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Air and Radiation

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Regulatory Impact Analysis:

Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements

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Executive Summary

This Regulatory Impact Analysis assesses the feasibility, costs, benefits, cost-effectiveness, and other issues associated with the Environmental Protection Agency's finalized program that sets new federal emission standards for heavy-duty vehicles and places limits on the level of sulfur in diesel fuel. A complete discussion of the details of the program can be found in the preamble to the regulations published in the Federal Register. The key results of this Regulatory Impact Analysis are discussed below.

Health and Welfare Concerns

When revising emissions standards for heavy-duty vehicles, the Agency considers the effects of air pollutants emitted from heavy-duty vehicles on public health and welfare. As discussed in more detail below, the outdoor, or ambient, air quality in many areas of the country is expected to violate federal health-based ambient air quality standards for ground level ozone and particulate matter during the time when this rule would take effect. In addition, some studies have found public health and welfare effects from ozone and PM at concentrations that do not constitute a violation of their respective NAAQS. Other studies have associated diesel exhaust with a variety of cancer and noncancer health effects. Of particular concern is human epidemiological evidence linking diesel exhaust to an increased risk of lung cancer. Emissions from heavy-duty vehicles also contribute to a variety of environmental and public welfare effects such as impairment of visibility/ regional haze, acid deposition, eutrophication/nitrification, and POM deposition. The standards finalized in this rule will result in a significant improvement in ambient air quality and public health and welfare.

Feasibility of Emission Standards

During the past 15 years advancements have continued to be made in the development of diesel exhaust emission control devices. Several emission control devices have emerged to control harmful diesel particulate matter constituents, including the diesel oxidation catalyst and the many forms of particulate filters or traps. Diesel oxidation catalysts have been shown to be durable in-use, but they control only a small fraction of the total particulate matter and consequently do not address our concerns sufficiently. The same is true of un-catalyzed diesel particulate filters. Catalyzed diesel particulate filters have the potential to provide major reductions in diesel particulate matter emissions and provide the durability and dependability required for diesel applications. Precious metal catalyzed particulate filters, in conjunction with low sulfur diesel fuel, have been shown to be more than 90 percent effective over the federal test procedure and the not-to-exceed zone, a level of efficiency that demonstrates a capability of meeting the applicable standards. Therefore, we believe the catalyzed diesel particulate filter will be the control technology of choice for future control of diesel particulate matter emissions.

However, these devices cannot be brought to market on diesel applications unless low sulfur diesel fuel is available.

Several exhaust emission control devices have also been developed to control diesel NOx emissions. Today’s lean NOx catalyst is capable at best of steady-state NOx reductions of less than 10 percent, eliminating it from serious consideration as a tool for meeting the future emission standards. Both selective catalytic reduction systems and NOx adsorbers have the potential to provide significant emission reductions, although we believe that the NOx adsorber is the most likely candidate to be used to meet future low diesel exhaust emission standards that apply to the heavy-duty diesel market. However, the NOx adsorber technology cannot be brought to market on diesel engines and vehicles unless low sulfur diesel fuel is available.

These developments make the widespread commercial use of diesel exhaust emission controls feasible. Through the use of these devices, emissions control similar to that attained by gasoline applications will be possible with diesel applications. However, without low sulfur diesel fuel, these technologies cannot be implemented on heavy-duty diesel applications. Low sulfur diesel fuel will at the same time allow these technologies to be implemented on light-duty diesel applications.

Improvements also continue to be made to technologies for controlling emissions from gasoline engines and vehicles. This includes improvements to catalyst designs in the form of improved washcoats and improved precious metal dispersion. Significant effort has also been put into improving cold start strategies that allow for more rapid light-off of the catalyst. These strategies include retarding the spark timing to increase the temperature of the exhaust gases and using air-gap manifolds, exhaust pipes, and catalytic converter shells to decrease heat loss from the system. These improvements to gasoline emission controls will be made in response to recent regulations from California and the EPA that established more stringent emission standards for the light-duty sector. These improvements should transfer well to the heavy-duty gasoline segment of the fleet. With the optimization of these and additional existing technologies for the heavy-duty gasoline sector, we believe that significant reductions in emissions from heavy-duty gasoline engines and vehicles can be realized, thus allowing vehicles to meet more stringent emission standards. The sulfur content of the fuel is a critical ingredient for gasoline engines as well. The Tier 2 gasoline sulfur reduction that requires sulfur levels to be reduced to a 30 parts per million average with an 80 parts per million cap will enable the technology needed to meet the heavy-duty standards in the same way that it enables compliance with the Tier 2 standards.

