APPENDIX D

COST ANALYSIS METHODOLOGY

I. METHODOLOGY

The proposed regulation would impose costs on both privately and publicly-owned solid waste collection vehicle fleets in the South Coast Air District. In order to estimate the potential magnitude of these costs, staff examined the most costly compliance option, which staff anticipates would be the purchase of alternative-fueled vehicles. In particular, costs reflect liquefied natural gas (LNG) vehicle technology, which tends to be preferred over compressed natural gas by collection vehicle owners. For reference, staff also examined a retrofit compliance option. In both cases, amortized capital costs, maintenance and repair costs, and fuel costs through the year 2020 were all brought to their present value and expressed in 2005 dollars.

From 2010 onward, staff anticipates that many unmodified diesel engines will be able to meet BEST criteria, and so the proposed amendments would not impose any special requirements on collection vehicle owners in that timeframe. Therefore, staff only considered new LNG vehicle purchases through the year 2009. Incremental maintenance and fuel costs on these vehicles, however, were accounted for through 2020. Staff also included the cost of constructing enough fueling stations to serve the vehicles purchased through 2009.

A. Capital Costs

The capital cost estimates used by staff in this analysis are shown in Table 1, below. Note that the LNG collection vehicle cost is expressed as an estimated incremental cost above that of a diesel vehicle.

Table 1. Capital Cost Estimates and Economic Parameters

Item	Cost/Value
LNG collection vehicle	$50,000 (incremental)
LNG Fueling Station (100 veh.)	$856,000
Diesel retrofit (SCR)	$20,000
Discount rate	5%
Amortization period	10 years
Capital Recovery Factor (CRF)	0.13

The $50,000 incremental cost for an LNG collection vehicle is a representative number for the difference in cost with a diesel vehicle today. It is based on discussions with various owners that have purchased both LNG collection vehicles and diesel vehicles. It is difficult to predict how this price differential may change in 2007 and subsequent years because both diesel and natural gas engines will undergo significant technological changes to meet stricter emissions standards. Given this uncertainty and the lack of any substantial cost data on future engines, staff elected to use the $50,000 increment for each year's purchases.

Staff used a new vehicle purchase rate of about 5 percent of the district-wide population per year[1]. Summing purchases from 2006 through 2009, the primary years of consideration, staff estimates approximately 1,035 new collection vehicles will be purchased. The $50,000 capital cost increment was applied to each of these purchases.

To accommodate the fueling needs of all the new LNG vehicles, staff included LNG fueling stations into the economic analysis. For each 100 new vehicles purchased, staff accounted for one new LNG fueling station at a cost of $856,000 each. A white paper on natural gas infrastructure written by staff of the SCAQMD lists actual LNG fueling station costs for collection vehicle fleets (SCAQMD 2005). The average cost of ten LNG fueling stations for privately-owned fleets comes out to $856,000 per station. Each station typically has a 15,000 gallon LNG storage tank which could conceivably fuel about 250 collection vehicles each day if vehicles used 50 gallons per day and the tank were refilled every day. However, such frequent refilling with LNG trucked in from other states is unrealistic given today's production levels. Staff therefore estimated 1 new station for every 100 new vehicles assuming a more realistic tank refilling rate of 2 times per week. Because the usage of existing fueling station capacity is not yet at 100 percent, it might be argued that a lower rate of fueling station construction should be assumed. Staff chose to err on the side of being conservative on this point. Therefore, staff's analysis includes the capital cost of 10 new fueling stations.

For the diesel retrofit cost comparison, staff chose to consider selected selective catalytic reduction (SCR) technology, which is one potential retrofit option. The estimated $20,000 capital cost is based on communications with SCR system manufacturers. Staff assumed that after 10 years, each SCR system would have to be replaced with a new one. Although the first round of SCR system capital costs were amortized, the replacement units were treated as lump sum capital costs in the years of purchase. This was done to account for the full capital costs before 2020.

