Preface

Reason Public Policy Institute first initiated a project to investigate the policy implication of proposed tightening of the National Ambient Air Quality Standards nearly two years ago. EPA's November 1996 announcement of proposed revisions to the ozone and particulate matter standards helped us refine the focus of our project, and led to our collaboration with Decision Focus Inc. to produce this report, analyzing the costs and economic impacts of the proposed ozone and $PM_{2.5}$ National Ambient Air Quality Standards.

Policy Study No. 226, June 1997

Costs, Economic Impacts, and Benefits of EPA's Ozone and Particulate Standards

By Anne E. Smith, D. Warner North, James P. Bekemeier, Nathan Y. Chan, Rana Glasgal, Justin L. Welsh
Project Director: Kenneth Green, D.Env.

Part 1

Costs and Economic Impacts of the Proposed Ozone and $PM_{2.5}$ Standards

I. Summary of Control-Cost Estimates

In the analysis described in this section, existing estimates of the costs of the proposed $PM_{2.5}$ and ozone National Ambient Air Quality Standards are evaluated in terms of their completeness and reasonableness. Based on this critique, the analysis provides a synopsis of the range of cost estimates that can be justified as reasonably complete and consistent with all the available evidence. These estimates are intended to reflect a balance of the considerations raised by both the Environmental Protection Agency (EPA) and by commenters, and the best judgment of the authors regarding cost assumptions that are either too high or too low to include in the range.

Estimates of control costs, however, are only an indicator of the scale of the program that might result from the proposed standards. A key question of interest to policy makers is what economic impacts may result from control costs of any given magnitude. This analysis therefore also includes an economic impact analysis using a regional economic-demographic model of the United States. The economic impact analysis takes into account the potential ways that industries and consumers will have to absorb control costs, and includes the off-setting benefits to those components of the economy often referred to as the "pollution control industry." This report summarizes the nature of the overall potential economic impacts in terms of real disposable incomes of individual consumers, employment impacts, and the distribution of these impacts to different income groups, business sizes, and occupational categories.

For ozone, the only publicly available national cost estimates that address the proposed standards by making use of air quality models, engineering cost estimates, and control cost optimization models are those summarized in EPA's December 1996 *Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standard* (the "ozone RIA"). For $PM_{2.5}$, there are several such cost estimates other than those in EPA's December 1996 *Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard* (the "PM RIA"). These use a variety of modeling assumptions but were all done by the same EPA contractor, using the same basic methodology as that used for the PM RIA cost estimates. None of the available cost estimates has been interpreted in terms of their potential economic impacts via use of economic modeling.

None of the ozone and PM cost estimates identifies and applies sufficient control measures to fully achieve attainment with the standards. While there are a number of other criticisms that can be made regarding the cost assumptions and modeling methods, the most important analysis gap for an independent cost reviewer to address is what the costs of *full* attainment might really be (and whether attainment is even feasible). EPA has declined to address the question of full attainment directly through use of its air quality and cost-assessment models. However, EPA, as well as a number of organizations that have commented on the proposed rules, have made attempts to estimate what those full attainment costs are by extrapolating from the limited evidence in the RIAs and supporting materials in the dockets.

There is great uncertainty generated by the types of assumptions required for such extrapolations. After careful review of the evidence in favor of alternative possible assumptions, this analysis concludes that:

- A realistic estimate of the full cost of attaining the proposed $PM_{2.5}$ standards (without accounting for any control actions associated with ozone) would be in the range of $70 billion to $150 billion annually. This compares to the cost cited by EPA in the PM RIA of $6.3 billion for partial attainment.

- A realistic estimate of the costs of fully attaining the proposed ozone standard (without accounting for any control actions associated with the proposed PM standard) would be $20 billion to $60 billion. This compares to the partial attainment cost range cited by EPA of $0.6 billion to $6.3 billion.

The authors do not believe that either of these ranges overstates the possible costs, as will be explained later in this report. In fact, there are several cost estimates that are much higher which were not included in developing these ranges because it is difficult to construct an argument that they are “conservative” (i.e., are more likely to understate the actual costs than to overstate them).

Determining the total costs of control for the combined standards is not as straightforward as adding the PM and ozone cost ranges because there may be overlap in the control measures for PM and ozone that implicitly lie behind these extrapolations. The control measures for ozone involve VOC and NO_x gases. Organic carbon (OC) particles and nitrate (NO_3) particles, which also can form from atmospheric VOC and NO_x gases, are two of the many constituents included in the generic category of pollution known as $PM_{2.5}$. Thus, although many VOC and NO_x control actions might not be selected as *cost-effective* ways of achieving $PM_{2.5}$ standards, if they *would be* selected in attempting to control ozone, then somewhat fewer PM control measures may be required to achieve a concurrent $PM_{2.5}$ air quality target. To the extent that the controls of VOCs and NO_x do reduce $PM_{2.5}$, the cost estimates for each standard on its own would not be completely additive. The degree of cost overlap, however, is not likely to be near 100 percent. For example:

- Less than about 1 percent of the manmade VOCs convert to particulate OC, yet these same VOCs are a primary target of the ozone control costs. Thus, perhaps as much as 99 percent of ozone-motivated VOC controls, which are probably a majority of the ozone control costs, would not contribute to $PM_{2.5}$ reductions.

- Some PM-ozone control cost overlap would result from that part of the costs of ozone controls related to NO_x reductions. However, even that overlap is unlikely to be complete because some NO_x reductions are likely to fail to reduce nitrate PM concentrations.[1]

The best examples where cost overlaps may occur are associated with changes in process or in fuel. Most salient of the possibilities is switching from oil, coal or wood fuel to natural gas. This control action would reduce ozone-creating NO_x at the same time that primary $PM_{2.5}$ and possibly secondary organic aerosols and sulfates would be reduced. It should be noted, however, that switching to natural gas is a control action that does not feature prominently in either the PM or ozone cost analyses, probably because it is not a generally cost-effective measure for either pollutant on its own. If an area were out of attainment with both standards, then gas switching could become more relevant to the cost estimates, and thus represent a potential for cost overlap in extrapolated cost estimates, even if not in the current “partial attainment” cost estimates.[2]

A combined cost range of $90 billion to $150 billion per year can be viewed as accounting for the range of potential cost overlap, while maintaining conservatism. On the low end, this total cost range is comparable to the lower bounds of each individual range being additive, or to a moderately low point estimate for PM of $90 billion, while also assuming a conservative 100 percent overlap with ozone control costs. At the high end, the total cost range is comparable to assuming the following types of cost combinations: that there is no overlap in costs, with middling-estimates for the costs of both PM and ozone (e.g., $120 billion for PM and $40 billion for ozone); that ozone is high and PM middling (e.g., $60 billion for ozone and $90 billion-120 billion for PM), with varying degrees of overlap; or that PM is at the upper end of its realistic range, but there is 100 percent overlap with ozone costs.

