# Chapter VI: Cost-Effectiveness

This Chapter will present the cost-effectiveness analysis we completed for our new heavy-duty gasoline vehicle, heavy-duty diesel engine, and diesel fuel sulfur standards. Under Clean Air Act Section 202(a)(3), we are required to promulgate standards which reflect the greatest degree of emission reduction achievable, giving appropriate consideration to cost, energy, and safety factors. The standards we set are not premised on the need to promulgate the most cost-effective standards. However, we have determined that cost-effectiveness is a useful tool in evaluating the appropriateness of our standards.

The cost-effectiveness analysis described in this Section relies in part on cost information from Chapter V and emissions information from Chapter II to estimate the dollars per ton of emission reductions produced from our standards. We have calculated the cost effectiveness using two different approaches, a per-vehicle approach that considers the costs incurred and emission reductions produced for a single vehicle or engine, and a 30-year net present value approach that accounts for all costs and emission reductions over a 30 year period beginning in 2006. The comparative merits and drawbacks of both approaches are described in Sections VI.A and VI.E. Finally, this Chapter compares the cost-effectiveness of the new provisions with the cost-effectiveness of other control strategies from previous and potential future EPA programs.

Sections VI.A, VI.B and VI.C describe the per-vehicle calculations for our combined heavy-duty diesel engine and diesel fuel sulfur standards, while Section VI.D describes the per-vehicle calculations for heavy-duty gasoline vehicles. Section VI.E describes the 30-year net present value cost effectiveness analysis. The results of all cost-effectiveness calculations are given in Section VI.F. Comments we received in response to our Notice of Proposed Rulemaking on the subject of cost effectiveness, along with our responses to those comments, can be found in Issue 5.9 of the Response To Comments document.

## A. Overview of the Per-vehicle Analysis

The per-vehicle cost-effectiveness analysis conducted for our standards focused on the costs and emission reductions associated with a single engine (or vehicle, in the case of heavy-duty gasoline vehicle standards) meeting the 2007 model year standards, and operating on low sulfur fuel. Both costs and emission reductions were calculated over the life of the engine and then discounted at a rate of seven percent. Costs and emission reductions were measured relative to a baseline consisting of the 2004 certification standards and average diesel sulfur levels falling under the current 500 ppm cap. The calculations were performed separately for each engine class and the results weighted according to the expected fleet mix. Details on the per-vehicle approach to cost-effectiveness follow. The presentation of the 30-year net present value cost effectiveness calculations can be found in Section VI.E. This latter approach includes the fuels costs incurred by the pre-2007MY fleet which are not accounted for in the per-vehicle analysis. Note that many of the issues discussed in this Section VI.A also apply to the calculation of 30-year net present value cost-effectiveness.

### 1. Temporal and Geographic Applicability

Our per-engine approach to our cost-effectiveness calculations produces $/ton values representing any controlled engine, no matter where that engine operates. In effect, this means that emission reductions in both attainment and nonattainment areas are included in our cost-effectiveness analysis. The same holds true for our 30-year net present value analysis. Although this may limit the usefulness of comparisons to stationary source controls, we believe that our approach is appropriate. Both the engine and diesel sulfur programs are to apply nationwide, so the same emission reductions will occur regardless of where the engine operates. Attainment area emission reductions also produce health benefits. In general, the benefits of NMHC reductions in ozone attainment areas include reductions in emissions of air toxics, reductions in the contribution from NMHC emissions to the formation of fine particulate matter, and reductions in damage to agricultural crops, forests, and ecosystems from ozone exposure. Emission reductions in attainment areas help to maintain clean air as the economy grows and new pollution sources come into existence. Also, ozone health benefits can result from reductions in attainment areas, although the most certain health effects from ozone exposure below the NAAQS appear to be both transient and reversible. The closure letter from the Clean Air Science Advisory Committee (CASAC) for the recent review of the ozone NAAQS states that there is no apparent threshold for biological responses to ozone exposure.[1]

In the Regulatory Impact Analysis for a recent rulemaking for highway heavy-duty diesel engine standards,[2] EPA also presented a regional ozone control cost-effectiveness analysis in which the total life-cycle cost was divided by the discounted lifetime NOx + NMHC emission reductions adjusted for the fraction of emissions that occur in the regions expected to impact ozone levels in ozone nonattainment areas. (Air quality modeling indicates that these regions include all of the states that border on the Mississippi River, all of the states east of the Mississippi River, Texas, California, and any remaining ozone nonattainment areas west of the Mississippi River not already included.) The results of that analysis show that the regional cost-effectiveness values were 13 percent higher than the nationwide cost-effectiveness values. Because of the small difference between the two results, EPA is presenting only nationwide cost-effectiveness results for this analysis.

Despite the fact that a per-engine approach to cost-effectiveness allows us to avoid the arbitrary choice of a specific year in which to conduct the analysis, there is some value in examining different points in time after the program is first implemented. The costs of the program will be higher immediately after it is implemented than they will be after several years, since engine and vehicle manufacturers can take advantage of decreasing capital and operating costs over time, and will learn how to produce their products more efficiently as time goes on. For the purposes of this rulemaking, therefore, we will present cost-effectiveness of our program on both a near-term and long-term basis. More details concerning per-engine costs are given in Section VI.B.2 for diesel engines and in Section VI.D.1 for heavy-duty gasoline vehicles.

We are also proposing that our combined engine/sulfur program (hereafter, this includes our standards for heavy-duty diesel engines, heavy-duty gasoline vehicles, and diesel sulfur) be an annual program. Since cost-effectiveness only has relevance when compared to alternative strategies, we must use an approach to calculating the cost-effectiveness of our annual program that is consistent with the approaches taken for other rulemakings. For programs that generate emission reductions outside of the ozone season, we generally include those "winter season" reductions in the cost-effectiveness calculations. Thus our cost-effectiveness estimates will include all the emission reductions produced as a result of our standards, no matter where or when those reductions occur. This is consistent with the methodology used in prior rulemakings and allows for an apples-to-apples comparison.

### 2. Baselines

There are two broad approaches to cost-effectiveness that can be taken, each of which requires a different baseline. These two approaches can be termed "incremental" and "average." Both incremental and average approaches to cost-effectiveness provide a measure of how much more stringent than the existing standards our standards can be before they cease to be cost-effective.