Fuel Standard Feasibility

In order to meet the 15 parts per million sulfur cap, refiners are likely to further hydrotreat their highway diesel fuel in much the same way as it is being done today to meet the current federal sulfur limits. Improvements to current hydrotreaters can be used to reduce diesel fuel sulfur beyond that being done to meet the current requirements. However, these improvements alone do not appear to be sufficient to provide compliance with the 15 parts per million cap. Based on past commercial experience, it is very possible to incorporate current distillate hydrotreaters into designs which provide compliance with the proposed 15 parts per million cap. Thus, the equipment added to meet the current requirements in the early 1990's will continue to be very useful in meeting a more stringent standard.

The primary changes to refiners' current distillate hydrotreating systems are likely to be:

1) the use of a second reactor to increase residence time, possibly incorporating counter-current flow characteristics, or the addition of a completely new second stage hydrotreater;
2) the use of more active catalysts, including those specially designed to desulfurize sterically hindered sulfur containing material;
3) greater hydrogen purity and less hydrogen sulfide in the recycle gas; and,
4) possible use of higher pressure in the reactor.

Existing commercial hydrotreaters are already producing distillate with average sulfur levels below 10 parts per million, which should be more than sufficient to meet the new requirements. Therefore, the 15 parts per million cap appears to be quite feasible given today's distillate processing technology. Advances continue to be made in catalyst technology, with greater amounts of sulfur being able to be removed at the same reactor size, temperature and pressure. Therefore, it is reasonable to expect that distillate hydrotreaters put into service in the 2006 timeframe will utilize even more active catalysts than those available today.

Other existing methods may help to reduce diesel fuel sulfur levels, but will generally not be sufficient to provide compliance with a 15 parts per million cap. However, we expect that a number of refiners will utilize these techniques to reduce the severity of their distillate hydrotreaters and reduce hydrogen consumption (particularly by avoiding aromatic saturation). Some of these techniques would tend to increase the supply of highway diesel fuel while others would tend to decrease it.

Biodesulfurization technology holds promise to reduce distillate sulfur without the high temperatures and pressures involved in hydrotreating. Efforts are underway to demonstrate that this technology can achieve 50 parts per million sulfur or less in the next few years. However, it is not clear whether this technology would be sufficient to meet a 15 parts per million cap.

In addition, despite the heightened challenge to the distribution industry caused by our sulfur program, it will be feasible to distribute 15 parts per million highway diesel fuel with relatively minor modifications to existing systems to limit contamination from higher sulfur products. These modifications can be accomplished at modest additional costs.

Economic Impact: Diesel Engines

The technologies we expect to be used to meet the new requirements represent significant technological advancements for controlling emissions, but also make clear that much effort remains to develop and optimize these new technologies for maximum emission-control effectiveness with minimum negative impacts on engine performance, durability, and fuel consumption. On the other hand, it has become clear that manufacturers have a great potential to advance beyond the current state of understanding by identifying aspects of the key technologies that contribute most to hardware or operational costs or other drawbacks and pursuing improvements, simplifications, or alternatives to limit those burdens. To reflect this investment in long-term cost savings potential, the cost analysis includes an estimated $385 million in R&D outlays for heavy-duty engine designs and $220 million in R&D for catalysts systems giving a total R&D outlay for improved emission control of more than $600 million. The cost and technical feasibility analyses accordingly reflect substantial improvements on the current state of technology due to these future developments.

Estimated costs are broken into additional hardware costs and life-cycle operating costs. The incremental hardware costs for new engines are comprised of variable costs (for hardware and assembly time) and fixed costs (for R&D, retooling, and certification). Total operating costs include the estimated incremental cost for low-sulfur diesel fuel, any expected increases in maintenance cost or fuel consumption costs along with any decreases in operating cost expected due to low-sulfur fuel. Cost estimates based on these projected technology packages represent an expected incremental cost of engines in the 2007 model year. Costs in subsequent years will be reduced by several factors, as described below. Separate projected costs were derived for engines used in three service classes of heavy-duty diesel engines. All costs are presented in 1999 dollars.