The next two sections of Part 1 demonstrate how these cost ranges are justified as being realistic and conservative by the limited facts provided to the public by EPA in its *Regulatory Impact Analyses*. However, it is important to emphasize that these estimates are extrapolations, not founded on a specific set of identified control actions. To develop cost estimates with such specific underpinnings would not be possible to do without access to EPA’s models, as well as a more extensive engineering analysis of control options than EPA has performed. Nevertheless, it is useful to explore what economic impacts might result from engaging in an emissions control program of the dollar magnitude suggested above.

An economic impact analysis, using a widely recognized and validated regional economic model of the United States, suggests that a major PM and ozone-oriented control program of the sort that might cost $90 billion to $150 billion per year would likely have widespread impacts throughout all regions and sectors of the economy. Assuming that the government could be completely effective in eliminating national employment impacts, *a program consistent with the $90 billion estimate* would:

---

[1] Nitrate particles form when NO_x and ammonia combine in the atmosphere. In some locations, there will be less ammonia available than NO_x for this particle-forming reaction to take place. This would be especially likely in areas where sulfate is a substantial portion of the PM mix, because sulfate combines with ammonia more readily than NO_x and uses it up first. Thus, much of the NO_x may remain in the atmosphere in non-particulate form, representing a reservoir of potential NO_3 particles, should more ammonia become present. Under these conditions, NO_x reductions would first reduce the reservoir of excess NO_x, without any impact on particulate concentrations. However, as sulfate concentrations are lowered, the size of that reservoir would be reduced, and it will be more likely that NO_x reductions would also generate $PM_{2.5}$ reductions.

[2] It should be noted, however, that there are probably some fundamental market limits to how broadly natural gas switching might be used.

- Cause lasting (long-run) *average* reductions in the real after-tax income *per capita* on the order of $250 per person, or about 1.2 percent of their personal budget. The negative net impact on income levels reflects both estimated price mark-ups due to the control measures, and reduced growth from the diversion of dollars to less economically productive investments.

This disposable income reduction may sound small to some, but actually creates substantial distributional impacts throughout the economy. For example, even if the federal government were to be able to keep overall unemployment rates in balance:

- The largest job losses in the economy will tend to come from the service and retail sectors (e.g., restaurants, nonprofit organizations, household workers, personal services). Although the retail and service sectors contribute the least to the pollution that is being reduced, they suffer reduced demand because of the real decline in household incomes that is necessary to pay for the cleaner air. Consumers have to divert consumption away from discretionary expenditures, which affects primarily the service and retail sectors.

- Industries and manufacturing sectors that do not substantially participate in supporting pollution control activities also suffer job losses.

- There would be a projected increase of jobs in engineering-related services, and in some of the durables industries (e.g., machinery, metals fabrication, mineral products, chemicals). In other words, those sectors that provide substantial inputs to the pollution control activities will grow, even some of those sectors that will be carrying a large pollution control cost of their own.

- Concomitant with the sectoral shifts will be a substantial reduction in clerical, sales, and blue collar jobs (about 50,000 to 100,000 jobs in each year) and an increase in professional, managerial, and construction-related jobs.

- Small establishments (less than 100 employees) will be more likely to experience job losses than larger ones.

- The above impact estimates explicitly include the beneficial economic impacts associated with building and maintaining pollution control equipment.

Again, all of the above impacts occur even when assuming that the federal government would be able to successfully keep overall employment in balance. However, one of the most important impacts of such a control program would be the difficulty that it would pose for managing the economy and maintaining stability. To achieve attainment by 2008 would result in an enormous potential for net job increases during about a five-year period (starting about 2002), followed suddenly (over the space of just a couple of years, e.g., between 2008 and 2010) by an equivalently large and long-term potential for net job losses. Given the magnitudes of potential net employment effects, their rapid shift in direction over the space of a few years, and given the many competing objectives in setting monetary policy, it could be very difficult for the federal government to effectively manage impacts of this nature, even without the wide directional swings of the first decade.

Even if one assumes that federal monetary policy will be, for example, about 90 percent effective in stabilizing unemployment rates, there is a potential for the early (and temporary) job increases to be on the order of about 100,000 jobs, and for later job decreases to involve up to 200,000 positions. Put in context with overall employment, this is a small net effect. It amounts to about 0.1 percent of overall jobs in the years after 2010 and would translate into about a 0.05 percent change in the national unemployment rate. Also, the potential for net job losses might be temporary, until the federal government can gradually steer the economy back to its target. However, it is also conceivable that some part of this reduced employment could be more enduring, since the total effect represents only a fraction of a percentage point in the observable national unemployment rate.[3] Nevertheless, there are more significant distributional impacts underlying this net national effect, similar to but larger than those described above. The economic model indicates the following quantitative economic effects in years after 2010, if the nation were to be experiencing a net loss of 200,000 jobs:

- A reduction in the average real disposable per capita income amounting to a total annual loss of about $275 per person.

- Behind this *average* annual real disposable income loss of $275 per person is a situation where individuals with little training or education will lose substantially more, and individuals in typically higher income categories will lose less, or may even experience increases in real income. Model results show that individuals in the top-paying 40 percent of jobs will experience net job growth and those in the bottom-paying 40–60 percent of jobs will see a net decline in jobs in their line of business.

- There would be a reduction of about 205,000 blue collar, sales, and clerical jobs, and an increase of about 5,000 professional, managerial, and construction-related jobs.

- Job reductions would be greatest in the service and retail sectors, and in industries that do not also serve the pollution control requirements (e.g., furniture, other wood-related products, petroleum, motor vehicles, printing, food).

- Of the total jobs lost, an estimated 85 percent will be associated with establishments with fewer than 100 employees. In the baseline, about 75 percent of establishments have fewer than 100 employees, so this represents a disproportionate impact. This disproportionate impact cannot be mitigated by making control requirements apply only to larger businesses because most of the disproportionate impact is due to losses in the retail and services sector, which are affected more by consumer spending impacts than by control requirements *per se.*

There is a potential for job *increases* during the years 2002–2006 when construction activities are at their peak (necessary to achieve attainment by 2008), and O&M costs have yet to take full effect. This potential also may be difficult to effectively offset through the government's monetary policies. Should there be an increase in jobs due to less than fully effective monetary policy, the model indicates that the following distributional impacts could result:

---

[3] Although economists have targets for unemployment rates, there is a definite band of uncertainty regarding what the "natural rate" really is. Thus, increments in the unemployment rate that are less than a half percentage point might go unobserved, or be viewed as a small structural shift rather than an enduring loss of potential job openings, and thus not be completely managed back to full employment by monetary policy.

- There is still a projected loss in real disposable income, although its magnitude may be lessened during the implementation period.

- The income loss that does occur is likely to fall very disproportionately on the lowest income brackets: the model indicates net job *losses* in the lowest-paying 20 percent of job categories, while net job increases would tend to be shared by all other income groups.

- Some job losses in nondurables manufacturing, service, and retail would start to appear, although in a lesser degree than in the case of post-implementation years.

The effects of a regulatory program that has a cost estimate in the range of $150 billion per year would be qualitatively comparable, but with impacts roughtly 75 percent larger. For example, the estimated reduction in real disposable income per capita is estimated to decline progressively to about $450 dollars per year, starting from the initial year of implementation, 2002. This would be a reduction of 2 percent of incomes on average, with disproportionately greater impacts to lower income groups.