Capital expenditures for the LNG vehicles, fueling stations, and the first round of SCR system purchases were all amortized over a period of ten years from the year of purchase with a 5 percent interest rate. Each year's costs for a given capital expenditure were calculated per the following equation:

$$\text{Annualized Capital Cost} = \text{CRF} * \text{Capital Cost}$$

where the capital recovery factor, CRF, is in turn given by the equation:

$$\text{CRF} = \frac{i(1+i)^N}{(1+i)^N - 1}$$

The CRF is determined by two parameters: N, the period (ten years) and i, the discount rate (5 percent).

[1] For details, see Appendix C: Emission Inventory.

Each year's annualized capital costs were brought back to their present value (2005) by multiplying by the present value factor:

$$\text{PV factor} = \frac{1}{(1+i)^n}$$

where n is the number of years from 2005.

B. Operation and Maintenance Costs

The operation and maintenance cost assumptions used by staff are shown in Table 2, below. As with the capital cost, note that the maintenance and repair cost per vehicle is cast as an incremental cost above that of a diesel vehicle.

Table 2. Operation and Maintenance Cost Estimates and Assumptions

Item	Value
LNG vehicle maintenance and repairs	$2,000/year/vehicle (incremental)
LNG fuel	$1.12/gallon
Diesel fuel	$2.00/gallon
Urea	$2.00/gallon
Annual engine operation	2600 hours
Diesel fuel consumption	2.48 gallons/hour
Annual diesel fuel consumption	6,450 gallons/vehicle
LNG to diesel fuel usage ratio (by vol.)	1.9
Annual LNG fuel consumption	12,300 gallons/vehicle
Annual urea consumption	58 gallons/vehicle

Staff selected a $2,000 per year incremental maintenance and repair cost for alternative fueled vehicles in the present analysis. In practice, there is a broad range of additional maintenance and repair costs, and a given fleet's experience depends on many variables. The trend, however, is that costs for alternative fueled collection vehicles have been significantly greater than for their diesel counterparts. Staff bases this conclusion on a limited amount of published data and numerous personal communications with owners during site visits and telephone calls. Very little actual cost data has been published comparing diesel and alternative fuel collection vehicles due to the sensitive nature of this information to the refuse industry and the fact that these vehicles have not been in service for a long time. Repair costs are often still covered by warranty, for example, and are not recorded. However, some published data or otherwise public data are available.

A refuse industry report issued in June 2003 (updated in 2005) by Environ Strategy Consultants does contain some detailed, specific cost information (Environ Strategy

Consultants, 2005). A fleet in the South Coast Air Basin tracked maintenance and repair costs from ten of its diesel collection vehicles and ten of its new dual-fuel collection vehicles over a period of 16 months from 10/31/01 to 2/26/03. Parts and labor costs averaged about $1035 more for each dual-fuel vehicle. The fleet also reported additional annual preventative maintenance costs which sum to $1005 per vehicle. Adding this number the $1035 figure scaled down to 12 months, the annual additional maintenance and repair cost per vehicle comes to about $1780.

A report produced by the National Renewable Energy Laboratory (NREL) in January 2001 detailed Waste Management's experiences with its dedicated LNG vehicles (Chandler et al, 2001). Researchers compared costs and performance of three diesel and five LNG collection vehicles in Waste Management's fleet over a period of 12 months from November 1998 to October 1999. The total maintenance cost per hour for the diesels averaged $5.95 while that for the LNG vehicles averaged $7.32. Multiplying by the hours of operation for each, the annual additional maintenance cost for the LNG vehicles averaged about $2,850 per vehicle.

The City of Long Beach submitted operating cost information to the SCAQMD as part of a Rule 1193 survey. It compared operating costs from three of its 2000 model year diesel vehicles with three of its 1996 model year CNG vehicles over a three-year period from 2001-2003. The annual parts and labor costs averaged $1,800 per diesel vehicle and $6,600 per CNG vehicle, giving an annual cost increment of $4,800 for each CNG vehicle.