The costs of these new technologies for meeting the 2007 model year standards are itemized in the RIA and summarized in Table V.A-1. For light heavy-duty vehicles, the cost of an engine is estimated to increase by $1,990 in the early years of the program reducing to $1,170 in later years and operating costs over a full life-cycle to increase by approximately $600. For medium heavy-duty vehicles the cost of a new engine is estimated to increase by $2,560 initially decreasing to $1,410 in later years with life-cycle operating costs increasing by approximately $1,200. Similarly, for heavy heavy-duty engines, the vehicle cost in the first year is expected to increase by $3,230 decreasing to $1,870 in later years. Estimated additional life-cycle operating costs for heavy heavy-duty engines are approximately $4,600. The higher incremental increase in operating costs for the heavy heavy-duty vehicles is due to the larger number of miles driven over their lifetime (714,000 miles on average) and their correspondingly high lifetime fuel usage. Emission reductions are also proportional to VMT and so are significantly higher for heavy heavy-duty vehicles.

We also believe there are factors that will cause cost impacts to decrease over time, making it appropriate to distinguish between near-term and long term costs. Our analysis incorporates the effects of this learning curve by projecting that the variable costs of producing the low-emitting engines decrease by 20 percent starting with the third year of production (2009 model year) and by reducing variable costs again by 20 percent starting with the fifth year of production. Additionally, since fixed costs are assumed to be recovered over a five-year period, these costs are not included in the analysis after the first five model years. Finally, manufacturers are expected to apply ongoing research to make emission controls more effective and to have lower operating cost over time. However, because of the uncertainty involved in forecasting the results of this research, we have conservatively not accounted for it in this analysis.

Table ES-1 lists the projected costs for each category of vehicle in the near- and long-term. For the purposes of this analysis, “near-term” costs are those calculated for the 2007 model year and “long term” costs are those calculated for 2012 and later model years.

Table ES-1. Projected Incremental System Cost and Life Cycle Operating Cost for Heavy-Duty Diesel Vehicles (Net Present Values in the year of sale, 1999 dollars)

Vehicle Class	Model Year	Hardware Cost	Life-cycle Operating Cost[A]
Light heavy-duty	near term	$1,990	$627
	long term	$1,170	$543
Medium heavy-duty	near term	$2,560	$1,165
	long term	$1,410	$1,007
Heavy heavy-duty	near term	$3,230	$4,626
	long term	$1,870	$4,030

[A] Incremental life-cycle operating costs include the incremental costs to refine and distribute low sulfur diesel fuel, the service cost of closed crankcase filtration systems, the maintenance cost for PM filters and the lower maintenance costs realized through the use of low sulfur diesel fuel (see discussion in Section V.C).

Economic Impact: Gasoline Vehicles

To perform a cost analysis for the final gasoline standards, we first determined a package of likely technologies that manufacturers could use to meet the standards and then determined the costs of those technologies. In making our estimates, we have relied on our own technology assessment which included publicly available information such as that developed by California, confidential information supplied by individual manufacturers, and the results of our own in-house testing.

In general, we expect that heavy-duty gasoline vehicles would (like Tier 2 light duty vehicles) be able to meet these standards through refinements of current emissions control components and systems rather than through the widespread use of new technology. More specifically, we anticipate a combination of technology upgrades such as the following:

- Improvements to the catalyst system design, structure, and formulation, plus an increase in average catalyst size and loading.
- Air and fuel system modifications including changes such as improved oxygen sensors, and calibration changes including improved precision fuel control and individual cylinder fuel control.
- Exhaust system modifications, possibly including air gapped components, insulation, leak free exhaust systems, and thin wall exhaust pipes.
- Increased use of fully electronic exhaust gas recirculation (EGR).
- Increased use of secondary air injection.
- Use of ignition spark retard on engine start-up to improve upon cold start emission control.
- Use of low permeability materials and minor improvements to designs, such as the use of low-loss connectors, in evaporative emission control systems.

We expect that the technologies needed to meet the heavy-duty gasoline standards will be very similar to those required to meet the Tier 2 standards for vehicles over 8,500 pounds GVWR. Few heavy-duty gasoline vehicles currently rely on technologies such as close coupled catalysts and secondary air injection, but we expect they would to meet the new standards.

For each group we developed estimates of both variable costs (for hardware and assembly time) and fixed costs (for R&D, retooling, and certification). Cost estimates based on the current projected costs for our estimated technology packages represent an expected incremental cost of vehicles in the near-term. For the longer term, we have identified factors that would cause cost impacts to decrease over time. First, since fixed costs are assumed to be recovered over a five-year period, these costs disappear from the analysis after the fifth model year of production. Second, the analysis incorporates the expectation that manufacturers and suppliers would apply ongoing research and manufacturing innovation to making emission controls more effective and less costly over time. Our analysis incorporates the effects of this “learning curve” by projecting that a portion of the variable costs of producing the new vehicles decreases by 20 percent starting with the third year of production.