The rest of this section first summarizes the details of the various partial- and full-attainment cost estimates for ozone and PM separately. A critical evaluation of the relative “quality” of each estimate is provided, as well as the rationale for composite “realistic” cost ranges. The section concludes with a more detailed summary of the economic impacts described above.

II. Ozone Control Costs

Table 1-1 provides a summary of the reported cost estimates that were identified and obtained for this analysis of the costs of the ozone standard. The table summarizes some of the key assumptions in each estimate, for purposes of comparison. Each of these estimates will be discussed and critiqued in this section. In addition, DFI will provide a few additional estimates based on the ones cited in Table 1-1.

The EPA RIA provides cost estimates for two different standards, neither of which is actually consistent with the proposed standard. They are supposed to bound the stringency of the actual standard, but the proposed standard is probably more consistent with the more stringent (higher cost) of the two.[4] For each of these two standards, EPA also provides the costs under two different scenarios for controls that will already be in place for other purposes (such as to achieve the current ozone standard). Since the United States has not yet determined how it will achieve the current ozone standard, there is some degree of uncertainty as to what should be assumed in the baseline. The “local control strategy” assumes only those controls in the current state implementation plans (SIPs). The “regional control strategy” assumes that, in addition to the well-defined SIPs control baseline, the country will also embark on a regional reduction of large NO_x sources amounting to a 75 percent reduction in current emissions levels over 37 states, *and* that the California LEV vehicle will be used in all states. Not surprisingly, the costs of achieving attainment when there is a pre-existing regional control program of this magnitude is reduced in some areas. Also, more areas actually come into attainment with this boost from the baseline assumptions.

---

[4] The two bounding standards are 80 ppb with an eight-hour concentration based second highest average daily maximum form (“1AX”) and with a fifth highest average daily maximum form (“4AX”). The proposed standard is a “2AX” form, which is probably closer to the “1AX” than “4AX” form.

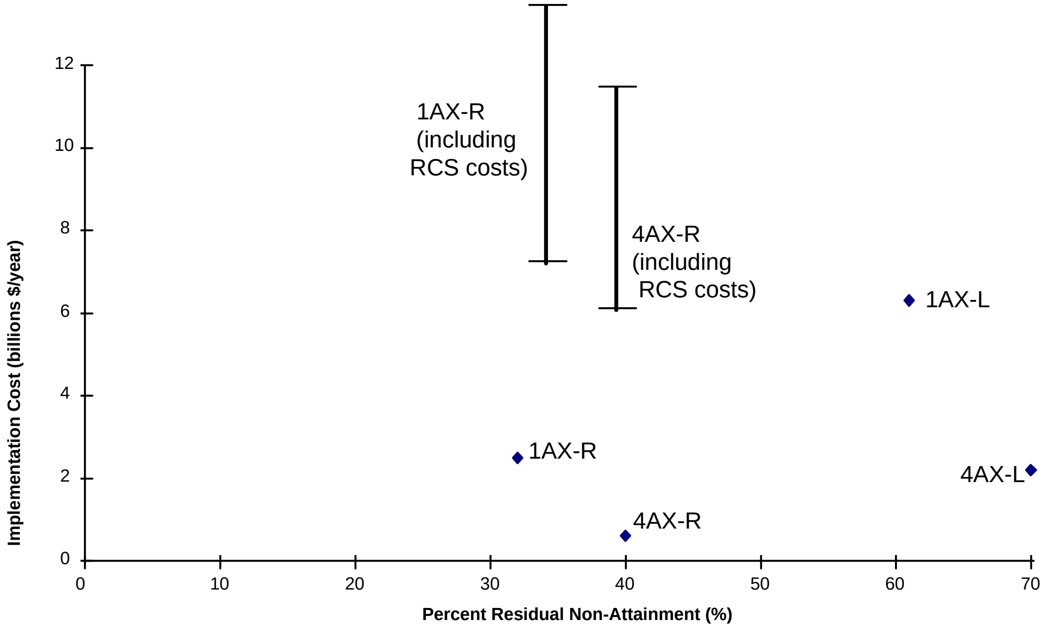
Table 1-1. Ozone Cost Estimates: Cost of compliance with proposed ozone NAAQS
Cost expressed in 1990 dollars

Label	A	B	C	D	E	F	G	H	I	J
Baseline w.r.t. Implementation of CAA Control Requirements										
• Incremental to full implementation of CAA control requirements by 2007	X	X	X	X	X	X	X	X	X	X
Baseline w.r.t. Ozone NAAQS Implementation										
• Incremental to the current ozone NAAQS as of the year 2007	X	X	X	X	X	X	X	X	X	X
Alternative Analyzed										
• Eight hour conc based fifth highest avg daily max 0.08 ppm (8H4AX-80)	X		X		X		X			
• Eight hour conc based third highest avg daily max 0.08 ppm (proposed standard)										
• Eight hour conc based second highest avg daily max 0.08 ppm (8H1AX-80)		X		X		X		X	X	X
Level of Attainment										
• Cost corresponds to partial attainment	X	X	X	X						
• Cost corresponds to "full" attainment					X	X	X	X	X	X
• (Marginal costs used to model "full" attainment may represent controls that do not exist)										
Baseline w.r.t. Implementation of a Regional NO_x Strategy										
• Regional control strategy, incremental to OTAG, CAPI, other efforts	X	X							X?	X?
• Local control strategy			X	X	X	X	X	X		
Marginal Attainment										
• Marginal areas (115% of standard, 0.092 ppm) not subject to further reductions	X	X	X	X	X	X				
• Marginal areas subject to further reduction							X	X	X	X
Reduction Targets										
• Areas failing to meet at least 75% of reduction target labeled residual nonattainment	X	X	X	X	X	X				
• Areas failing to meet 100% of reduction target labeled residual nonattainment							X	X	X	X
Bounds of Uncertainty Range (if provided)										
• Cost estimate represents lower bound									X	
• Cost estimate represents upper bound										X
Results										
• No. of Initial Non-Attainment Areas	30	75	30	75	30	75	30	75	75	75
• No. of Residual Non-Attainment Areas	12	24	21	46	0	0	0	0	0	0
• NO_x Emission Reduction (1000 tons)	50	290	450	1100						
• VOC Emission Reduction (1000 tons)	115	660	400	1200						
• Percent Residual Non-Attainment (%)	40	32	70	61	0	0	0	0	0	0
• Implementation Cost (billion $/year)	0.6	2.5	2.2	6.3	9.1	83.1	53.8	328	11.6	60
• Implementation Cost (billion $/year per nonatt. area)	0.02	0.03	0.07	0.08	0.30	1.11	1.79	4.38	0.15	0.80
• (estimates A & B do not yet include the cost of the RCS, this should be added)										