The City of Ontario also submitted data as part of the SCAQMD survey, but had very different results. Ontario compared costs from four of its 2000 model year diesel vehicles with four of its 2003 model year CNG vehicles from January through October 2003. The result was that the labor and parts costs averaged $2,170 per diesel vehicle, which was actually $1,150 in excess of the $1,020 average for the CNG vehicles.

Out of all the published or public data discussed thus far, Ontario's are the only data that are for today's natural gas engine technology. Though the data are limited in scope and duration, they reflect what several owners have indicated qualitatively in personal communications with staff, namely that today's natural gas engines are performing noticeably better than earlier models. While this might suggest using an incremental maintenance and repair cost lower than the $2,000 per year selected by staff, there is yet another variable to consider. The 2007 natural gas engines will employ different technology from today's engines to achieve the 0.2 g/bhp-hr NOx emission level. Because of the uncertainty of the performance of this future technology, staff decided to take a more conservative stance and use the $2,000 per year estimate for each year.

The price per gallon of LNG and diesel fuel used by staff in this analysis are shown in Table 2. The price of LNG excluding taxes is assumed to be $0.90 per gallon based on conversations with LNG fuel suppliers. Staff applied state sales tax (8.25 percent) to this price in addition to federal and state excise taxes of 11.9 and 6 cents per gallon, respectively, giving a total cost of $1.15 per gallon. Because public fleets are exempt

from the federal excise tax and comprise 29 percent of the total fleet, staff weighted the price to arrive at a basin-wide average of $1.12 per gallon. The price of diesel fuel is particularly volatile and difficult to predict with any accuracy. For this analysis, staff examined rack diesel prices for Los Angeles over the past year and found an average price of about $1.46 per gallon. Staff applied state sales tax to this price in addition to federal and state excise taxes of 24.4 and 18 cents per gallon, respectively, and another 6 cents per gallon for transportation costs and profit margin. This gave a total cost of $2.07 per gallon. Weighting the price as for LNG to account for public fleets' federal excise tax exemption, the average basin-wide price comes to $2.00 per gallon.

For both LNG and diesel collection vehicles, staff assumed 2600 hours of engine operation per year based on survey data. Staff used detailed survey data from a fleet of 34 diesel collection vehicles of various types to determine the diesel fuel consumption rate of 2.48 gallons per hour. For the ratio of LNG to diesel fuel consumption, staff relied on two sets of data. Survey data from a fleet of 34 diesel and 125 LNG vehicles all doing approximately the same work showed that the LNG consumption was 2.1 times the diesel consumption on a gallons per hour basis. The NREL report cited earlier found the ratio to be 1.7, LNG to diesel. Staff took the average of these two, namely 1.9, for the present analysis.

Using the figures in Table 2, staff calculated that the annual incremental operation and maintenance cost for an LNG vehicle would be $2,900 per vehicle. Staff accounted for this extra cost through 2020. Each year's costs were brought back to their present value (2005) as described in the capital costs section above.

Staff also estimated the cost of continuously supplying urea to a diesel collection vehicle using an SCR retrofit. In communications with a supplier of urea for SCR systems, staff learned that $2 per gallon delivered is a representative price. The quantity of urea required for a given collection vehicle depends on how much total NOx must be reduced. In a report to the Engine Manufacturers Association, the company TIAX estimated that a 1 g/bhp-hr NOx reduction would require an amount of urea equivalent to 0.9 percent of the amount of diesel fuel consumed (TIAX 2003). Staff therefore estimated an annual urea consumption of approximately 58 gallons per vehicle.

II. RESULTS

The estimated costs through 2020 that are directly attributable to the proposed amendments are summarized below in Table 3. For the alternative fuel compliance option, the total additional costs come to about $83 million. Again, this is the estimated cost of what staff expects to be one of the most costly compliance options, namely purchasing LNG collection vehicles. Of the $83 million, about $56 million (or about two thirds) comes from additional capital costs, while the remaining $27 million comes from additional operation and maintenance costs. The example SCR retrofit option selected for comparison has a total incremental cost of about $32 million, dominated by capital costs.

