APPENDIX D

COST ANALYSIS METHODOLOGY

I. Cost Analysis Methodology

This cost analysis addresses only two of the four options presented to the Air Resources Board (ARB) in this rule-making. As discussed in the Staff Report, there are two main options: 1) changing the statewide urban bus emission standards and 2) requiring all transit agencies in the South Coast Air Quality Management District (SCAQMD) to follow the alternative-fuel path for urban buses. Within option #1 there are three ways the ARB could choose to change the statewide standards, and only the third option (Alternative 1.3), of requiring all transit agencies statewide to follow the alternative-fuel path for urban buses, would require additional expenditures by transit agencies and hence entail a specific cost analysis. Alternative 2, where all transit agencies in the SCAQMD would be required to follow the alternative-fuel path for urban buses, would also entail additional costs for transit agencies.

California transit agencies provide the ARB with annual reports of the composition of their urban bus fleets, as required in the Fleet Rule for Transit Agencies. The complete inventory of urban buses operated by transit agencies is described in Appendix C. Alternative 1.3 would require all California transit agencies to convert to the alternative-fuel path in the next year or so, while Alternative 2 would only require that all transit agencies located in the SCAQMD that are on the diesel path switch to the alternative-fuel path. To determine the number of alternative-fuel buses which transit agencies would buy instead of diesel buses for Alternative 1.3, staff modeled the urban bus purchases which would be alternative-fuel rather than diesel (Table 1). For Alternative 2, staff surveyed the six transit fleets on the diesel path and requested their purchasing plans for 2005 to 2009. Estimated costs of Alternative 2 are based on these planned purchases (Table 2).

Table 1. Modeled Statewide Purchases of Alternative-Fuel Urban Bus Purchases

Year	CNG Bus[1]
2005	127
2006	84
2007	382
2008	400
2009	379
2010	992
2011	776
2012	189
2013	240
2014	273
2015	327

[1]Compressed Natural Gas Bus

Table 2. Reported Plans for Alternative-Fuel Urban Bus Purchases, SCAQMD Diesel Path Agencies Only

Year	GHEB[1]	CNG Bus[2]
2005	71	14
2006	23	-
2007	55	9
2008	64	-
2009	51	-

[1]Gasoline Hybrid Electric Bus
[2]Compressed Natural Gas Bus

A. Cost Calculations

The cost-effectiveness analysis is based on estimates of expected emissions reductions and of costs for implementation for Alternatives 1.3 and 2. Staff estimated the incremental cost of each Alternative by determining the difference between the capital and operations and maintenance costs of diesel urban buses and alternative-fuel urban buses.

Cost estimates were obtained from technicians and engineers in the field, as well as from published references. For the main cost categories, ARB staff determined typical or average costs based on the cost estimates obtained for each category. Alternate-fuel urban buses represent relatively new and still-evolving technology, and so there is a dearth of operating experience on which to base cost estimates.

As is explained below, natural gas buses entail a number of cost categories that are avoided when gasoline HEBs are used. Thus, although gasoline HEBs themselves are more expensive than natural gas buses, the auxiliary costs for the latter result in higher estimated lifetime costs for natural gas buses.

1. Capital Costs for Buses

For bus replacement costs, current prices of new buses were used to determine the premium of an alternative-fuel bus over a comparable diesel fuel bus (Table 2). The Federal Transportation Authority provides 80%-83% of the capital cost of new buses, so transit agencies see only a portion of the per-bus additional capital cost (FTA 2004). As a conservative estimate, staff assumed a 20 percent transit agency share (Table 3), although the cost to society is the full incremental difference. Staff did not subtract from the capital cost any incentive funds that may be available to offset the purchase of alternative-fuel buses. Staff has shown the two different types of buses that transit agencies in the SCAQMD are purchasing: gasoline hybrid-electric (HEB) and compressed natural gas (CNG) buses.

Table 3. Estimated Premiums for Alternative-Fuel Vehicles

Bus Type	100% Premium	20% Premium
Gasoline HEB	$122,700	$24,546
CNG Bus	$50,000	$10,000

2. Capital Costs for Fueling Stations and Maintenance Facilities

Staff expects that many transit agencies affected by Alternative 1.3 will have to construct new alternative-fueling facilities, while the six transit providers affected by Alternative 2 have already either built a fueling station or have one planned and financed, based on staff's survey of transit agencies. Thus, only the cost analysis for Alternative 1.3 includes the capital costs of new fueling facilities, although both Alternatives include operating and maintenance costs for fueling infrastructure. Staff assumed that half of the natural gas fueling facilities constructed pursuant to Alternative 1.3 would be L/CNG stations (gasification) and that half would be CNG (compression) stations.