References
A ... EPA's December 1996 "RIA for Proposed Ozone NAAQS" ... page VI-9
B ... EPA's December 1996 "RIA for Proposed Ozone NAAQS" ... page VI-11
C ... EPA's December 1996 "RIA for Proposed Ozone NAAQS" ... page VI-21
D ... EPA's December 1996 "RIA for Proposed Ozone NAAQS" ... page VI-22
E ... Dudley's March 1997 "Comments ..." ... page C-3
F ... Dudley's March 1997 "Comments ..." ... page C-3
G ... Dudley's March 1997 "Comments ..." ... page C-4
H ... Dudley's March 1997 "Comments ..." ... page C-4
I ... CEA's December 1996 memo "Ozone NAAQS" ... page 3
J ... CEA's December 1996 memo "Ozone NAAQS" ... page 3

The problem with comparing the cost estimates of these various scenarios is that each one achieves a different amount of control. In effect, each one represents a different position on the spectrum between no control and controls consistent with full attainment. To facilitate comparison of these costs, it is useful to estimate the degree to which each cost scenario approaches full attainment. In the case of the ozone scenarios, the ozone RIA provides an estimate of the tons of NO_x and VOC reductions necessary to achieve attainment. After defining the degree of residual nonattainment in terms of the number of tons remaining to be reduced once all of the available cost estimates have been taken up, Figure 1- 1 compares the annual implementation costs for these four estimates as a function of degree of control. Using notation that may be useful to those who are familiar with the RIAs, "4AX-R" and "1AX-R" reflect the costs of the two bounding standards when the regional control strategy is in place. "4AX-L" and "1AX-L" reflect the costs of the same respective bounding standards when there is no regional NO_x and VOC control scenario in the baseline.

Figure 1-1. EPA's Estimates of Implementation Cost for Proposed Ozone NAAQS and Corresponding Levels of Non-Attainment



Normally, one would expect to see that the annual costs would increase with decreasing degree of residual nonattainment. However, that would only be the case if these estimates were all starting from the same baseline, which they are not. Since the costs of the regional control strategy are not included in the incremental costs for attainment of the proposed new standard, "1AX-R" and "4AX-R" are lower than "1AX-L" and "4AX-L," respectively. If the costs of the regional control strategy were added to points "4AX-R" and "1AX-R," then a more typical control cost curve would emerge. For example, cost estimates of the 75 percent seasonal NO_x reduction proposed under OTAG (0.15 lb/MMBtu cap) range from $2.3 billion (1990$) to $5.5 billion (1995$).[5] Cost estimates for the LEV program throughout OTAG range from $0.6 billion to $6.2 billion annually.[6] If these control measures were attributed to "4AX-R" and "1AX-R," those points would be raised by about $4 billion to $11 billion, to the range of the bars shown above them on Figure 1-1, which then present a figure consistent with the expected increasing incremental cost. Thus, EPA's statement that the local control strategy "provides an upper bound to the anticipated costs of the new ozone NAAQS in the event regional efforts fail to arise before 2007"[7] is misleading: although it has higher *incremental* costs than the regional control scenario baseline,

---

[5] Low end: The EPA analysis of the CAPI proposal ("Supporting Analysis for EPA's Clean Air Power Initiative," Office of Air and Radiation, U.S. EPA, October 1996) shows an annual cost of $2.7 billion in 2010 (1995$) to achieve a .15 lb/MMBtu seasonal NO_x reduction from utilities only. EPA interpolates to 2007 to derive an estimate of $2.3 billion. (Note, however, that the OTAG proposal also includes other combustion boilers, whereas the basis for this low end estimate is for utility boilers only.); High end: by Hewson and Stamberg, "At What Cost? An Evaluation of the Proposed 37-State Seasonal NO_x Control Program -- Compliance Costs and Issues," report by Energy Ventures Analysis, November 1995.

[6] Low end: EPA's RIA p. VI-4, December 1996; high end, E.H. Pechan very recently reported a range of $1.2 billion to $6.2 billion to OTAG in "Cost of Strategies to Reduce Ozone Transport" Draft, March 21, 1997 (slides).

[7] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standard*, December 1996, p. VI-2.

it also provides much less progress towards attainment. If the controls assumed in the regional control scenario's baseline do not materialize, then the equivalent control cost estimates *for a comparable degree of attainment* would be more like the bars above points "4AX-R" and "1AX-R" in Figure 1-1. And the full costs of attainment would be higher still, as is discussed later.

An appropriate question with regard to whether to use "4AX-R" and "1AX-R" or "4AX-L" and "1AX-L" is whether the cost of the regional control strategy really should be attributed to the baseline or to the proposed standard. Some commenters have argued against including the regional control strategy in the baseline because these control strategies are not currently mandated, and there is no clear legal basis for such requirements.[8] Even EPA's RIA acknowledges that their regional control scenario is more stringent than all but one of the alternatives that OTAG is currently analyzing. However, it does appear that, from an attainment standpoint, a good part or all of the NO_x portion of these control costs may be required to achieve the current standard, and regardless of their current implementation status, should not be attributed to the *change* in the standard that is being proposed now. Therefore, if it were not for other major problems that plague *all* of these cost estimates (and which are described below), it might be reasonable to accept points "1AX-R" and "4AX-R" as a reasonable basis for estimating the *incremental* costs of partial attainment, rather than "4AX-L" or "1AX-L." Further, it seems more reasonable to use "1AX-R" specifically as being closer to a simulation of the proposed standard. The proposed standard is a "2AX" standard, and is thus probably more like the stringent 1AX form than the 4AX form. Numerous uses by EPA of the costs of the "1AX-R" estimates suggest that EPA may also be implicitly assuming that this standard is closer to the proposed standard than the "1AX" scenarios.

The more important cost issue, however, is how the costs rise *out of* the point "1AX-R" in the direction of full attainment of the new proposed standard. The uncertainty on this point has greater impact on the ultimate cost estimate than whether to accept the regional control strategy as part of the effort of achieving the current standard. EPA's cost analysis does not provide that estimate based on detailed modeling. Instead, EPA's analysis of costs stops counting costs when it has used up all of the control actions that EPA's analysts have specifically identified and provided cost estimates for. The limits of this control action list rather than attainment become the determining factor in the costs reported in the ozone RIA.

This not only creates an artificial cap on degree of attainment associated with the cost estimates, but also creates some very nonsensical cost outcomes. For example, Los Angeles is one of the most severe ozone attainment problems that must be contended with. Its problem is so severe that it apparently has already used up all of the control options that EPA has on its list. Thus, rather than being one of the areas that will have the highest costs of going the extra mile to achieve the proposed tightened standard, EPA's estimates attribute *zero* incremental costs to the Los Angeles area (but many remaining tons to be removed). Los Angeles, San Diego, and Bakersfield, Calif. do not even generate incremental costs for attaining the *current* standard. Instead, they just rack up zero-cost "credits" of "tons per year of residual nonattainment." For the estimated costs of achieving the "1AX-R" standard, these three cities are joined by New York City and 20 others[9] that contribute relatively little to the total cost estimate before starting

---

[8] See, for example, the comments on the rule submitted by the Regulatory Analysis Program of George Mason University, prepared by S. Dudley of Economists Incorporated.