An incremental approach to cost-effectiveness requires that we evaluate a number of different potential standards, each of which is compared to the potential standards closest to it. Using this approach, the cost-effectiveness of our standards would be calculated with respect to another set of potential standards which is less stringent than our standards. In this way, the $/ton values represent the last increment of control, highlighting any nonlinearities that exist in either the costs or emission reductions.

An average approach to cost-effectiveness, on the other hand, requires that we compare the costs and emission reductions associated with our standards to those for the previous set of standards that are being met by manufacturers. In this case, the $/ton values represent the full range of control from the last applicable standard to our standards.

As stated above, we must use an approach to cost-effectiveness that is consistent with the approach taken in other rulemakings in order to provide an apples-to-apples comparison. Most other mobile source rulemakings use average cost-effectiveness, including our recently promulgated standards for Tier 2 vehicles and gasoline sulfur. Therefore, we have chosen to calculate cost-effectiveness on an average rather than an incremental basis for our standards.

Since today's program includes both fuel standards and engine standards, it was necessary for us to define a baseline for both fuels and engines. For highway diesel fuel, the previous standard was set in 1990, limiting the sulfur content to a maximum of 500 ppm starting in 1993. However, the average sulfur level has been significantly less than 500 ppm, closer to 340 ppm.[3] Therefore we have determined that the sulfur baseline should be 340 ppm.

For heavy-duty diesel engines, the previous set of standards was originally set in 1997 and applies to the 2004 model year.[1] These standards included a 2.4 g/bhp-hr cap for NOx+NMHC or 2.5 g/bhp-hr with a 0.5 g/bhp-hr cap on NMHC. For the purposes of analysis we have assumed that manufacturers will met this standard with 2.3 g/bhp-hr NOx and 0.2 g/bhp-hr NMHC. However, unlike the PM standards we are proposing today, 2004 model year urban buses are required to meet a different PM standard (0.05 g/bhp-hr) than other heavy-duty engines (0.1 g/bhp-hr). Thus we have used two different baselines for PM, one for urban buses and another for other heavy-duty engines. Despite this, we are calculating only a single set of cost-effectiveness values for all engines since we are proposing that a single set of standards apply to urban buses and other heavy-duty engines.

For heavy-duty gasoline vehicles, the previous set of standards applies to the 2005 model year. For incompletes, these include a 1.0 g/bhp-hr NOx+NMHC standard, which we assume separates practically into a 0.8 g/bhp-hr standard for NOx and a 0.2 g/bhp-hr standard for NMHC. For Class 2b completes, the 2005 standards include 0.9 g/mile for NOx and 0.28 g/mile for NMHC. Finally, for Class 3 completes, the 2005 standards include 1.0 g/mi for NOx and 0.33 g/mi for NMHC.

## B. Diesel Costs

The costs used in our cost-effectiveness calculations are the sum of the added costs of compliance with the 2007 engine and diesel sulfur standards on a per-engine basis, in comparison to the engine and fuel baselines. Costs result from discounting over the lifetime of an engine at a seven percent discount rate. In addition, all costs represent the fleet-weighted average of all light, medium, and heavy-heavy engines, as well as urban buses.

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[a] Under a consent decree, many manufacturers will be complying with these heavy-duty standards as early as 2002. Standards were finalized in the Federal Register at 65 FR 59896, October 6, 2000.

### 1. Near and Long-Term Cost Accounting

Since the costs of complying with the 2007 engine standards will vary over time, we believe that it is appropriate to consider both near-term and long-term costs in our cost-effectiveness analysis. First, the capital costs associated with the manufacture of engines that will meet the 2007 standards would generally be amortized over five years. Thus in the sixth year of production, a portion of the capital costs become zero and the total costs of production drop. Manufacturers also gain knowledge about the best way to meet new standards as time goes on (the so-called "learning curve"), and as a result their operating costs decrease over time. The implications of this learning curve on engine costs is discussed in Section V.A.1.

Thus near-term costs represent the highest costs of the program, as they include all capital costs and no cost savings due to the manufacturer's learning curve. Long-term costs, on the other hand, represent the lowest costs of the program which occur after a portion of capital cost amortizations have ended and all learning curve cost savings have been accounted for. For the purposes of this rulemaking, therefore, we will present cost-effectiveness of our program on both a near-term and long-term basis. Details about the calculation of near and long-term engine costs can be found in Section V.A.

### 2. Diesel Engine and Fuel Costs

The per-engine costs used in our cost-effectiveness calculations were derived and presented in Section V.A. Engine hardware costs were presented in Section V.A for the four engine categories affected by our standards. For the purposes of calculating cost-effectiveness, we weighted the costs for those four individual engine categories by the expected fleet fractions (see Table VI.C-2 below) to obtain fleet-average costs for our emissions standards. Also, we treated first-year production costs as the "near-term" costs, and sixth-year production costs as the "long-term" costs. For low sulfur diesel, we used the discounted lifetime costs presented in Table V.C-36 which include costs for desulfurization, lubricity additives, and distribution costs. The costs used in our cost-effectiveness calculations are shown in Table VI.B-1.

**Table VI.B-1. Fleet-average, Per-engine Costs for HDDE**

| | *NOx adsorber, PM trap, and oxy catalyst ($)* | *Fuel cost ($)* | *Total costs ($)* |
|---|---|---|---|
| Near-term | 2457 | 1881 | 4338 |
| Long-term | 1332 | 1993 | 3325 |

Note that the total costs in Table VI.B-1 were used for establishing "uncredited" cost-effectiveness values. As described in Section VI.B.4, the costs from Table VI.B-1 were also adjusted to produce "credited" cost-effectiveness values.

### 3. Methodology for assigning costs to NOx, NMHC, and PM

The object of our cost-effectiveness analysis is to compare the costs to the emission reductions in an effort to assess the program's efficiency in helping to attain and maintain the NAAQS. Thus the primary purpose of our standards is to reduce emissions of the ozone precursors hydrocarbons and oxides of nitrogen, as well as emissions of particulate matter. Therefore, consistent with our approach in previous rulemakings such as the recently finalized standards for Tier 2 vehicles and gasoline sulfur, we have calculated cost-effectiveness on the basis of total NOx + NMHC emissions.

However, since we are also proposing that a new standard be set for PM, we must develop a separate cost-effectiveness value for that pollutant. We do not think it appropriate to combine NOx, NMHC, and PM all into a single cost-effectiveness value, since there are separate NAAQS for ozone and PM, and these two pollutants do not have identical effects on human health and the environment. We must therefore determine a reasonable way to split the costs of compliance with our combined engine/diesel sulfur program between NOx+NMHC and PM.