In addition, transit agencies that are purchasing gasoline HEBs will use existing facilities. One transit agency, Long Beach Transit, has financed an upgraded gasoline fueling station already and thus those costs were also not attributed to this rule. Thus, no capital costs were accounted for constructing fueling facilities for Alternative 2.

In some cases transit agencies have upgraded maintenance facilities or constructed new ones, often in conjunction with onsite fueling stations, and in other cases they have been able to rearrange existing facilities to accommodate the additional safety requirements for working with natural gas engines. Since such upgrades are apparently optional, staff did not include capital costs for construction or upgrades of maintenance facilities in the estimated cost of the rule.

3. Maintenance Costs

Staff believes that maintenance costs for natural gas buses are likely to be somewhat higher than for diesel buses for a variety of reasons. Natural gas engines and fuel systems are somewhat more complex, and mechanics may not have had as much experience with them. In addition, spare parts are more expensive primarily because natural gas engines and their replacement parts are simply not manufactured in the same high volumes as diesel engines. Also, it appears that natural gas engines are much more sensitive to deferred maintenance than traditional diesel engines. On the other hand, diesel bus engines are becoming significantly more complex than they have been in the past, which tends to reduce the extra cost entailed in selecting alternative-fuel buses.

Based on transit agency staff estimates, extra maintenance costs range from $0.06 to $0.17 per mile, with an average of $0.10 per mile. Assuming 43,500 miles per year, per-bus extra maintenance costs are expected to be about $4,300 per year.

Extra maintenance costs for gasoline HEBs relative to diesel buses are quite uncertain, because gasoline HEBs are an even newer technology and are all still under warranty. Gasoline HEBs are expected to offer excellent fuel economy and thus lower fuel costs. Some preliminary data indicates that lifetime repair costs for gasoline HEBs may be lower than those for diesel buses because diesel buses typically require at least one engine and transmission replacement or major overhaul during the life of the bus, while the gasoline HEB has no transmission and a much less expensive engine. Gasoline HEBs may also have significantly lower costs on brake repair.

Transit agencies may find that extended warranties on new technologies, while likely more expensive per year than staff's maintenance estimates, greatly reduce downside risk and uncertainty. Also, it appears that there may be significant differences in natural gas bus maintenance costs among transit agencies. Transit operators with higher per-bus maintenance costs may well be able to learn from the practices of operators with lower per-bus maintenance costs. Of course, accurate comparison of these costs requires careful attention to operators' variations in internal accounting practices.

4. Operational Costs or Benefits

In the absence of published, verifiable data, staff made several assumptions regarding the costs of labor and fuel. The cost analyses are based on the incremental cost differences between diesel and alternative-fuel urban bus purchase and use. Labor costs for natural gas buses and gasoline HEBs are expected to increase modestly over typical diesel bus costs. Initial training costs, and ongoing training associated with regular recertification of technicians for natural gas maintenance, are primarily responsible for expected minor increases in labor costs.

Fuel costs are the primary and most uncertain operational cost. Staff assumed an annual mileage of 43,500 miles/year for urban buses. Natural gas engines are about 10 percent less efficient than diesel. Fuel cost differences in running buses on natural gas rather than diesel are therefore technologically precise, but, as is explained below, economically highly uncertain over the life of the regulation.

Although at present natural gas is less expensive than diesel, it is impossible to be certain about fossil fuel market conditions between now and 2020. In recent years CNG has been 15 - 20 percent more expensive (on a $/mile basis) than diesel. Thus, two cases were presented; one based on current fuel prices (D>NG) and another based on recent history (NG>D) (Tables 4 though 7). The current fuel prices were averages of retail and transit agency contract prices, and yielded a price difference of about $0.70/equivalent gallon. The recent historical prices were based on the past few years using California data from U.S. DOE EIA and South Coast agencies, which yielded a price difference of $0.10/gallon. Historically, natural gas prices have been between residual oil (#6) prices and heating oil (#2) prices. Diesel fuel is essentially the same as #2 oil. Thus, if market stability continues, natural gas may continue to be less expensive than diesel.