[9] Atlanta, Ga.; Atlantic City, N.J.; Baltimore, Md.; Washington, D.C.; Baton Rouge, La.; Chicago, Ill.; Fairfield, Ill.; Fresno, Calif.; Hartford Conn,; Huntington, W.Va; Manitowoc, Wis.; Modesto, Calif.; Muskegon, Mich.; New London, Conn.; Philadelphia, Pa.; Providence, R.I.; Redding, Calif.; Sacramento, Calif.; Santa Barbara, Calif.; Stockton, Calif.; and Visalia, Calif.

to generate "tons per year of residual nonattainment." Overall, the costs in the "1AX-R" standard are for 950 tons of reduced NO_x and VOCs, and the same cost analysis racks up 495 to 753 tons of residual nonattainment that are not reflected in the cost estimate of $2.5 billion annually.

In EPA's 4-page *Fact Sheet on EPA's Regulatory Impact Analysis for the Ozone Standard* (but not in its RIA or any other document), EPA provides an estimated cost of full attainment of up to $10 billion per year. Although it is not documented, one can determine that this cost estimate was based on an assumed $10,000 per ton for reducing the remaining 753 "hard to achieve" tons. This marginal cost assumption is inconsistent with other evidence on how costly the last 40 percent of the attainment effort may be. The marginal costs at the end of the list of identified controls range up to $80,000 (and even higher in a few cases). This provides a different indicator of how costs may escalate beyond the $2.5 billion per year "partial attainment" estimate.

Several groups have used the information about the marginal control cost and the remaining tons to be reduced to roughly estimate what the full attainment cost is. In other words, where EPA estimates zero cost for some areas like Los Angeles, the extrapolations have attempted to approximate what it would really cost for "the L.A.'s" in EPA's analysis to get into attainment. The actual control measures associated with these actions are "unidentified," but under current technological conditions, it is only reasonable to suspect that on average these measures will cost more per ton than those control measures that we can easily identify. It is also likely that any of a range of "lifestyle changes" may become the control measures of choice.[10] While such changes may have no technical price tag, it is reasonable to believe that our societal willingness-to-pay to avoid taking these actions is at least as high as all of the control actions that we are currently engaged in. Otherwise, severe ozone nonattainment areas would be taking such actions more enthusiastically already.[11]

Existing estimates of the possible full attainment costs, including those attributable to EPA, range from $4 billion to $328 billion annually, although the estimates cluster around the range of $35 billion to $60 billion. Table 1-2 summarizes the extrapolation assumptions associated with each estimate. These extrapolations come from EPA's own estimates,[12] from comments by the Council of Economic Advisors (CEA)[13] on the proposed rule, and from comments by the Regulatory Analysis Program of the Center for

---

[10] "Lifestyle changes" would include any behavioral change that would result in fewer emissions per person than in today's world. Changes that might be effective in reducing emissions include using more public transportation (reducing annual vehicle miles traveled per person), simply traveling less (e.g., via telecommuting), changing traffic patterns to reduce congestion (e.g., by using flextime to alter rush hour patterns), conservation of energy in the home (e.g., cutting off air conditioners during peak daytime hours), etc. There are other options that may affect consumers directly and are not considered in EPA's analysis, yet which are not formally lifestyle changes: requiring more energy-efficient home appliances, reducing use of solvents in many different but individually small applications, use of electric-powered lawn maintenance equipment.

[11] While one can make a strong argument that these lifestyle changes have a high willingness-to-pay for avoidance, we should be careful to recognize that costs based on these assumptions will not filter through the economy in the same way as "hard" technology and operating change costs.

[12] They are attributed to EPA, and the high end is consistent with the $10 billion in the *Fact Sheet*, however, these estimates are actually "documented" in a CEA memo from Alicia Munnell (see next note).

[13] Memorandum from Alicia Munnell, Council of Economic Advisors, to Sally Katzen, OMB, "Ozone NAAQS," December 10, 1996.

Study of Public Choice at George Mason University (RAP).[14] Table 1-2 also shows additional estimates prepared by DFI, based on our own assessment of appropriate extrapolation assumptions, to be discussed below. The costs in this table are also illustrated graphically in Figure 1-2.

Table 1-2. Extrapolated Estimates of Cost of Full Attainment for Proposed Ozone Standard.

Estimate Source	Baseline Standard	Marginal Cost for Residual Tons	Other Changes in EPA Assumptions	Cost of Full Attainment ($b/yr)
EPA-1	1AX-R	$ 3,000/ton	none	**4.0**
EPA-2	1AX-R	$10,000/ton	none	**10.0**
CEA-1	1AX-R	$18,016/ton[††]	may have slightly altered estimated residual tons in some cities	**11.6**
CEA-2	1AX-R	$74,058/ton[††]	may have slightly altered estimated residual tons in some cities	**60.0**
RAP-1	4AX-L	$30,000/ton	none	**9.1**
RAP-1a	4AX-L	$80,000/ton	none	29 [†]
RAP-2a	1AX-L	$30,000/ton	none	25 [†]
RAP-2	1AX-L	$80,000/ton	none	83.1
RAP-3	4AX-L	$30,000/ton	remove 25% modeling bias assumption and 15% cap	53.8
RAP-3a	4AX-L	$80,000/ton	remove 25% modeling bias assumption and 15% cap	212 [†]
RAP-4a	1AX-L	$30,000/ton	remove 25% modeling bias assumption and 15% cap	87 [†]
RAP-4	1AX-L	$80,000/ton	remove 25% modeling bias assumption and 15% cap	**328.3**
DFI-1	1AX-R	$30,000/ton	mid-range on the estimate of residual tons per year	21
DFI-2	1AX-R	$90,000/ton	mid-range on the estimate of residual tons per year	59

[†] These costs are attributed to RAP but were estimated by DFI, working from the results that are provided in the RAP report and their own stated assumptions. It is our belief that these values were actually calculated by RAP, but then lost when results were reported only in the form of ranges. Values in bold face in Table 1-2 are the values that can actually be observed in the reference.

