Level 3 diesel emission control strategies or repowers that would be needed to meet the agencies' 2007 and 2010 deadlines. For DPFs, staff counted the number of vehicles in the 1994 to 2002 MY and 2003 and newer MY. There are DPFs currently verified for the 1994 to 2002 MY engine category. There are no DPFs currently verified for 2003 and newer MYs. Equipment is under evaluation for these MYs and staff expects devices to be verified for these engine categories. Staff does expect the cost to be higher, therefore MY 2003 and newer vehicles were counted separately.

Staff does not expect a Level 3 DECS to be available for 1993 and earlier MYs, therefore staff counted the remaining engines as repowered to a new engine that meets the 2007 engine emission standard. The PM engine emission standard drops to 0.01 g/bhp-hr in 2007. Repowering with an earlier MY would not provide the emission reduction required by the proposed regulation.

4. Total Number of Repowers and DPF

The total numbers of vehicle replacements and Level 3 DECSs determined from the above analyses is summarized in Table 1 below. Staff calculated the numbers of repowers and DPFs required to meet the December 31, 2007 and December 31, 2010 fleet NOx average and diesel PM emission total requirements. For the December 31, 2007 NOx fleet average, staff calculated that 6 heavy duty diesel buses and 26 heavy duty trucks would need to be repowered to a 2002 or newer model year engine. For meeting the December 31, 2007 diesel PM total reduction requirements, staff calculated that 1190 buses and 26 trucks would require the installation of DPFs and 3 trucks would need to repower to a 2007 MY engine. For meeting the December 31, 2010 NOx fleet average, staff calculated that 0.21 heavy duty diesel buses and 18 heavy duty trucks would need to be repowered to a 2007 or newer model year engine. For meeting the December 31, 2010 diesel PM total reduction requirements, staff calculated that 353 buses and 33 trucks would require the installation of DPFs and 5 trucks would need to repower to a 2007 MY engine.

Table 1. Number of Repower and Diesel Emission Control Strategies

Type of Vehicle	NOx	PM
Bus	**Number of Vehicles & Actions**	**Number of Vehicles & Actions**
by 12/31/07	6 (equivalent) HDD bus repower w/ 2002+ MY engine	1190 DPFs[1]
by 12/31/10	0.21 (equivalent) HDD bus repower w/ 2002+ MY engine	353 DPFs[1]
Truck		
by 12/31/07	26 upgrade to 2002+ MY engine	3 Repower to 2007+ MY engine, 26 DPFs[1]
by 12/31/10	18 upgrade to 2002+ MY engine	5 Repower to 2007+ MY engine 33 DPFs[1]

[1]verification received or expected

B. Cost Calculations

The cost-effectiveness analysis is based on estimates of expected emissions reductions and of costs for implementation of this regulation.

Most of the estimated implementation costs are capital costs for one-time purchases of diesel particulate filters (DPFs) (retrofit), new or used vehicles (replacement), and replacement of engines with new and/or alternative-fuel engines (repower). There are also some ongoing operational costs required by the regular cleaning required by DPFs, typically on an annual basis.

Cost estimates were obtained from technicians and engineers in the field, as well as from transit agency staff and industry associations. For each cost category, ARB staff determined a low, average, and high cost based on the cost estimates obtained for each category. Low and high estimates were the minimum and maximum cost estimate in each category, and the average estimates were averages of all the estimates obtained for each category.

1. Capital Costs

For bus replacement costs, current prices of new buses were used. For truck replacements required for NOx reductions, staff used estimates of the net cost of replacing an older truck with a newer truck. The used-truck market is a large market, much larger than the used-bus market, so transit agencies are more likely to find a used truck that meets emission-reduction specifications. In addition, transit agency staff will have time to shop around, increasing the likelihood that they will be able to find a good deal on a truck that meets their needs.

Those few truck replacements required for PM emissions reductions entail upgrading to 2007 engines, and buying used trucks would be practically impossible in 2007 and likely still difficult in 2010, so in those cases current prices of new trucks were used. While it might be possible to find used 2007 trucks in 2010, assuming transit agencies will buy new trucks is slightly more conservative in terms of the cost estimate.

For repowers where staff expects older engines to be replaced by new or newer engines, various estimates of the overall cost of such replacements were obtained and used to calculate the likely range of possible costs shown in Table 2 below. Such engine repowers are not inexpensive, especially on a one-vehicle basis. Another engine must be purchased, and if the old engine is a different model or is scrapped, there may be no trade-in on the old engine to offset the cost of the new engine. Also, additional systems subsidiary to the engine itself, such as the transmission, the radiator, the electronic control system, the fuel system, and unpredictable other components may also require replacement. Lastly, engine technicians may be faced with a unique and completely new situation which requires them to figure out how to fit the new engine into a configuration for which it was not designed.