As described in Section III.A and in our Draft RIA, we expect that manufacturers will use both NOx adsorbers and PM traps to comply with our engine standards. However, since publication of the NPRM we have determined that NMHC emissions may not be sufficiently controlled by the NOx adsorber without the use of a clean-up oxidation catalyst downstream of the adsorber. See Section III.A.4 for a more detailed discussion of this issue. The NOx adsorber and oxidation catalyst will together enable heavy-duty diesel engines to meet our new NOx and NMHC standards. As a result, we believe that the total hardware costs associated with the NOx adsorber and oxidation catalyst should be applied to the calculation of NOx+HC cost-effectiveness. The PM trap will continue to provide reductions in both PM and HC as well as pre-conditioning the engine-out exhaust stream for introduction to the NOx adsorber. As a result, for the purposes of calculating cost-effectiveness, we believe that the hardware costs of the PM trap should be divided equally between PM and NOx+HC, consistent with the approach taken in the NPRM.

In order to divide the fuel costs appropriately between NOx+HC and PM, we have taken an approach consistent with that described in the Draft RIA. The diesel fuel sulfur cap of 15 ppm has been implemented in order to enable the two aftertreatment components of PM trap and NOx adsorber (+ oxidation catalyst) to operate properly. Since the fuel sulfur standard applies equally to both components of the aftertreatment, we believe it is appropriate to divide fuel costs evenly between the PM trap and the NOx adsorber (+ oxidation catalyst).

However, as described above, the PM trap will continue to provide reductions in both PM and HC, pre-conditioning the engine-out exhaust stream for introduction to the NOx adsorber. We therefore believe it is appropriate to divide the fuel costs applicable to the trap, calculated as half of total fuel costs, equally between PM and HC. As a result, 25 percent of total fuel costs would apply to the calculation of PM cost effectiveness, while the remaining 75 percent would apply to the calculation of cost effectiveness for NOx+NMHC. Likewise, half of the hardware costs for the PM trap would be included in the calculation of cost effectiveness for NOx+NMHC. This approach is consistent with that taken in the NPRM

### 4. Cost Crediting for $SO_2$

The reduction in diesel sulfur levels that would result from our standards will necessarily result in reductions in sulfur-containing compounds that exit the engine. These compounds are limited to sulfur dioxide ($SO_2$) and sulfate particulate matter. The latter will be taken into account as manufacturers seek to comply with our new PM standard, and thus will be automatically represented in our cost-effectiveness estimates of $/ton PM. However, there is no engine standard for $SO_2$. Since reductions in emissions of $SO_2$ are beneficial and represent a true value of our program, we believe it is appropriate to account for them in our cost-effectiveness analysis.

The primary benefit of reductions in $SO_2$ emissions is a reduction in secondary PM, formed when $SO_2$ reacts with water and ammonia in the atmosphere to form ammonium sulfate. Therefore, we believe that any crediting for reductions in $SO_2$ should be applied to our PM costs.

To account for reductions in emissions of $SO_2$ in our cost-effectiveness calculations, we have calculated a second set of $/ton values in which we credit some of the costs to $SO_2$, with the remaining costs being used to calculate $/ton PM. As a result, we have produced both "credited" and "uncredited" $/ton PM values; the former takes into account the $SO_2$ emission reductions associated with our standards, while the latter does not.

Cost-effectiveness values for the control of $SO_2$ represent conservative estimates of the cost of measures that would need to be implemented in the future in order for all areas to reach attainment. Such cost-effectiveness values are therefore an appropriate source for estimating the amount of the costs to credit to $SO_2$. As a result, we credited some costs to $SO_2$ through the application of cost-effectiveness ($/ton) values for this pollutant drawn from other sources.

In concept, we would consider the most expensive program needed to reach attainment to be a good representation of the ultimate value of $SO_{2.}$ However, in this rulemaking, we chose to simplify by using more conservative approaches to establish crediting values for $SO_2$. The potential future programs evaluated as part of the NAAQS revisions rulemaking (discussed in more detail in Section VI.F below) provided a reasonable source for identifying the value of $SO_2$

in terms of its cost-effectiveness. In this process we did not make a distinction between $SO_2$ emissions from mobile or stationary sources since there is little data to suggest that a tons of $SO_2$ from one source contributes differently to PM or acid rain problems than a ton of $SO_2$ from another source.

Out of the nine $SO_2$ control programs evaluated in the NAAQS revisions rule, eight were actually used in the modeling of ambient concentrations of PM based on their contribution to secondary PM (sulfate) levels in PM nonattainment areas. The cost-effectiveness of the eight $SO_2$ control programs ranged from $1600/ton to $111,500/ton. In this particular rulemaking, we have for simplicity's sake used the average cost effectiveness of the eight $SO_2$ control programs, calculated to be $4800 a ton. This average value of $4800/ton was used in the crediting of some costs to $SO_2$, and represents a conservative valuation of $SO_2$.

The cost crediting was applied after all costs associated with compliance with our standards were calculated and summed. The per-engine tons reduced of $SO_2$ was multiplied by the representative cost-effectiveness value of $4800/ton (see Section VI.C.2 below for $SO_2$ tons calculations). As a result, $446 of the total costs were apportioned to $SO_2$ in the calculation of PM cost-effectiveness. This amount is independent of whether we are considering a near-term or long-term cost-effectiveness calculation, since the lifetime tons reduced for this compound is the same, on a per-engine basis, in any year of the program. A summary of the costs used in our cost-effectiveness calculations is given below in Table VI.B-2, including all engine, fuel, and fuel economy costs.

**Table VI.B-2. Fleet Average Per-Engine Costs for HDDE Used in Cost-effectiveness**

| | *Near-term costs ($)* | | *Long-term costs ($)* | |
|---|---|---|---|---|
| | NOx+NMHC | PM | NOx+NMHC | PM |
| Total uncredited costs | 3381 | 956 | 2563 | 762 |
| $SO_2$ credit allocation | n/a | -446 | n/a | -446 |
| Total credited costs | 3381 | 510 | 2563 | 316 |

## C. Emission Reductions from Diesel Engines

In order to determine the overall cost-effectiveness of the standards we are proposing, it was necessary to calculate the lifetime tons of each pollutant reduced on a per engine basis. This section will describe the steps involved in these calculations. In general, emission reductions were calculated for NOx, NMHC, PM, and $SO_2$ in a manner analogous to the discounted lifetime fuel costs described in Section V.C.6.