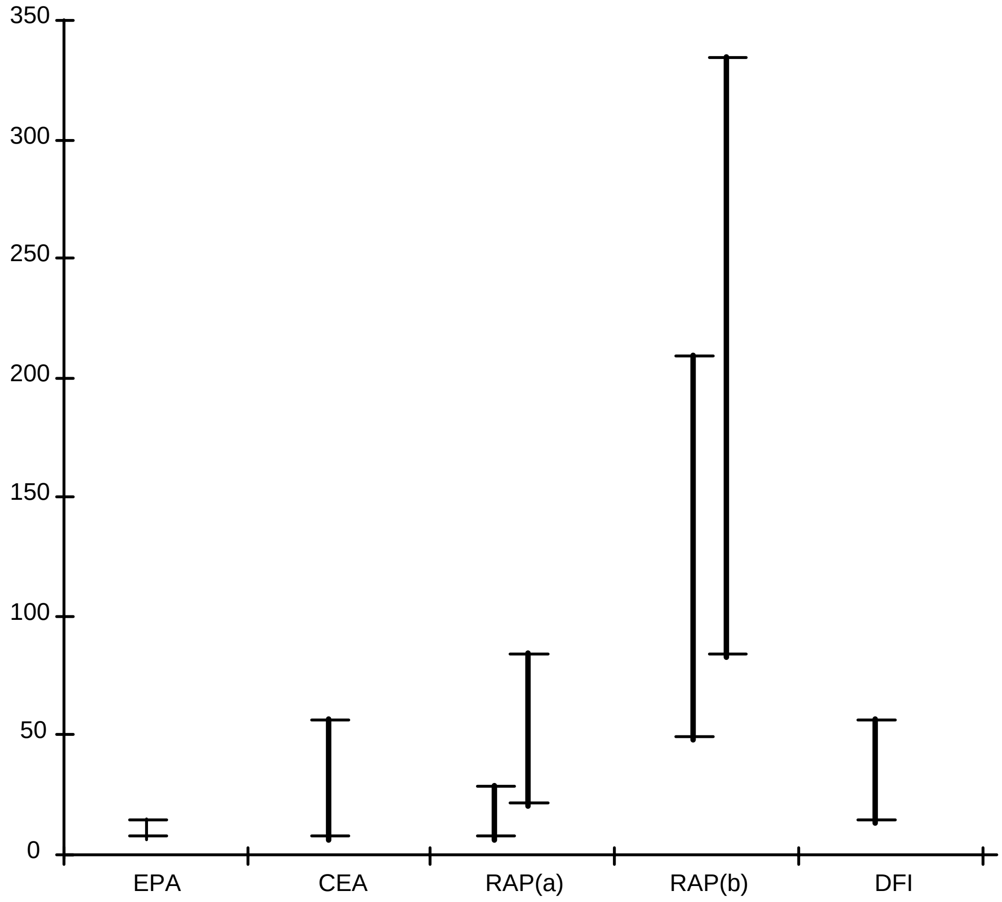
[††] These appear to be the costs per ton used by CEA. The CEA memo indicates that they used a cost per ton for the second-most expensive program averaged over three "representative" cities (Chicago, Fresno, Philadelphia). That average value (from Table B-4, see our Appendix 1) does not reproduce the range that CEA says results. However, the lowest and highest values of those three second-most expensive programs do reproduce the CEA estimates. Although CEA would not reply to our requests to discuss these numbers, the coincidence is strong enough for us to assume that these are indeed the marginal costs used in CEA's estimates.

The main difference between the EPA and CEA estimates appears to be a difference of opinion about the appropriate estimate for dollars per ton for all of the residual tons that need to be somehow removed to achieve full attainment. EPA uses the costs per ton experienced across the bulk of control actions that are part of partial attainment on the presumption that additional controls, not yet identifiable, would be found and used simply because they are less than the marginal cost of $30,000 to $80,000 per ton that *is* experienced in the partial attainment scenarios. To assume that additional "unidentified" controls would have a cost comparable with the most cost-effective controls now identifiable is unjustified, as CEA points out, particularly since much higher control costs are experienced even in the partial attainment scenarios.

---

[14] S.E. Dudley, "Comments on the U. S. Environmental Protection Agency's Proposed National Ambient Air Quality Standard for Ozone," prepared for The Regulatory Analysis Program, Center for Study of Public Choice, George Mason University, March 12, 1997.

Figure 1-2. Estimates of Costs of Fully Attaining Proposed Ozone Standard



CEA recomputes the costs of full attainment with a cost per ton for the residual tons that it believes is more justified. For their lower bound, CEA uses a conservative estimate of the marginal cost that is embodied in EPA's partial attainment scenarios by looking at the second most extreme cost estimate in several of EPA's cities. Their upper bound (resulting in the $60 billion estimate) is associated with a higher marginal cost assumption, consistent with the assumption that the highest marginal costs in the partial attainment scenarios reflect the true marginal costs. CEA apparently also adjusts for what appear to be computational errors on the part of EPA, where residual tons required are reported as zero for some areas that are clearly far from attainment. Overall, the extrapolations by CEA are more realistic than those of EPA, and are quite conservative at their low end. Even at the high end, one could argue that there may be an element of conservatism: in some cases, the marginal costs for some of the cities for the 1AX-R standard are in fact much higher than the $80,000 per ton that EPA cites. (This can be seen from information in Table B-4 of the ozone RIA, which is reproduced in marginal cost format for the reader in Appendix 1 of this report).

RAP comments that the local control scenarios are a more appropriate starting point, given the current absence of any mandate for a regional control program. RAP provides two separate ranges for extrapolated costs of full attainment. The first ($9 billion to $84 billion) is very similar in method to the CEA extrapolation except that it uses the local control scenarios as the starting point, and uses a slightly higher range for the possible marginal costs of control, based on EPA's own statement about the range of marginal costs. For these reasons, the range extends to a higher level than the CEA estimate. On the other hand, RAP includes the less stringent "4AX-L" standard in this range, which accounts for the lower end of the range being below CEA's, even though RAP is using higher marginal cost assumptions. The estimated range specifically for the "1AX-L" standard is $25 billion to $83 billion.

The second range of estimates provided by RAP ($54 billion to $328 billion) attempts to account for another source of underestimation in the EPA estimates. RAP points out that the definition that EPA uses for "full attainment" is likely to be an understatement, since EPA assumes that no additional control costs are undertaken once any nonattainment area gets within 15 percent of its target. RAP also takes issue with an "off the top" 25 percent reduction in model-estimated tons required to get to attainment, which EPA makes to address asserted (but poorly documented) bias in the ozone model. The latter cost range redefines full attainment as requiring the full amount of reduction in tons that the model estimates as necessary, and attempts to add back into the residual nonattainment tonnage an estimate of the tons that would be associated with the 15 percent "marginal attainment."

DFI authors feel that adjustments for model bias, while poorly documented on the part of EPA, would be reasonable to make if EPA can show that the model truly does have a persistent upward bias. On the other hand, it does not seem appropriate for EPA to assume no further control costs (other than minor administrative ones) whenever any region gets to the marginal attainment status. However, a close reading of the RIA and information gathered from EPA staff indicate that the estimates of residual tons of nonattainment cannot be used to estimate how many tons of residual nonattainment are associated with areas that were designated as "marginal": no tonnage reductions were ever estimated for the 35 to 54 counties (for the regional and local control cases, respectively) that were found by modeling to be within 15 percent of attainment prior to control estimates. The remaining counties for which tonnage estimates were developed apparently did not benefit from a marginal attainment status once they were modeled to be within 15 percent of the required tonnage reduction.[15] Overall, these concerns suggest that the higher set of RAP's cost extrapolations are overly conservative.