Table 2. Estimated Costs for Repowering Vehicles

Repower w/ Different Engine	Low	Medium	High
Newer Diesel	$16,500	$31,769	$70,000
Alternative Fuel Engine	$60,000	$115,000	$160,000

Staff found that overall estimates of repower costs were in generally reasonable agreement with estimates constructed by adding sub-estimates of new-engine, extra equipment, and extra labor. Staff also obtained information about some mass conversions (such as a dozen or several dozen buses) to configurations not anticipated by vehicle designers, where significant economies of scale were realized by performing unprecedented conversions en masse. Transit agencies would be well-advised to confer, perhaps via their industry association, on coordinating such processes in order to substantially reduce costs.

For passive DPFs, the market is mature enough that retail prices are easily obtained. No caveats about engine size accompanied the cost estimates that staff obtained from manufacturers or distributors, so the same price range of $6,000 to $11,000 was used for all engine sizes. The filters themselves, as well as typical installation costs and backpressure monitors, were included in the basic capital cost estimate which averaged $7,725.

An active DPF and a DPF suitable for engines with EGR are expected to be verified by ARB in the near future. Cost estimates for these were also obtained, though their future prices are less predictable than for products that have already been ARB-verified. The most-feasible scenario developed by staff assumes that transit agencies may use a DPF for an engine with EGR, but not an active DPF. The estimated cost range for a DPF for engines with EGR is $8,500-$20,000, with an average of $14,250.

2. Maintenance Costs

The only ongoing costs modeled for the most-feasible scenario are for the periodic cleaning required to keep DPFs operating properly. The estimated cost range for cleaning is $250-$500, with an average of $333. Filter cleaning is done annually, and is usually outsourced so the cost doesn't vary much. Filter cleaning machines are available for about $8000, and are expected to be cost-effective for fleets of about 17 or more. Since most non-urban fleets are small, staff did not include this option in the cost calculation. This option would also require accumulation and disposal of small amounts of hazardous waste, which is expected to be an insignificant expense compared to the other expenses involved. DPFs are expected to last ten years, and nine years of cleaning costs are included in the calculation.

3. Operational Costs or Benefits

There may be small costs or benefits due to increased fuel efficiencies and decreased maintenance costs realized by installing new or newer engines, and decreased fuel efficiencies due to the increased engine pressure required with DPFs. These costs and benefits are expected to be small and to offset each other, so staff did not explicitly include them in the calculation.

As low-sulfur diesel will be the standard diesel fuel in the market by the time transit agencies are expected to start using DPFs pursuant to this regulation, no incremental added costs for the fuel required for DPFs are included.

4. Present-Value Cost Basis

All costs are presented in present value terms of 2005 dollars, where the "present" is defined as January 1, 2005. Capital costs are simply discounted at the real interest rate, exclusive of inflation. Thus, current prices can be used. Ongoing costs, which are annual DPF cleaning costs, are also discounted at the real interest rate.

For converting future values (FV or prices) to present value (PV), the standard formula PV/FV = 1/((1+r)^n) is used , where r is the real interest rate and n is the number of years in the future. The standard formula for converting present value to an equal amount (AV) spread over a certain number of years can also be used to evaluate how initial capital expenditures can be financed. AV/PV = ((r(1+r)^n)/((1+r)^n-1), where r is the real interest rate and n is the number of years for which equal annual amounts are desired. These equations can be found in many standard references, such as the study guide for the professional engineering exam (NCEES 2003).

For the purpose of the discounting, staff assumed that transit agencies will wait until the last possible time (December 31, 2007 and December 31, 2010) to make the expenditures required by each phase. This is a reasonable approximation of reality because buses and trucks are typically paid for on delivery. Thus, the costs for the first phase are discounted by three years, and for the second phase, by six years. In addition, the annual costs of filter cleaning are also discounted by the appropriate interval.

All these costs are predictions of future prices, so they could vary noticeably depending on demand, competition, and economic conditions, among other reasons. It is also important to note that some of these estimates pertain to equipment that is not yet available on the market. For this kind of equipment, prices for newly available equipment may be expected to start out on the high side of the range, and decline over time to the low side of the estimated price range.

The overall range of cost estimates above is equivalent to an annualized amount ranging from $1.13-$2.37 million, with a medium annual amount of $1.66 million, over the 16 years from 1/1/05 to 12/31/20. These values are in 2005 dollars.

The overall costs of this scenario can also be presented on an actual annual basis. The values below represent 2005 dollars. The averages of the cost estimates were used in Table 3 below.

Table 3. Annual Average Costs

Year	PM Requirements	NOx Average Requirements	Total
2007	$11,364,611	$546,921	$11,911,533
2008	$333,469		$333,469
2009	$317,589		$317,589
2010	$3,461,223	$219,174	$3,680,397
2011	$379,504		$379,504
2012	$361,432		$361,432
2013	$344,221		$344,221
2014	$327,830		$327,830
2015	$312,219		$312,219
2016	$297,351		$297,351
2017	$283,192		$283,192
2018	$64,985		$64,985
2019	$61,891		$61,891
2020	$58,944		$58,944
Total	$17,968,460	$766,097	$18,734,557

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