We have prepared our cost estimates for meeting the new heavy-duty gasoline standards using a baseline of current technologies for heavy-duty gasoline vehicles and engines. Finally, we have incorporated what we believe to be a conservatively high level of R&D spending at $2,500,000 per engine family where no California counterpart exists. We have included this large R&D effort because calibration and system optimization is likely to be a critical part of the effort to meet the standards. However, we believe that the R&D costs may be generous because the projection probably underestimates the carryover of knowledge from the development required to meet the light-duty Tier 2 and CARB LEV-II standards.

Table ES-2 provides our estimates of the per vehicle cost for heavy-duty gasoline vehicles and engines. The near-term cost estimates are for the first years that vehicles meeting the standards are sold, prior to cost reductions due to lower productions costs and the retirement of fixed costs. The long-term projections take these cost reductions into account. In the absence of changes to gasoline specifications and with no decrease in fuel economy expected, we do not expect any increase in vehicle operating costs.

Table ES-2. Projected Incremental System Cost and Life Cycle Operating Cost for Heavy-Duty Gasoline Vehicles (Net Present Values in the year of sale, 1999 dollars)

Vehicle Class	Model Year	Incremental System Cost	Life-cycle Operating Cost
Heavy-Duty Gasoline	near term	$198	$0
	long term	$167	$0

Economic Impact: Fuel Sulfur Requirements

We estimate that the overall net cost associated with producing and distributing 15 ppm diesel fuel, when those costs are allocated to all gallons of highway diesel fuel, will be approximately 5.0 cents per gallon in the long term, or an annual cost of roughly $2.2 billion per year once the program is fully effective starting in 2010. During the initial years under temporary compliance option, the overall net cost is projected to be 4.5 cents per gallon, or an annual cost of roughly $1.7 billion per year.

This cost consists of a number of components associated with refining and distributing the new fuel. The majority of the cost is related to refining. From 2006-2010, refining costs are estimated to be approximately 3.3 cents per gallon of highway diesel fuel, increasing to 4.3 cents per gallon once the program is fully in place. In annual terms, the 2006-2010 refining costs are expected to be about $1.4 billion per year, increasing to about $1.8 billion in 2010. These figures include the cost of producing slightly more volume of diesel fuel because: 1) desulfurization decreases the energy density of the fuel and 2) slightly more highway diesel fuel is expected to be downgraded to nonroad diesel fuel in the distribution system.

A small cost of 0.2 cents per gallon is associated with an anticipated increase in the use of additives to maintain fuel lubricity. Also, distribution costs are projected to increase by 1.0 cents per gallon during the initial years under the temporary compliance option, including the cost of distributing slightly greater volumes of fuel. Together, these two cost components only amount to about $0.5 billion per year beginning in 2006. These costs drop to only about $0.3 billion in 2011 when the temporary compliance option and hardship provisions are over.

Operation with 15 parts per million sulfur diesel fuel is expected to reduce average vehicle maintenance costs by approximately 1 cent on a per gallon basis. Beginning in 2011, this reduction in maintenance costs will total roughly $400 million per year.

Economic Impact: Aggregate Costs

Using current data for the size and characteristics of the heavy-duty vehicle fleet and making projections for the future, the diesel per-engine, gasoline per-vehicle, and per-gallon fuel costs described above can be used to estimate the total cost to the nation for the emission standards in any year. Figure ES-1 portrays the results of these projections.