However, key parameters of the natural gas market appear to be changing. Canadian imports, which have met domestic demand growth in the past 10-15 years, are becoming insufficient. Knowledgeable observers expect liquefied natural gas (LNG) imports from Asia or the Mideast to meet demand growth for the foreseeable future, however there may be a period of turbulence as LNG terminals on the Pacific coast are still in the planning stages, and require at least 5 years to permit and construct. Natural gas prices are apparently now high enough to motivate investment in LNG import facilities. Also, it appears that LNG import terminals will be primarily designed to gasify LNG imports for pipeline distribution; it's unclear if sufficient LNG demand exists to also include dedicated LNG distribution which would avoid re-refrigeration costs. Staff estimates that transit agencies using LNG could realize noticeable if modest savings by avoiding these energy-based processing costs, given typical bus mileage and current and future energy prices.

At the same time, it is in the interests of oil producers to keep prices high enough to make as much money as they can, but low enough so users aren't really motivated to make changes which will reduce structural demand for oil and decrease their sales revenues.

In addition, environmental concerns continue to favor natural gas combustion over oil and coal, and demand for cleaner fuels may well continue to push up natural gas prices. However, it should be noted that imported LNG tends to include minor fractions of petroleum gases heavier than methane; if used as-is for transportation, these fractions would affect emissions slightly. The vast majority of natural gas is used for heating and other industrial processes; transportation is a minuscule portion of consumption. Thus, natural gas prices will be determined by forces largely unrelated to motor vehicle use.

Another aspect of infrastructure that may affect short-term prices would be the amount of natural gas storage in the South Coast region. Lack of sufficient storage may expose natural gas buyers to short-term price spikes, especially when demand equals or exceeds supply.

Historically, almost all LNG has been sold in long-term contracts with stable (though not necessarily unchanging) prices. Observers report that the market is diversifying, with short and medium term contracts becoming more available. Transit agencies that commit themselves to natural gas as a fuel would be well-advised to seriously consider medium or long-term contracts to ensure price stability for themselves, as well as to obtain the lower per-unit prices typical of larger contracts.

Lastly, reduced heating demand due to consistent weather changes such as global warming would tend to keep natural gas prices from rising as much as otherwise.

No extra fuel cost was included for gasoline HEBs, as HEB efficiencies and modest repair costs are expected to offset any price premium between gasoline HEBs and diesel.

5. Present-Value Cost Basis

All costs are presented in present value terms of 2005 dollars, where the "present" is defined as July 1, 2005. Capital costs are simply discounted at the annual real interest rate of 0.05, exclusive of inflation. Thus, current prices can be used for future purchases. Ongoing annual costs, such as maintenance and fuel, are also discounted at the real interest rate to put them in terms of 2005 dollars.

For converting future values (FV) to present values (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 (amortized) 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).

All these costs are predictions of future prices, so they could vary noticeably depending on demand, competition, and economic conditions, among other reasons.

6. Summary of Expected Costs

The most likely cost of complying with Alternative 1.3 is about $319,000,000, not including fuel surcharges or savings over the years. On an annualized basis, this is equivalent to about $29,400,000 per year over the 16 years from 2005 to 2021. These values are in 2005 dollars. As mentioned above, substituting CNG for diesel may turn out to yield either costs or savings, as predictions of future fuel prices are by far the most uncertain of the estimates used in the cost analysis of this regulation. Based on current market conditions where diesel is more expensive, average savings are estimated to be about $200,000,000 over the life of the regulation. Based on recent years when natural gas has been more expensive, additional costs of about $128,000,000 are estimated. Thus, estimated total costs are presented without fuel, and with estimates for both possible fuel savings and costs, for clarity.

The most likely cost of complying with Alternative 2 is about $7,676,000, not including fuel surcharges or savings over the years. On an annualized basis, this is equivalent about $708,000 per year over the 16 years from 2005 to 2021. These values are in 2005 dollars. As mentioned above, substituting CNG for diesel may turn out to yield either costs or savings, as predictions of future fuel prices are by far the most uncertain of the estimates used in the cost analysis of this regulation. Based on current market conditions where diesel is more expensive, average savings are estimated to be about $1,552,000 over the life of the regulation. Based on recent years when natural gas has been more expensive, additional costs of about $984,000 are estimated. As with Alternative 1.3, estimated total costs are presented without fuel, and with estimates for both possible fuel savings and costs, for clarity.

As mentioned above, overall total costs for natural gas buses are higher than for gasoline HEBs, so the per-bus costs for natural gas buses shown in Table 4 are higher than in Table 5 where most of the buses are gasoline HEBs.