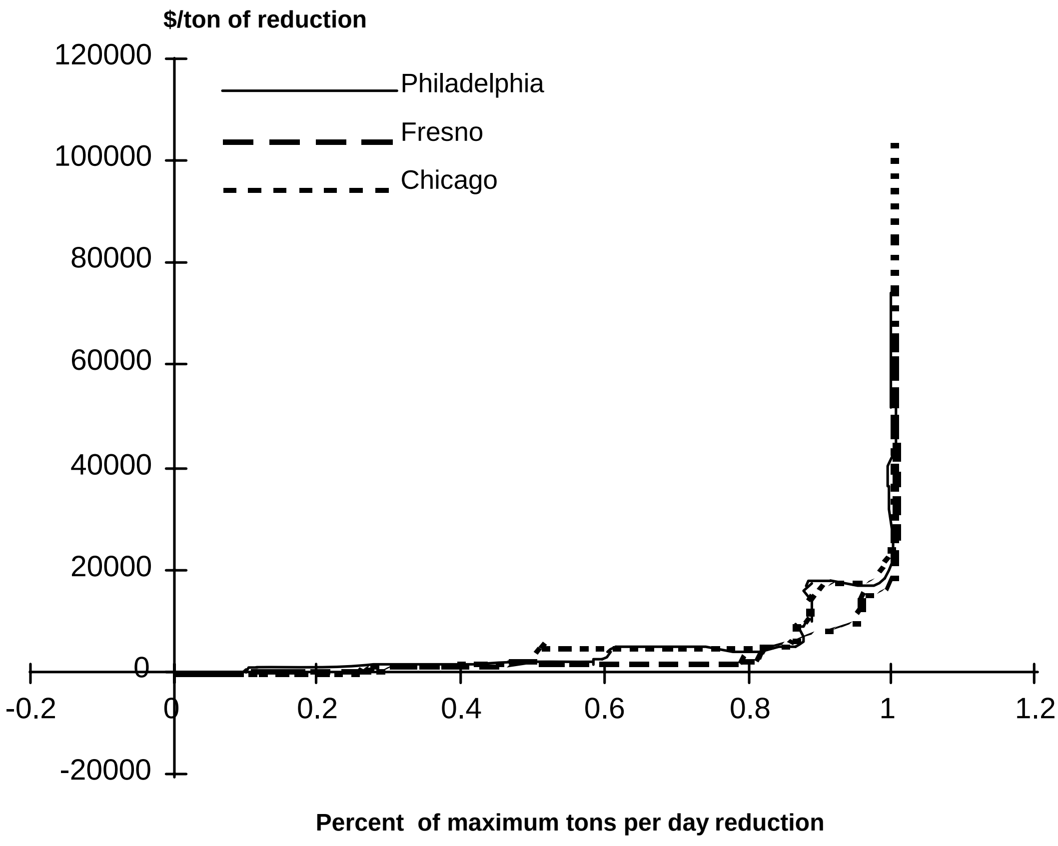
A realistic estimate of the full attainment costs, given the limited information currently available to the public, will depend primarily on making a sound judgment regarding the marginal cost of the controls necessary to bring all of the residual nonattainment and marginal attainment areas into compliance. Thus this analysis focused on determining whether the range of marginal cost estimates used in the above estimates could be refined further. Data in Appendix B of EPA's RIA (see Appendix 1 of this report) were used to graph the marginal cost curves for three typical cities that have residual nonattainment. Figure 1-3 shows the marginal costs as a function of the percent of all controls explicitly identified by EPA. In Figure 1-3, one can see how the marginal costs remain under about $10,000 per ton until the last 10 to 20 percent of the tons reduced. At that point, marginal costs dramatically escalate in each nonattainment region.

EPA makes two arguments for why costs would not actually escalate as rapidly as the marginal cost curves of Figure 1-3 indicate.

---

[15] Michelle McKeever, EPA Office of Air Quality Planning and Standards, personal communication, April 22, 1997.

Figure 1-3. Examples of Typical Marginal Cost Curves in Ozone RIA



- EPA argues that control cost programs are always cheaper than anticipated, and also implies that emissions trading would keep costs at the average that we see in their data, not at the margin. This is not a compelling argument. The control costs have already been selected in least-marginal cost order, which is consistent with having assumed that emissions trading is occurring. Further, the fact that control costs in the past have been less than projected in exercises such as these does not imply that actual control costs have turned out to be *as cheap as* the cheap actions that have already been taken. Costs do still tend to escalate as the stringency of the control program has increased.

- EPA argues that the control costs in its RIA have been estimated by using only those control options that exist literally *within* the defined area of nonattainment. EPA argues that, ultimately, control options will be taken from a wider area, particularly nearby counties that do influence the nonattainment region, but are not themselves formally in nonattainment. This does provide a sound argument for assuming that cost curves will not escalate exactly as shown in Figure 1-3. Without assuming that a truly regional control strategy would ensue, states do already have the ability to obtain controls from other sources within their own state, even if such sources are in attainment areas of the state. The control options in the surrounding areas may not be as effective in reducing nonattainment area ozone, however, and thus one should still expect marginal costs to increase, but in a more measured degree than the case where controls are constrained to the nonattainment area specifically.

The solid dashed lines in Figure 1-4 show more moderate marginal cost extrapolations, which are consistent with current data, but still accommodate the likelihood that there are additional controls in surrounding areas of influence that are more cost-effective than what remains within the region. Although there remains much uncertainty about the exact marginal cost, these costs are far more conservative than simply assuming that all of the additional tons will cost as much to reduce as the last control measure identified solely within a nonattainment region's boundaries. On the other hand, they do not simply assume that the remaining residual tons can be reduced as easily as the first few.

These cost curve extrapolations are applicable at the level of the residual nonattainment area, rather than for the total residual tonnage at the national level, which is all that EPA reports in its RIA. Using them thus also requires an understanding of how much *more* control is needed in each of the 24 residual nonattainment areas associated with the 1AX-R scenario to achieve attainment. EPA has not released sufficient information to determine this for any of the cities individually. However, the RIA does indicate that the total residual tons necessary over all of the 24 remaining nonattainment regions (after accounting for the 75 percent model bias) is 495,000 to 753,000 tons per year.[16] The RIA also indicates that these 24 areas have only achieved reductions in the partial attainment scenario on the order of 293,000 tons.[17] In other words, the partial attainment cost estimate seems to only carry the 24 areas that are deemed to remain in nonattainment an average of about one-third of the way to attainment.[18] If we assume that 90 percent of the additional tonnage that needs to be reduced is associated with the four worst nonattainment areas (those which cannot even achieve the current standard), then an additional 293,000 tons would reflect an average of a 20 percent incremental reduction beyond the 100 percent point in Figure 1-3 for the other 20 residual nonattainment areas. Using the two heavy-dashed lines in Figure 1-3, the average incremental cost associated with another 20 percent of tonnage reduction would range from $30,000 to $60,000 per ton.[19] If we were to reduce the assumption that 90 percent of the national residual tons are associated with the four worst cities to 80 percent, then the remaining 20 cities would require an average 40 percent incremental reduction from the 100 percent point, which the dashed lines imply could cost from $40,000 to $90,000 per ton.