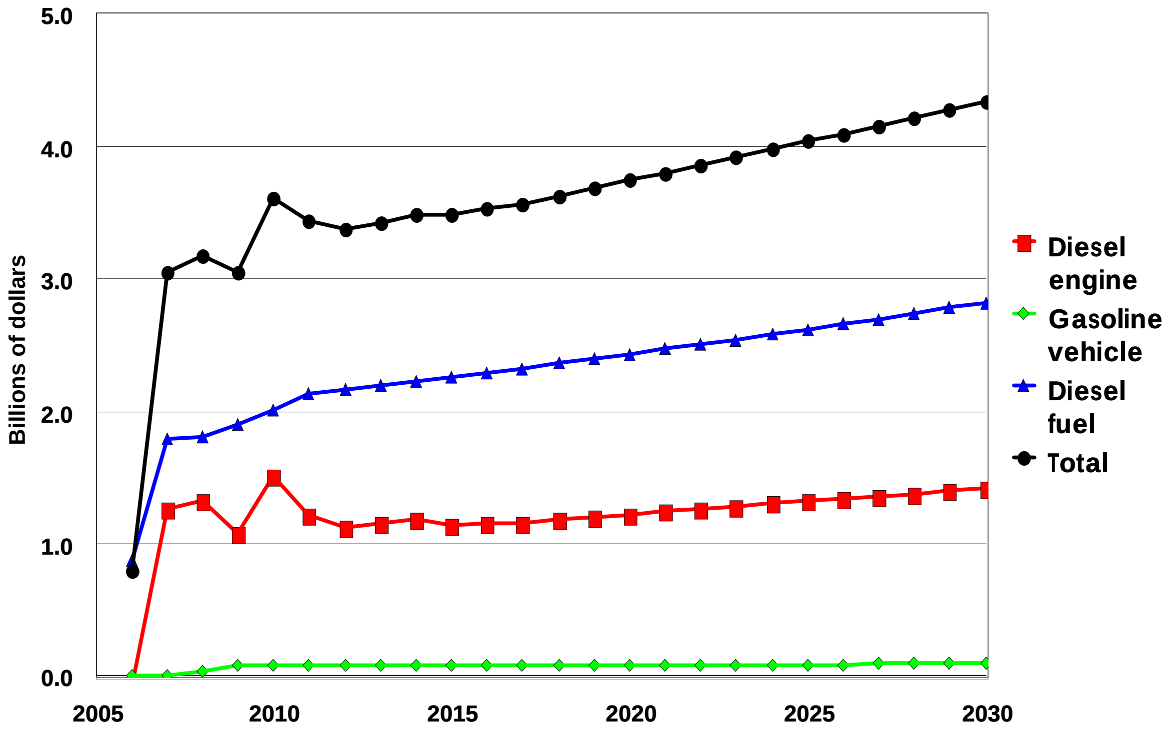

Figure ES-1. Total Annualized Costs

As can be seen from the figure, the annual costs start out at less than 1.0 billion dollars in year 2006 and increase during the initial years to about $3.6 billion in 2010. Thereafter, total annualized costs are projected to continue increasing due to the effects of projected growth in engine sales and fuel consumption.

Future consumption of 15 parts per million diesel fuel may be influenced by a potential influx of diesel-powered cars and light trucks into the light-duty fleet. The possibility exists that diesels will become more prevalent in the car and light-duty truck fleet, since automotive companies have announced their desire to increase their sales of diesel cars and light trucks. A sensitivity analysis of diesel penetration into the light-duty vehicle fleet results in the expectation that the effect of increased penetration of desiels in the light-duty fleet will likely have little or no impact on the aggregate costs estimated for the standards being finalized in today's action.

Cost-Effectiveness

We have calculated the cost-effectiveness of our diesel engine/gasoline vehicle/diesel sulfur standards based on two different approaches. The first considers the net present value of all costs incurred and emission reductions generated over the life of a single vehicle meeting our standards. This per-vehicle approach focuses on the cost-effectiveness of the program from the point of view of the vehicles and engines which will be used to meet the new requirements. However, the per-vehicle approach does not capture all of the costs or emission reductions from our diesel engine/gasoline vehicle/diesel sulfur program since it does not account for the use of 15 parts per million diesel fuel in current diesel engines. Therefore, we have also calculated a 30-year net present value cost-effectiveness using the net present value of costs and emission reductions for all in-use vehicles over a 30-year time frame. The baseline or point of comparison for this evaluation is the previous set of engine, vehicle, and diesel sulfur standards (in other words, the applicable 2006 model year standards).

The cost of complying with the new standards will decline over time as manufacturing costs are reduced and amortized capital investments are recovered. To show the effect of declining cost in the per-vehicle cost-effectiveness analysis, we have developed both near term and long term cost-effectiveness values. More specifically, these correspond to vehicles sold in years one and six of the vehicle and fuel programs.

The 30-year net present value approach to calculating the cost-effectiveness of our program involves the net present value of all nationwide emission reductions and costs for a 30 year period beginning with the start of the diesel fuel sulfur program and introduction of model year 2007 vehicles and engines in year 2006. This 30-year timeframe captures both the early period of the program when very few vehicles that meet our standards will be in the fleet, and the later period when essentially all vehicles in the fleet will meet the new standards. We have calculated the 30-year net present value cost-effectiveness using the net present value of the nationwide emission reductions and costs for each calender year.