Table 3. Estimated Cost of Compliance with BEST Requirements

Compliance Option	Item	Incremental Cost (2005 $)
Alternative fuel (LNG collection vehicles)	Capital	$ 55.6 million
	Operation and Maintenance	$ 27.1 million
	Total Incremental Cost	**$ 82.7 million**
Diesel retrofit (SCR systems)	Capital	$ 30.5 million
	Operation and Maintenance	$ 1.1 million
	Total Incremental Cost	**$ 31.6 million**

Tables 4 and 5 below show the year-by-year breakdown of the costs summarized in Table 3.

Table 4. Estimated Annual Costs – Alternative Fuel Compliance Option

Year	LNG Vehicles Purchased	LNG Fueling Stations Purchased	Discounted Incremental Capital Costs	Discounted Incremental O&M Costs	Total Annual Cost
2006	246	0	1,515,336	684,034	2,199,370
2007	256	2.5	3,198,127	1,330,186	4,528,312
2008	254	2.5	4,704,501	1,907,508	6,612,009
2009	279	2.5	6,196,244	2,488,262	8,684,505
2010	0	2.5	6,118,331	2,369,773	8,488,104
2011	0	0	5,826,982	2,256,927	8,083,908
2012	0	0	5,549,506	2,149,454	7,698,960
2013	0	0	5,285,244	2,047,099	7,332,343
2014	0	0	5,033,566	1,949,618	6,983,184
2015	0	0	4,793,872	1,856,779	6,650,651
2016	0	0	3,635,307	1,768,361	5,403,669
2017	0	0	2,384,811	1,684,153	4,068,964
2018	0	0	1,252,972	1,603,956	2,856,927
2019	0	0	139,974	1,527,577	1,667,551
2020	0	0	0	1,454,835	1,454,835
TOTAL	**1035**	**10**	**55,634,773**	**27,078,522**	**82,713,295**

Table 5. Estimated Annual Costs – Diesel Retrofit Compliance Option

Calendar Year	SCR Systems Purchased	Discounted Incremental Capital Costs	Discounted Incremental O&M Costs	Total Annual Cost
2006	246	606,135	27,161	633,296
2007	256	1,178,701	52,819	1,231,520
2008	254	1,690,277	75,743	1,766,020
2009	279	2,204,893	98,803	2,303,696
2010	0	2,099,898	94,098	2,193,996
2011	0	1,999,903	89,617	2,089,520
2012	0	1,904,670	85,350	1,990,019
2013	0	1,813,971	81,285	1,895,256
2014	0	1,727,591	77,415	1,805,006
2015	0	1,645,325	73,728	1,719,054
2016	246	4,068,228	70,217	4,138,446
2017	256	3,619,803	66,874	3,686,677
2018	254	3,074,801	63,689	3,138,490
2019	279	2,821,082	60,656	2,881,738
2020	0	0	57,768	57,768
TOTAL	**2069**	**30,455,279**	**1,075,224**	**31,530,502**

III. REFERENCES

Chandler, K.; Norton, P.; Clark, N. 2001. Waste Management's LNG Truck Fleet: Final Results. Alternative Fuel Truck Evaluation Project. U.S. Department of Energy. January 2001.

Environ Strategy Consultants, Inc. 2003. Natural Gas Vehicle/Engine Users Refuse Industry Report. June 18, 2003, updated February 2005.

SCAQMD 2005. Status Report of Natural Gas Infrastructure Expansion in the South Coast District. April 22, 2005.

SCAQMD. Rule 1193 survey data from the cities of Ontario and Long Beach.

TIAX 2003. SCR-Urea Infrastructure Implementation Study Final Report. Created for the Engine Manufacturers Association, July 30, 2003.