### 1. NOx, NMHC, and PM

The discounted lifetime tonnage numbers for NOx, NMHC, and PM for our combined diesel engine and diesel fuel standards were based on the difference between emissions produced by engines meeting our 2004 and 2007 standards, as described in Section II.B.1. These in-use emission levels were expressed in terms of average g/bhp-hr emissions for each year in a engine's life, up to 30 years. From this basis, lifetime tonnage estimates were developed using the following procedure:

1) Annual mileage accumulation levels for MOBILE6 were applied to the in-use emission rates for each year in a engine's life to generate total mass emissions produced in each year by that engine (this step included the use of bhp-hr/mile conversion factors)

2) The resultant mass emissions were multiplied by the probability of survival in the appropriate year, known as the "survival" rate.

3) A seven percent annual discount factor, compounded from the first year of the engine's life, was then applied for each year to allow calculation of net present value lifetime emissions.

Converting to tons and summing across all years results in the total discounted lifetime per-engine tons. This calculation can be described mathematically as follows:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \bullet (ER)_i \bullet (CF) \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE = Discounted lifetime emissions in tons/engine
$(AVMT)_i$ = Annual miles traveled in year i of a engine's operational life[4]
$(SURVIVE)_i$ = Probability of engine survival after i years of service
$(ER)_i$ = Emission rate, g/bhp-hr in year i of an engine's operational life
CF = Heavy-duty engine conversion factor, bhp-hr/mile (see Appendix VI-A)
K = Mass conversion factor, $1.102 \times 10^{-6}$ tons/gram
i = Engine years of operation, counting from 1 to 30

For NOx, NMHC, and PM, we generated discounted lifetime tonnage values for each engine class (LH, MH, HH, and urban buses) using the above equation. This was done separately for the baseline and control cases. The baseline case included the 2004 model year engine standards and the in-use diesel sulfur level of 340 ppm. The control case entailed our 2007 model year engines standards and 7 ppm diesel sulfur. The tonnage values that we calculated according to this procedure are shown in Table VI.C-1.

**Table VI.C-1. Per-engine Discounted Lifetime Tons for HDDE**

| | *NOx* | *NMHC* | *PM* |
|---|---|---|---|
| Baseline | | | |
| LH | 0.409 | 0.037 | 0.017 |
| MH | 0.970 | 0.086 | 0.041 |
| HH | 3.661 | 0.325 | 0.157 |
| Urban bus | 4.300 | 0.174 | 0.097 |
| Control | | | |
| LH | 0.035 | 0.025 | 0.001 |
| MH | 0.084 | 0.059 | 0.002 |
| HH | 0.320 | 0.224 | 0.009 |
| Urban bus | 0.357 | 0.155 | 0.010 |

The final step before calculating the cost-effectiveness of our program was to weight the discounted lifetime tonnage values for each engine class by their respective fraction of the HDDE fleet. These fractions were based on engine count projections for use in MOBILE6 for the year 2020 for diesel-powered heavy-duty engines (see Appendix VI-A), which in turn were based on current sales fractions for new vehicles. Table VI.C-2 presents the final weighting factors we used to develop fleet-average tonnage values.

**Table VI.C-2. Engine Class Sales Weighting Factors for HDDE**

| | |
|---|---|
| Light-heavy duty | 0.342 |
| Medium-heavy duty | 0.323 |
| Heavy-heavy duty | 0.326 |
| Urban buses | 0.009 |

The final discounted lifetime tonnage values for an average fleet engine meeting either the 2004 or 2007 standards are shown in Table VI.C-3. It is these values that were used directly in calculating the cost-effectiveness of our program.

**Table VI.C-3. Fleet average, Per-engine Discounted Lifetime Tons for HDDE**

| | NOx + NMHC | PM |
|---|---|---|
| Baseline: 2004 standards with 340 ppm fuel | 1.8329 | 0.07117 |
| Control: 2007 standards with 7 ppm fuel | 0.2490 | 0.00399 |
| Reduction | 1.5839 | 0.06718 |

## 2. Sulfur Dioxide

The sulfur contained in diesel fuel exits the tailpipe as either sulfuric acid, a sulfate which is a component of primary particulate matter, or as sulfur dioxide ($SO_2$). Sulfur dioxide is formed in the engine, and its conversion into sulfuric acid is a function of the type of aftertreatment and temperature in the tailpipe. If there is no aftertreatment (as is expected to be the case for engines meeting the 2004 standards), only about 2 percent of sulfur ends up being converted into sulfuric acid, with the remaining 98 percent being retained as $SO_2$. A large percentage of the $SO_2$ exiting the tailpipe is converted to sulfate (primarily ammonium sulfate) in the atmosphere. For engines meeting our 2007 standards, however, we expect the conversion rate of $SO_2$ to sulfuric acid to be much higher, closer to 30 percent, due to the use of particulate traps. Thus the calculation of tons of $SO_2$ reduced due to our program compares a baseline of 340 ppm and 98 percent $SO_2$ retention to a control of 7 ppm and 70 percent $SO_2$ retention.

Discounted lifetime tons of $SO_2$ reduced is calculated as the difference between tons of $SO_2$ for the baseline minus tons of $SO_2$ for our program, where tons are calculated according to the following equation:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \div (FE) \bullet (D) \bullet (SUL) \bullet (F) \bullet (MC) \bullet (CF) \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE = Discounted lifetime emissions of $SO_2$ in tons/engine for either the baseline or our control program
$(AVMT)_i$ = Annual engine miles traveled in year i of a engine's operational life
$(SURVIVE)_i$ = Fraction of engines still operating after i years of service
FE = Fuel economy by engine class (see Appendix VI-A)
D = Density of diesel, 7.1 lb/gal
SUL = Diesel sulfur concentration, 3.4 $x10^{-4}$ lb sulfur/lb fuel (340 ppm) for the baseline and 0.07 $x10^{-4}$ lb sulfur/lb fuel (7 ppm) for our program
F = Fraction of total sulfur which exits the tailpipe as $SO_2$ (0.98 for baseline case and 0.70 for control case)
MC = Molar conversion factor, 2 lb $SO_2$ per lb sulfur
CF = Heavy-duty engine conversion factor, bhp-hr/mile
K = Mass conversion factor, 5.0 x $10^{-4}$ tons/lb
i = Engine years of operation, counting from 1 to 30

After applying the above equation separately for each engine class and weighting the resulting tonnage values according to the factors presented in Table VI.C-2, we determined that the fleet-average, per-engine discounted lifetime tons of $SO_2$ reduced is 0.0929. This is the value that was used to determine the $SO_2$-based credit that was applied to the total costs as described in Section VI.B.4 and summarized in Table VI.B-2.