Our per-vehicle and 30-year net present value cost-effectiveness values are given in the following tables. The tables summarize the net present value lifetime costs, NMHC + NOx and PM emission reductions, and resulting cost-effectiveness results for our diesel engine/gasoline vehicle/diesel sulfur standards using sales weighted averages of the costs (both near term and long term) and emission reductions of the various vehicle and engine classes affected for the two different approaches. Diesel fuel costs applicable to diesel engines have been divided equally between the adsorber and trap, since 15 parts per million diesel fuel is intended to enable all technologies to meet our standards. In addition, since the trap produces reductions in both PM and hydrocarbons, we have divided the total trap costs equally between compliance with the PM standard and compliance with the NMHC standard.

The tables also display cost-effectiveness values based on two approaches to account for the reductions in SO_2 emissions associated with the reduction in diesel fuel sulfur. While these reductions are not central to the program and are therefore not displayed with their own cost-effectiveness, they do represent real emission reductions due to our program. The first set of cost-effectiveness numbers in the tables simply ignores these reductions and bases the cost-effectiveness on only the NOx, NMHC, and PM emission reductions from our program. The second set accounts for these ancillary reductions by crediting some of the cost of the program to SO_2. The amount of cost allocated to SO_2 is based on the cost-effectiveness of SO_2 emission reductions that could be obtained from alternative, potential future EPA programs. The SO_2 credit was applied only to the PM calculation, since SO_2 reductions are primarily a means to reduce ambient PM concentrations.

Table ES-3. Per-Engine[A] Cost Effectiveness of the Standards for 2007 and Later MY Vehicles

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[B]
Near-term costs				
NOx + NMHC	$1937	0.8421	$2,300	$2,300
PM	$1055	0.0672	$15,697	$9,058
Long-term costs				
NOx + NMHC	$1346	0.8421	$1,599	$1,599
PM	$755	0.0672	$11,243	$4,604

[A] As described above, per-engine cost effectiveness does not include any costs or benefits from the existing, pre-control, fleet of vehicles that would use the 15 parts per million diesel fuel.

[B] $446 credited to SO_2 (at $4800/ton) for PM cost effectiveness

Table ES-4. 30-year Net Present Value[A] 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[B]
NOx + NMHC	$34.7 billion	16.2 million	$2,137	$2,137
PM	$10.2 billion	0.8 million	$13,598	$4,383

[A] This cost effectiveness methodology reflects the total fuel costs incurred in the early years of the program when the fleet is transitioning from pre-control to post-control diesel vehicles. In 2007 <10% of highway diesel fuel is anticipated to be consumed by 2007 MY vehicles. By 2012 this increases to >50% for 2007 and later MY vehicles.

[B] $6.9 billion credited to SO_2 (at $4800/ton).

Cost-Benefit Analysis

We also made an assessment of the monetary value of the health and general welfare benefits that are expected from the HD Engine/Diesel Fuel rule in 2030. We estimate that this rule would, in the long term, result in substantial benefits, such as the yearly avoidance of: approximately 8,300 premature deaths, approximately 5,500 cases of chronic bronchitis, roughly 361,400 asthma attacks, and significant numbers of hospital visits, lost work days, and multiple respiratory ailments (including those that affect children). Our standards will also produce welfare benefits related to the reduction of agricultural crop damage, impacts on forest productivity, visibility, and nitrogen deposition in rivers and lakes.

Total monetized benefits of the HD Engine/Diesel Fuel rule in 2030 are expected to be approximately $70.4 billion. Total monetized benefits, however, are driven primarily by the value placed on the reductions in premature deaths. In the primary estimate, these represent close to 89 percent of total monetized benefits. We estimate the monetary benefit of reducing premature mortality risk using the "value of statistical lives saved" (VSL) approach, even though the actual valuation is of small changes in mortality risk experienced by a large number of people. Since the publication of the Tier 2/Gasoline Sulfur standards earlier this year, EPA has obtained additional advice from its Science Advisory Board (SAB) on the proper characterization of this value and alternatives to EPA's primary estimate of mortality benefits. Following the advice of the SAB, EPA currently uses the VSL approach in calculating the primary estimate of mortality benefits, because the method reflects the direct application of what EPA and the SAB consider to be the most reasonable estimates for valuation of premature mortality available in the current economics literature.