Table 4. Total Typical Costs for Statewide Alternative-Fuel Case

Total	**Typical**
All But Fuel	**$319,000,125**
w/ Fuel NG>D	$446,670,798
w/ Fuel D>NG	$117,677,083
Total Per Bus	
All But Fuel	$76,517
w/ Fuel NG>D	$107,141
el D>NG	$28,227
Annualized	
All But Fuel	**$29,434,112**
w/ Fuel NG>D	$41,214,273
w/ Fuel D>NG	$10,858,054

Table 5. Total Typical Costs for SCAQMD Diesel Path Agencies Only

Total	**Typical**
All But Fuel	**$7,675,748**
w/ Fuel NG>D	$8,659,981
w/ Fuel D>NG	$6,123,718
Total Per Bus	
All But Fuel	$26,745
w/ Fuel NG>D	$30,174
el D>NG	$21,337
Annualized	
All But Fuel	**$708,241**
w/ Fuel NG>D	$799,056
w/ Fuel D>NG	$565,035

The overall costs of this scenario can also be presented on an actual expected annual basis. The averages of the cost estimates in 2005 dollars were used in Tables 6 and 7 below.

Table 6. Annual Expected Costs for Statewide Alternative-Fuel Case

Expected Annual Costs in $2005						
	Capital	Operations	Fuel D>NG	Total (D>NG)	Fuel NG>D	Total (NG>D)
2005	$5,188,703	$833,237	-$898,976	$5,122,965	$570,093	$6,592,033
2006	$3,268,475	$1,318,432	-$1,422,451	$3,164,456	$902,059	$5,488,966
2007	$14,155,979	$3,528,911	-$3,807,327	$13,877,562	$2,414,448	$20,099,338
2008	$14,117,156	$5,627,895	-$6,071,912	$13,673,139	$3,850,553	$23,595,605
2009	$12,739,053	$7,405,622	-$7,989,895	$12,154,781	$5,066,858	$25,211,533
2010	$31,755,599	$12,152,500	-$13,111,281	$30,796,818	$8,314,627	$52,222,726
2011	$23,658,165	$15,372,996	-$16,585,860	$22,445,301	$10,518,060	$49,549,221
2012	$5,487,719	$15,522,203	-$16,746,839	$4,263,083	$10,620,146	$31,630,068
2013	$6,636,697	$15,848,815	-$17,099,220	$5,386,292	$10,843,612	$33,329,124
2014	$7,189,755	$16,248,689	-$17,530,642	$5,907,802	$11,117,201	$34,555,645
2015	$8,201,814	$16,792,044	-$18,116,865	$6,876,992	$11,488,960	$36,482,817
2016		$15,992,423	-$17,254,157	-$1,261,734	$10,941,866	$26,934,289
2017		$14,766,901	-$15,931,947	-$1,165,046	$10,103,376	$24,870,277
2018		$13,771,446	-$14,857,955	-$1,086,509	$9,422,295	$23,193,741
2019		$11,849,826	-$12,784,727	-$934,901	$8,107,540	$19,957,366
2020		$10,023,183	-$10,813,970	-$790,787	$6,857,768	$16,880,951
2021		$9,545,889	-$10,299,019	-$753,130	$6,531,208	$16,077,096

Table 7. Annual Expected Costs for SCAQMD Diesel Path Agencies Only

Expected Annual Costs in $2005						
	Capital	Operations	Fuel D>NG	Total (D>NG)	Fuel NG>D	Total (NG>D)
2005	$1,882,737	$91,853	-$99,100	$1,875,491	$62,845	$2,037,435
2006	$537,665	$87,479	-$94,381	$530,764	$59,852	$684,997
2007	$1,306,129	$136,872	-$147,670	$1,295,331	$93,646	$1,536,648
2008	$1,357,018	$130,354	-$140,638	$1,346,734	$89,187	$1,576,559
2009	$1,029,880	$124,147	-$133,941	$1,020,085	$84,940	$1,238,967
2010		$118,235	-$127,563	-$9,328	$80,895	$199,130
2011		$112,605	-$121,489	-$8,884	$77,043	$189,648
2012		$107,243	-$115,704	-$8,461	$73,374	$180,617
2013		$102,136	-$110,194	-$8,058	$69,880	$172,016
2014		$97,272	-$104,947	-$7,674	$66,553	$163,825
2015		$92,640	-$99,949	-$7,309	$63,384	$156,024
2016		$88,229	-$95,190	-$6,961	$60,365	$148,594
2017		$66,528	-$35,474	$31,053	$22,496	$89,024
2018		$63,360	-$33,785	$29,575	$21,425	$84,785
2019		$50,139	-$32,176	$17,962	$20,405	$70,543
2020		$47,751	-$30,644	$17,107	$19,433	$67,184
2021		$45,477	-$29,185	$16,292	$18,508	$63,985

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