## D. Costs and Emission Reductions for Heavy-duty Gasoline Vehicles

Since we are also proposing new standards for heavy-duty gasoline vehicles (HDGV), we have calculated the costs and tons reduced for these standards as well. We did this on a per-vehicle basis, consistent with our approach for diesel engines described above. However, unlike for our diesel engine standards, our HDGV standards are not associated with new gasoline specifications, since a standard of 30 ppm sulfur has already been set in the preceding Tier 2/gasoline sulfur rulemaking.

### 1. Gasoline Vehicle Costs

The impact of our standards for HDGV was discussed in Section III.B and the associated compliance costs were discussed in Section V.B.5. We have made use of the per-vehicle costs shown in Table V.B-5 in our cost-effectiveness analysis, assuming that near-term costs are represented by the 2008-2009 values, and long-term costs are represented by the 2013+ values. We weighted the costs for the incompletes, Class 2b completes, and Class 3 completes by their respective contributions to the 2020 fleet (see Table VI.D-3). The fleet-average costs are repeated in Table VI.D-1 below.

**Table VI.D-1. Fleet-average, Per-vehicle Costs for HDGV Used in Cost-effectiveness**

| | *Total costs ($)* |
|---|---|
| Near-term | 198 |
| Long-term | 167 |

## 2. Emission Reductions from Gasoline Vehicles

The discounted lifetime tonnage numbers for NOx and NMHC for our HDGV standards were based on the difference between emissions produced by vehicles meeting our 2005 and 2007 standards. Section II.B describes the base emission factors, conversions, and adjustments used to calculate the in-use emissions in grams/mile produced by HDGVs for each year of a vehicle's life. From this basis, lifetime tonnage estimates were developed using the following procedure:

1) Annual mileage accumulation levels for MOBILE6 were applied to the in-use emission rates for each year in a vehicle's life to generate total mass emissions produced in each year by that vehicle

2) The resultant mass emissions were multiplied by the probability of survival in the appropriate year, known as the "survival" rate.

3) A seven percent annual discount factor, compounded from the first year of the engine's life, was then applied for each year to allow calculation of net present value lifetime emissions.

Converting to tons and summing across all years results in the total discounted lifetime per-vehicle tons. This calculation can be described mathematically as follows:

$$LE = \sum [\{(AVMT)_i \bullet (SURVIVE)_i \bullet (ER)_i \bullet (K)\}/(1.07)^{i-1}]$$

Where:

LE = Discounted lifetime emissions in tons/vehicle
$(AVMT)_i$ = Annual miles traveled in year i of a HDGV's operational life
$(SURVIVE)_i$ = Probability of survival after i years of service
$(ER)_i$ = Emission rate, g/mi in year i of a vehicle's operational life
K = Mass conversion factor, $1.102 \times 10^{-6}$ tons/gram
i = Vehicle years of operation, counting from 1 to 24

For NOx and NMHC, we generated discounted lifetime tonnage values for each vehicle class (incompletes, Class 2B completes, and Class 3 completes) using the above equation. This was done separately for the baseline and control cases. The baseline case included the 2005 model year vehicle standards, while the control case entailed our 2007 model year vehicle standards. The tonnage values that we calculated according to this procedure are shown in Table VI.D-2.

**Table VI.D-2. Per-vehicle Discounted Lifetime Tons for HDGV**

| | *NOx + NMHC* |
|---|---|
| <u>Baseline</u> | |
| Incompletes | 0.261 |
| Class 2B completes | 0.271 |
| Class 3 completes | 0.269 |
| <u>Control</u> | |
| Incompletes | 0.170 |
| Class 2B completes | 0.166 |
| Class 3 completes | 0.192 |

The final step before calculating the cost-effectiveness of our program was to weight the discounted lifetime tonnage values for each vehicle class by their respective fraction of the HDGV fleet. These fractions were based on vehicle count projections for 2020 for gasoline-powered heavy-duty vehicles, which in turn were based on current sales of new vehicles. Table VI.D-3 presents the final weighting factors we used to develop fleet-average tonnage values.

**Table VI.D-3. Vehicle Class Sales Weighting Factors for HDGV**

| | |
|---|---|
| Incompletes | 0.288 |
| Class 2B completes | 0.692 |
| Class 3 completes | 0.020 |

The final discounted lifetime tonnage values for an average fleet engine meeting either the 2005 or 2007 standards are shown in Table VI.D-4. It is these values that were used directly in calculating the cost-effectiveness of our program.

**Table VI.D-4. Fleet average, Per-vehicle Discounted Lifetime Tons for HDGV**

| | *NOx + NMHC* |
|---|---|
| Baseline: 2004 standards | 0.268 |
| Control: 2007 standards | 0.167 |
| Baseline - control | 0.100 |

Note that although we are proposing new PM standards for HDGV in order to establish consistency with the HDDE PM standards, current HDGV are believed to already meet this PM standard. Therefore, there are no PM emission reductions associated with HDGV.

Since we are calculating a single set of cost-effectiveness values for both diesel engines and gasoline vehicles, it was necessary for us to weight the costs and emission reductions for HDDE and HDGV by the fraction of new diesel-powered and gasoline-powered heavy-duty vehicles in the fleet. These fractions are based on current sales of new vehicles, or the corresponding estimates of in-use vehicle counts far into the future. We have chosen 2020 to represent the far future for the purposes of this analysis. The According to projections for MOBILE6, in year 2020 the in-use heavy-duty fleet will be composed of approximately 50 percent diesel-powered and 50 percent gasoline-powered vehicles. We applied this weighting to the NOx+NMHC costs from Tables VI.B-2 and VI.D-1 to obtain per-vehicle costs representing all heavy-duty vehicles (PM reductions are only produced by our HDDE standards, so the PM cost-effectiveness values represent only HDDE). We likewise applied the 50:50 weighting to the NOx+NMHC tons reduced from Tables VI.C-3 and VI.D-4. Final costs and tons reduced for the entire heavy-duty fleet on a per-vehicle basis are given in Table VI.F-1 below.