However, the economics literature concerning the appropriate method for valuing reductions in premature mortality risk is still developing. There is general agreement that the value to an individual of a reduction in mortality risk tends to vary based on several factors, including the age of the individual, the type of risk, the level of control the individual has over the risk, the individual's attitudes towards risk, and the health status of the individual. While the limited empirical basis for adjusting the VSL used by EPA for many of these factors does not meet the SAB's standards of reliability at this time, a thorough discussion of these factors is contained in the benefits TSD for this RIA (Abt Associates, 2000). Age in particular may be an important difference between populations affected by air pollution mortality risks and populations affected by workplace risks. Premature mortality risks from air pollution tend to affect the very old more than the working age population. As such, any adjustments to VSL for age differences may have a large impact on total benefits. EPA recognizes the need for further research to improve estimates of the value of premature mortality risk reduction, including potential adjustments to VSL for age and other factors mentioned above.

Based on recent advice from the SAB, our benefits estimates account for expected growth in real income. Economic theory argues that a person's willingness to pay for most goods (such as environmental protection) will increase as real incomes increase. There is substantial empirical evidence in the economics literature for this idea, although there is uncertainty about its exact value. Based on a review of the available literature, we adjust the valuation of human health benefits and visibility improvements upward to account for projected growth in real U.S. income to 2030.

As summarized in Table ES-5, our primary estimate of monetary benefits realized in 2030 will be approximately $70.4 billion dollars ($1999), including an adjustment for growth in real income as described above. Comparing this estimate of the economic benefits with the adjusted cost estimate indicates that in 2030 the net economic benefits of the HD Engine/Diesel Fuel rule to society are approximately $66.2 billion dollars ($1999). Due to the uncertainties associated with this estimate of net benefits, it should be considered along with other components of this RIA, such as: reductions in adverse health and environmental outcomes, total cost, cost-effectiveness, and other benefits and costs that could not be monetized.

Table ES-5. 2030 Annual Monetized Costs, Benefits, and Net Benefits for the Final HD Engine/Diesel Fuel Rule[A]

	Billions of 1999$
Annual compliance costs	$4.2
Monetized PM-related benefits[B]	$69.0 + $\mathbf{B_{PM}}$
Monetized Ozone-related benefits[B,C]	$1.4 + $\mathbf{B_{Ozone}}$
NMHC-related benefits	not monetized ($\mathbf{B_{NMHC}}$)
CO-related benefits	not monetized ($\mathbf{B_{CO}}$)
Total annual benefits	$70.4 +$\mathbf{B_{PM}}$ + $\mathbf{B_{Ozone}}$ + $\mathbf{B_{NMHC}}$ + $\mathbf{B_{CO}}$
Monetized net benefits[D]	$66.2 + **B**

[A] For this section, all costs and benefits are rounded to the nearest 100 million. Thus, figures presented in this chapter may not exactly equal benefit and cost numbers presented in earlier sections of the chapter.

[B] Not all possible benefits or disbenefits are quantified and monetized in this analysis. Potential benefit categories that have not been quantified and monetized are listed in Table VII-1**.** Unmonetized PM- and ozone-related benefits are indicated by B_{PM}. And B_{Ozone}, respectively.

[C] Ozone-related benefits are only calculated for the Eastern U.S. due to unavailability of reliable modeled ozone concentrations in the Western U.S. This results in an underestimate of national ozone-related benefits. See US EPA (2000a) for a detailed discussion of the UAM-V ozone model and model performance issues.

[D] **B** is equal to the sum of all unmonetized benefits, including those associated with PM, ozone, CO, and NMHC.

Table ES-6 shows the impact of alternative assumptions about key inputs to the benefits analysis, including the concentration-response function relating particulate matter and premature mortality and the dollar value of reductions in the risk of premature mortality. These calculations are based on specific, plausible alternatives to the inputs used in deriving our primary estimate in Table ES-5. See Chapter VII of the RIA for a complete discussion of these and other important alternative calculations and their associated uncertainties.

Table ES-6. Key Alternative Benefits Calculations for the HD Engine/Diesel Fuel Rule in 2030[A]

Description of Alternative		Avoided Incidences	Impact on Primary Benefits Estimate Adjusted for Growth in Real Income (billion 1999$)
Alternative Concentration-Response Functions for PM-related Premature Mortality			
1	Krewski/ACS Study Regional Adjustment Model[B]	9,400	+$7.4 (+11%)
2	Pope/ACS Study[C]	9,900	+12.8 (+18%)
3	Krewski/Harvard Six-city Study[D]	24,200	+$118.5 (+169%)
Alternative Methods for Valuing Reductions in Incidences of PM-related Premature Mortality			
Value of avoided premature mortality incidences based on age-specific VSL.[E]	Jones-Lee (1989)	8,300	-$28.5 (-41%)
	Jones-Lee (1993)	8,300	-$6.8 (-10%)

[A] Please refer to Section 7.F of the RIA for complete information about the estimates in this table.