## E. 30-year Net Present Value Cost-Effectiveness

The per-vehicle approach described in the preceding sections is designed to show the cost-effectiveness of our program for 2007 and later model year engines complying with our new standards. It presumes that all delays and the Temporary Compliance Option have been completed and the fleet has fully turned over to engines meeting our standards. However, the per-vehicle approach does not account for costs and emission reductions associated with the existing (pre-2007 model year) fleet due to operation on diesel fuel meeting our 15 ppm cap, nor does it take into account phased-in engine or temporary fuel provisions at the start of the program.

We have also calculated the cost effectiveness of our program using a “30-year net present value” approach that includes all nationwide emission reductions and costs for a 30 year period. This timeframe captures both the early period of the program when very few vehicles/engines meeting our standards will be in the fleet, and the later period when essentially all vehicles/engines in the fleet will meet our standards. The 30-year net present value approach also accounts for cost and emission impacts of our 15 ppm sulfur cap on engines manufactured before model year 2007. The 30-year net present value approach does have one important drawback in that it includes the engine costs for engines sold 30 years after the program goes into effect, but includes almost none of the emission benefits from those engines. Thus the 30-year net present value approach does not necessarily match all costs with all the emission reductions that those costs are intended to produce. It is presented here, nevertheless, as a reasonable measure of the cost effectiveness of this combined vehicle-fuel program.

We have calculated this “30-year net present value” cost-effectiveness using the net present value of the annual emission reductions and costs described in Sections II and V, respectively. The calculation of 30-year net present value cost-effectiveness follows the pattern described above for the per-engine analysis:

$$\text{DNAE} = \sum (\text{NE})_i / (1.07)^{i-2006}$$

Where:

DNAE = Reduction in nationwide 30-year net present value emissions in tons
$(\text{NE})_i$ = Reduction in nationwide emissions in tons for year i of the program
i = Year of the program, counting from 2006 to 2035

and

$$\text{DNAC} = \sum (\text{NC})_i / (1.07)^{i-2006}$$

Where:

DNAC = Nationwide 30-year net present value costs in dollars
$(NC)_i$ = Nationwide costs in dollars for year i of the program
i = Year of the program, counting from 2006 to 2035

The 30-year net present value cost-effectiveness is produced by dividing DNAC by DNAE. The nationwide reductions in emissions for each year are given in Section II. The nationwide costs are given in Table V.D-1. The results are given in Table VI.F-2 below.

## F. Results

We calculated the cost-effectiveness of our standards using two different approaches. The first divides the total per-vehicle, discounted lifetime costs by the total per-vehicle, discounted lifetime tons reduced for our HDDE standards, diesel sulfur standard, and HDGV standards. The results are given in Table VI.F-1.

**Table VI.F-1. Per-vehicle Cost-effectiveness of the Standards**

| *Pollutants* | *Discounted lifetime vehicle & fuel costs* | *Discounted lifetime emission reductions (tons)* | *Discounted lifetime cost effectiveness per ton* | *Discounted lifetime cost effectiveness per ton with $SO_2$ credit** |
|---|---|---|---|---|
| <u>Near-term costs</u> | | | | |
| NOx + NMHC | 1789 | 0.8421 | 2,125 | 2,125 |
| PM | 956 | 0.0672 | 14,237 | 7,599 |
| <u>Long-term costs</u> | | | | |
| NOx + NMHC | 1365 | 0.8421 | 1,621 | 1,621 |
| PM | 762 | 0.0672 | 11,340 | 4,701 |

* $446 credited to $SO_2$ (at $4800/ton) for PM cost effectiveness

We also calculated the cost-effectiveness of our program on a 30-year net present value basis for our diesel engine, diesel fuel sulfur, and gasoline vehicle standards. To do this, we summed net present value of total costs from Section V.D, and divided by the sum of the net present value of tons reduced from Sections II.B.2 and II.C. These costs and emission reductions are repeated in Appendices VI-B and VI-C. The results are given in Table VI.F-2.

**Table VI.F-2. 30-year Net Present Value Cost-effectiveness of the Standards**

| | *30-year n.p.v. engine, vehicle, & fuel costs* | *30-year n.p.v. reduction (tons)* | *30-year n.p.v. cost effectiveness per ton* | *30-year n.p.v. cost effectiveness per ton with $SO_2$ credit** |
|---|---|---|---|---|
| NOx + NMHC | $34.9 billion | 16.2 million | $2,149 | $2,149 |
| PM | $10.3 billion | 0.8 million | $13,607 | $4,195 |

* $7.1 billion credited to $SO_2$ (at $4800/ton)

The values in Tables VI.F-1 and VI.F-2 differ from those in the NPRM for several reasons. First, our estimate of costs increased for HDDE, HDGV, and diesel fuel sulfur as described in SectionV. Second, the NMHC benefits associated with HDDE were reduced due to our re-evaluation of the means through which manufacturers would meet our new standards, as described in Section II.B. Third, our final program includes a phase-in for the engine standards and a Temporary Compliance Option for the fuel sulfur standards, which reduced both the costs and emission reductions in the first few years of the program.

Since many of the benefits and costs are manifest in future years, we apply discounting methods to adjust the dollar values of these effects to reflect the finding that society as a whole typically values the realization (or avoidance) of a given effect differently depending on when the effect occurs. In the discounting calculations used to produce the net present values that were used in our cost-effectiveness calculations, we used a discount rate of 7 percent, consistent with the 7 percent rate reflected in the cost-effectiveness analyses for other recent mobile source programs. OMB Circular A-94 requires us to generate benefit and cost estimates reflecting a 7 percent rate.

However, we anticipate that the primary cost and cost-effectiveness estimates for future proposed mobile source programs will reflect a 3 percent rate. The 3 percent rate is in the 2 to 3 percent range recommended by the Science Advisory Board's Environmental Economics Advisory Committee for use in EPA social benefit-cost analyses, a recommendation incorporated in EPA's new *Guidelines for Preparing Economic Analyses (November 2000).* This recommendation was published after the current program was proposed. Therefore, we have also calculated the overall cost-effectiveness of today's rule based on a 3 percent rate to facilitate comparison of the cost-effectiveness of this rule with future proposed rules which use the 3 percent rate. The results are shown in Tables VI.F-3 and VI.F-4.

**Table VI.F-3. Per-vehicle Cost-effectiveness of the Standards Using 3 Percent ROI and Discount Rate**

| *Pollutants* | *Discounted lifetime vehicle & fuel costs* | *Discounted lifetime emission reductions (tons)* | *Discounted lifetime cost effectiveness per ton* | *Discounted lifetime cost effectiveness per ton with $SO_2$ credit** |
|---|---|---|---|---|
| Near-term costs | | | | |
| NOx + NMHC | 1860 | 0.9961 | 1,867 | 1,867 |
| PM | 1008 | 0.0786 | 12,817 | 6,168 |
| Long-term costs | | | | |
| NOx + NMHC | 1452 | 0.9961 | 1,458 | 1,458 |
| PM | 821 | 0.0786 | 10,439 | 3,790 |

* $523 credited to $SO_2$ (at $4800/ton) for PM cost effectiveness.

**Table VI.F-4. 30-year Net Present Value Cost-effectiveness of the Standards Using 3 Percent ROI and Discount Rate**

| | *30-year n.p.v. engine, vehicle, & fuel costs* | *30-year n.p.v. reduction (tons)* | *30-year n.p.v. cost effectiveness per ton* | *30-year n.p.v. cost effectiveness per ton with $SO_2$ credit** |
|---|---|---|---|---|
| NOx + NMHC | $54.6 billion | 30.6 million | $1,784 | $1,784 |
| PM | $16.0 billion | 1.4 million | $11,791 | $3,384 |

* $11.4 billion credited to $SO_2$ (at $4800/ton)

Because the primary purpose of cost-effectiveness is to compare our program to alternative programs, we made a comparison between the values in Tables VI.F-1 and VI.F-2 and the cost-effectiveness of other programs. Table VI.F-5 summarizes the cost effectiveness of several recent EPA actions for controlled emissions from mobile sources for NOx and NMHC, while Table VI.F-6 does the same for PM. The programs shown in these tables are those for which cost-effectiveness was calculated in a similar manner allowing for an apples-to-apples comparison.

**Table VI.F-5. Cost-effectiveness of Previous Mobile Source Programs for NOx + NMHC**

| *Program* | *$/ton* |
|---|---|
| Tier 2 vehicle/gasoline sulfur | 1,340 - 2,260 |
| 2004 Highway HD diesel | 212 - 414 |
| Off-highway diesel engine | 425 - 675 |
| Tier 1 vehicle | 2,054 - 2,792 |
| NLEV | 1,930 |
| Marine SI engines | 1,171 - 1,846 |
| On-board diagnostics | 2,313 |
| Marine CI engines | 24 - 176 |

Note: costs adjusted to 1999 dollars.

**Table VI.F-6. Cost-effectiveness of Previous Mobile Source Programs for PM**

| *Program* | *$/ton* |
|---|---|
| Marine CI engines | 5222 -3881 |
| 1996 urban bus | 12,264 - 19,622 |
| Urban bus retrofit/rebuild | 30,251 |
| 1994 highway HD diesel | 20,900 - 24,467 |

Note: costs adjusted to 1999 dollars.

By comparing values from Tables VI.F-1 and VI.F-2 for NOx+NMHC to those in Table VI.F-5 we can see that the cost-effectiveness of our engine/diesel sulfur standards falls within the range of these other programs. Our program overlaps the range of the recently promulgated standards for Tier 2 light-duty vehicles and gasoline sulfur shown in Table VI.F-5. Our program also overlaps the cost-effectiveness of past programs for PM. It is true that some previous programs have been more cost efficient than the program we are proposing today. However, it should be expected that the next generation of standards will be more expensive than the last, since the least costly means for reducing emissions is generally pursued first.

The primary advantage of making comparisons to previously implemented programs is that their cost-effectiveness values were based on a rigorous analysis and are generally accepted as representative of the efficiency with which those programs reduce emissions. Unfortunately, previously implemented programs can be poor comparisons because they may not be representative of the cost-effectiveness of potential future programs. Therefore, in evaluating the cost-effectiveness of our engine/diesel sulfur program, we also considered whether our proposal is cost-effective in comparison with potential future means of controlling emissions.  In the context of the Agency's rulemaking which would have revised the ozone and PM NAAQS[2], the Agency compiled a list of additional known technologies that could be considered in devising new emission reductions strategies.[5]  Through this broad review, over 50 technologies were identified that could reduce NOx, VOC, or PM.  The cost-effectiveness of these technologies averaged approximately $5,000/ton for VOC, $13,000/ton for NOx, and $40,000/ton for PM. Although a $10,000/ton limit was actually used in the air quality analysis presented in the NAAQS revisions rule, these values clearly indicate that, not only are future emission control strategies likely to be more expensive (less cost-effective) than past strategies, but the cost-effectiveness of our engine/diesel sulfur program falls within the range of potential future strategies.

In summary, given the array of controls that will have to be implemented to make progress toward attaining and maintaining the NAAQS, we believe that the weight of the evidence from alternative means of providing substantial NOx + NMHC and PM emission reductions indicates that our engine/diesel sulfur program is cost-effective.  This is true from the perspective of other mobile source control programs or from the perspective of other stationary source technologies that might be considered.

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[b] This rulemaking was remanded by the D.C. Circuit Court on May 14, 1999.  However, the analyses completed in support of that rulemaking are still relevant, since they were designed to investigate the cost-effectiveness of a wide variety of potential future emission control strategies.

# APPENDIX VI - A: Factors Used in Diesel Engine Calculations for Cost-effectiveness

| *MOBILE6 engine class* | *Weight category*[A] | *Sales weighting*[B] | *Conversion factors, bhp-hr/mi*[B] | *Fuel economy, miles/gal*[D] |
|---|---|---|---|---|
| Class 2B | LH | 0.199 | 1.09 | 12.96 |
| Class 3 | LH | 0.060 | 1.25 | 11.66 |
| Class 4 | LH | 0.056 | 1.458 | 10.2 |
| Class 5 | LH | 0.027 | 1.573 | 9.88 |
| Class 6 | MH | 0.115 | 1.942 | 8.71 |
| Class 7 | MH | 0.164 | 2.409 | 7.53 |
| Class 8A | HH | 0.098 | 2.763 | 6.59 |
| Class 8B | HH | 0.227 | 3.031 | 6.3 |
| School buses | MH | 0.044 | 2.989 | 6.18 |
| Urban transit buses | HH | 0.009 | 4.679 | 3.79 |

[A] LH = Light heavy duty, MH = Medium heavy duty, HH = Heavy heavy duty.

[B] Based on 2020 heavy-duty diesel engine count, Tables 17 & 18 from EPA Report Number EPA420-P-99-011, April 1999, "Fleet characterization data for MOBILE6: development and use of age distributions, average annual mileage accumulation rates and projected vehicle counts for use in MOBILE6."