[B] This C-R function is included as a reasonable specification to explore the impact of adjustments for broad regional correlations, which have been identified as important factors in correctly specifying the PM mortality C-R function..

[C] The Pope et al. C-R function was used to estimate reductions in premature mortality for the Tier 2/Gasoline Sulfur benefits analysis. It is included here to provide a comparable estimate for the HD Engine/Diesel Fuel rule.

[D] The Krewski et al. “Harvard Six-cities Study” estimate is included because the Harvard Six-cities Study featured improved exposure estimates, a slightly broader study population (adults aged 25 and older), and a follow-up period nearly twice as long as that of Pope, et al. and as such provides a reasonable alternative to the primary estimate.

[E] Jones-Lee (1989) provides an estimate of age-adjusted VSL based on a finding that older people place a much lower value on mortality risk reductions than middle-age people. Jones-Lee (1993) provides an estimate of age-adjusted VSL based on a finding that older people value mortality risk reductions only somewhat less than middle-aged people.

Regulatory Flexibility Act

Our Regulatory Flexibility Analysis evaluates the impacts of the heavy-duty engine standards and diesel fuel sulfur standards on small businesses. Prior to issuing our proposal we analyzed the potential impacts of our program on small businesses. We convened a Small Business Advocacy Review Panel, as required under the Regulatory Flexibility Act (RFA) as amended by the Small Business Regulatory Enforcement Fairness Act of 1996 (SBREFA). The small business provisions of today’s action reflect revisions to the proposed program based upon updated analysis as well as comments heard at the public hearings on the rulemaking and those submitted in writing during the public comment period. The RFA requires us to determine, to the extent feasible, our rule’s economic impact on small entities, explore regulatory options for reducing any significant economic impact on a substantial number of such entities, and explain our ultimate choice of regulatory approach.

In developing this rule, we concluded that the heavy-duty engine and diesel fuel sulfur standards would likely have a significant impact on a substantial number of small entities. We identified several categories of small entities associated with diesel fuel production or distribution. To our knowledge, no manufacturers of heavy-duty engines meet the Small Business Administration definition of a small business. We have determined that the only small entities that may be significantly affected by today's rule are small refiners, since they will have to invest in desulfurization technology to produce low sulfur highway diesel fuel. We quantified the economic impacts on the identified small entities. We determined the refinery costs for average size refineries and small refiners to produce low sulfur diesel fuel. We also estimated diesel distribution costs for the entire distribution system, including pipeline and tank wagon deliveries.

For today's action, we have structured a selection of temporary flexibilities for qualifying small refiners, both domestic and foreign. Generally, we structured these provisions to address small refiner hardship while achieving air quality benefits expeditiously and ensuring that the reductions needed in diesel sulfur coincide with the introduction of 2007 model year diesel vehicles.

All refiners producing highway diesel fuel are able to take a advantage of the temporary compliance option offered in the final regulations. Diesel producers that also market gasoline in the GPA may receive additional flexibility under today's rule. Refiners that seek and are granted small refiner status may choose from the following three options under the diesel sulfur program. These three options have evolved from concepts on which we requested and received comment in the proposal.

> *500 ppm Option.* A small refiner may continue to produce and sell diesel fuel meeting the current 500 ppm sulfur standard for four additional years, until June 1, 2010, provided that it reasonably ensures the existence of sufficient volumes of 15 ppm fuel in the marketing area(s) that it serves.
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> *Small Refiner Credit Option.* A small refiner that chooses to produce 15 ppm fuel prior to June 1, 2010 may generate and sell credits under the broader temporary compliance option. Since a small refiner has no requirement to produce 15 ppm fuel under this option, any fuel it produced at or below 15 ppm sulfur will qualify for generating credits.
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> *Diesel/Gasoline Compliance Date Option.* For small refiners that are also subject to the Tier 2/Gasoline sulfur program (40 CFR Part 80), the refiner may choose to extend by

three years the duration of its applicable interim gasoline standards, provided that it also produces all its highway diesel fuel at 15 ppm sulfur beginning June 1, 2006.