[C] Tables 28 and 30 from EPA Report Number EPA420-P-98-015, May 1998, "Update heavy-duty engine emission conversion factors for MOBILE6: Analysis of BSFCs and calculation of heavy-duty engine emission conversion factors."

[D] Tables 14 and 15 from EPA Report Number EPA420-P-98-014, May 1998, "Update heavy-duty engine emission conversion factors for MOBILE6: Analysis of fuel economy, non-engine fuel economy improvements, and fuel densities.

# APPENDIX VI - B: Costs used in 30-year Net Present Value Cost Effectiveness Analysis ($millions)

| | *Diesel NOx adsorber + oxy catalyst* | *Diesel PM trap* | *Gasoline vehicle* | *Diesel sulfur* |
|---|---|---|---|---|
| 2006 | (49) | (32) | 0 | 880 |
| 2007 | 765 | 501 | 0 | 1,786 |
| 2008 | 798 | 523 | 46 | 1,809 |
| 2009 | 648 | 425 | 80 | 1,904 |
| 2010 | 918 | 602 | 81 | 2,014 |
| 2011 | 740 | 485 | 82 | 2,128 |
| 2012 | 684 | 449 | 83 | 2,160 |
| 2013 | 699 | 458 | 78 | 2,192 |
| 2014 | 713 | 467 | 79 | 2,225 |
| 2015 | 689 | 452 | 80 | 2,258 |
| 2016 | 698 | 458 | 82 | 2,292 |
| 2017 | 700 | 459 | 83 | 2,327 |
| 2018 | 714 | 468 | 84 | 2,362 |
| 2019 | 728 | 477 | 85 | 2,397 |
| 2020 | 741 | 486 | 86 | 2,433 |
| 2021 | 753 | 494 | 87 | 2,469 |
| 2022 | 766 | 502 | 89 | 2,506 |
| 2023 | 778 | 510 | 90 | 2,544 |
| 2024 | 789 | 518 | 91 | 2,582 |
| 2025 | 801 | 525 | 92 | 2,621 |
| 2026 | 812 | 532 | 93 | 2,660 |
| 2027 | 823 | 540 | 94 | 2,700 |
| 2028 | 834 | 547 | 95 | 2,741 |
| 2029 | 844 | 554 | 97 | 2,782 |
| 2030 | 855 | 561 | 98 | 2,824 |
| 2031 | 865 | 567 | 99 | 2,866 |
| 2032 | 876 | 574 | 100 | 2,909 |
| 2033 | 886 | 581 | 101 | 2,953 |
| 2034 | 896 | 588 | 102 | 2,997 |
| 2035 | 906 | 594 | 104 | 3,042 |

# APPENDIX VI - C: Emission Reductions Used in 30-year Net Present Value Cost Effectiveness Analysis (thousand tons)

| | *Diesel NOx* | *Diesel VOC* | *Diesel PM* | *Diesel SOx* | *Gasoline NOx* | *Gasoline VOC* |
|---|---|---|---|---|---|---|
| 2006 | 0 | 0 | 5 | 78 | 0 | 0 |
| 2007 | 58 | 2 | 11 | 79 | 0 | 0 |
| 2008 | 160 | 7 | 19 | 80 | 2 | 1 |
| 2009 | 255 | 12 | 27 | 82 | 7 | 2 |
| 2010 | 406 | 17 | 35 | 107 | 13 | 5 |
| 2011 | 599 | 22 | 41 | 109 | 19 | 7 |
| 2012 | 776 | 27 | 46 | 111 | 24 | 9 |
| 2013 | 939 | 32 | 51 | 113 | 29 | 10 |
| 2014 | 1,090 | 37 | 56 | 115 | 34 | 12 |
| 2015 | 1,228 | 43 | 61 | 117 | 38 | 13 |
| 2016 | 1,356 | 47 | 65 | 119 | 43 | 15 |
| 2017 | 1,473 | 52 | 69 | 121 | 48 | 16 |
| 2018 | 1,581 | 56 | 73 | 122 | 51 | 18 |
| 2019 | 1,680 | 60 | 77 | 124 | 55 | 20 |
| 2020 | 1,772 | 64 | 82 | 126 | 58 | 21 |
| 2021 | 1,857 | 66 | 85 | 128 | 63 | 23 |
| 2022 | 1,939 | 69 | 88 | 129 | 67 | 24 |
| 2023 | 2,017 | 71 | 91 | 131 | 70 | 25 |
| 2024 | 2,091 | 74 | 93 | 133 | 72 | 26 |
| 2025 | 2,163 | 76 | 96 | 134 | 75 | 27 |
| 2026 | 2,232 | 78 | 99 | 136 | 78 | 28 |
| 2027 | 2,299 | 80 | 101 | 137 | 80 | 29 |
| 2028 | 2,364 | 83 | 104 | 139 | 83 | 30 |
| 2029 | 2,428 | 85 | 106 | 140 | 86 | 31 |
| 2030 | 2,490 | 87 | 109 | 142 | 88 | 32 |
| 2031 | 2,552 | 89 | 111 | 143 | 91 | 33 |
| 2032 | 2,615 | 91 | 113 | 144 | 94 | 34 |
| 2033 | 2,677 | 93 | 116 | 146 | 96 | 35 |
| 2034 | 2,739 | 94 | 118 | 147 | 99 | 36 |
| 2035 | 2,801 | 96 | 120 | 149 | 102 | 37 |

## Chapter VI. References

1. U.S. EPA; Review of NAAQS for Ozone, Assessment of Scientific and Technical Information, Office of Air Quality Planning and Standards Staff Paper; document number:  EPA-452\R-96-007.

2. "Final Regulatory Impact Analysis: Control of Emissions of Air Pollution from Highway Heavy-Duty Engines."  September 16, 1997.  Alan Stout, U.S. EPA, OAR/OMS/EPCD.

3. "A Review of Current and Historical Nonroad Diesel Fuel Sulfur Levels", Memorandum from David J. Korotney to EPA Air Docket A-97-10, March 3, 1998, Docket Item II-B-01.

4. Table 6, Agency Report Number EPA420-P-99-011, "Fleet characterization data for MOBILE6: development and use of age distributions, average annual mileage accumulation rates and projected vehicle counts for use in MOBILE6," April 1999.

5. “Regulatory Impact Analyses for the Particulate Matter and Ozone National Ambient Air Quality Standards and Regional Haze Rule,” Appendix B, “Summary of control measures in the PM, regional haze, and ozone partial attainment analyses,” Innovative Strategies and Economics Group, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, NC, July 17, 1997.