---

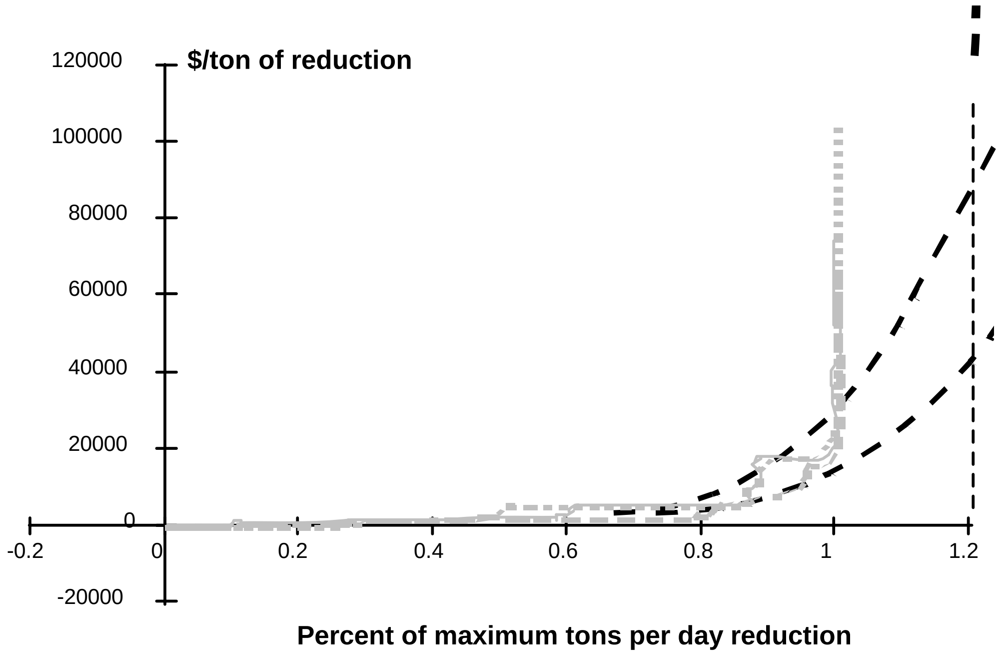
[16] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standard*, December 1996, Table VI-9.

[17] Summation of total NOx and VOC reductions achieved over these 24 areas, taken from Table B-4 of Ozone *Regulatory Impact Analysis*, December 1996. (Information reproduced in this paper's Appendix 1.)

[18] We need to recognize that these 24 areas include San Diego, Los Angeles, New York City, and Bakersfield CA, not one of which is shown to add *anything* to the reductions in this scenario because all are projected to be in residual nonattainment even with the current standard, and to have already exhausted all of EPA's identified control options. However, the required additional tonnage of control for these four cities is reflected in the residual tonnage for the current standard (which is another 370,000 to 562,000 tons per year).

[19] For a curve that is close to linear, the average cost over a range can be approximated as the value on the curve at about the half way point, or at 1.1 in this case.

Figure 1-4: More Conservative Extrapolations of Marginal Cost Curves for Ozone



As Table 1-2 shows, even if one applies these lower marginal costs to the remaining 80 to 90 percent of the residual tons that are associated with the four cities that cannot even achieve the current standard, full attainment costs could be between $20 billion to $59 billion per year. Note that although these cost estimates are similar to those of other groups, they were derived by much more detailed efforts to simulate the actual cost structure, and at each step of the analysis, a substantial degree of conservatism was built into the estimates. Thus, a cost range between $20 billion and $60 billion is quite realistic and probably even conservative:

- To the extent that the actual costs might be higher than this range, this would most likely be due to costs associated with the four worst-case cities, which are treated in this extrapolation as if they would have marginal control costs comparable to what we have estimated for the other, less problematic nonattainment areas. This is probably a major source of conservatism. The amount of residual nonattainment in these four areas, when including their difficulties in achieving even the *current* standard, is between 500,000 and 1,000,000 tons per year, even assuming that they would also benefit from a major regional control strategy. It is probably best to surmise that these four areas would remain in nonattainment even with the controls implicit in the $20 billion to $60 billion per year range, unless there are substantial changes in infrastructure and individual patterns of behavior. The latter changes are difficult to quantify except through use of concepts such as willingness to pay to avoid these measures. The evidence available on this avoidance value is that it appears to currently be higher than the marginal control costs currently being experienced, since our society has resisted these measures in favor of the quite costly technological controls that are the subject of the current extrapolations.

- This range also fails to account for the 35 "marginal" nonattainment areas, for which EPA assumed almost zero control costs. However, these 35 areas would likely have much lower marginal costs as well as fewer tons to reduce. Assuming the average marginal nonattainment area would have marginal costs in the range of $2000 per ton, and an average per area reduction requirement comparable to the residual requirements of 24 residual nonattainment areas of the "1AX-R" scenario[20] (probably a significant overestimate), the total cost for these areas would be only $2 billion per year. This is clearly a small error in comparison to the potential costs associated with the less marginal nonattainment areas.

III. Particulate Matter Control Costs

As with ozone, the only publicly available cost estimates for the proposed $PM_{2.5}$ standard are those prepared by EPA, and those costs are for a "partial attainment" outcome, when in fact, the costs of interest to the public should be the full attainment costs. The majority of this section will also deal with the question of how to extrapolate the available cost estimates to a full attainment cost. However, there is a larger record of alternative cost estimates for $PM_{2.5}$, based on a record in the PM regulatory docket of a series of cost modeling exercises leading to the actual cost presented in the published RIA.

Before turning to the issue of full attainment extrapolations, a review of all of the various cost estimates that EPA has produced for $PM_{2.5}$ is made. This review can shed some light on the differences and similarities in this series of cost estimates, and perhaps narrow some of the uncertainty regarding the appropriate starting point for extrapolations.

Table 1-3 compares the assumptions for all the PM cost estimates that were identified and obtained. The annual cost estimates for "partial attainment" vary from $4.3 billion to $17.1 billion. The PM RIA gives $6.3 billion as its official estimate of the costs ("A" in Table 1-3), although in the same document it suggests that the costs may be as low as $4.3 billion ("b" in Table 1-3). The latter cost estimate is supposed to reflect the "potential impact of additional regional SO_2 emissions reductions beyond the CAA Title IV requirements."[21] However, it is incorrect to thus suggest that the cost range may be as low as $4.3 billion. As with ozone, this sets up a situation where the cost curve appears to be *falling*, when in fact, there are additional costs associated with the starting point for the lower cost estimate. The underlying cost of this "additional SO_2 control" program are anywhere from $2.2 billion to $4.8 billion[22]. Unlike in the case of ozone and its "regional control scenario," this underlying cost *should* be included in the total estimated cost of the PM standard, since there is no existing regulatory program or standard that would mandate this action other than the proposed $PM_{2.5}$ standard itself. Thus, the appropriate cost for the "additional SO_2 control" alternative is between $6.5 billion and $9.1 billion, and is thus actually higher than EPA's primary cost estimate of $6.3 billion.

---

[20] That is, there are 24 residual nonattainment areas requiring about 625,000 tons residual reduction, or 26,000 tons per residual area on average.

[21] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard*, December 1996, p. 7-17.

[22] Low estimate from EPA's CAPI proposal ("Supporting Analysis for EPA's Clean Air Power Initiative," Office of Air and Radiation, U.S. EPA, October 1996, Table 11); high estimate from EPA's *Acid Deposition Standard Feasibility Study Report to Congress*, as reported in EPA's December 1996 PM RIA on p. 7-17.

Many commenters have noted that all earlier drafts of EPA's cost estimates (as revealed by other documents in the PM Docket) indicated annualized costs significantly higher than the \$6.3 billion per year in the PM RIA. However, it is difficult to directly compare these estimates because they vary in terms of the degree to which they approach full attainment. Thus, as with the ozone costs, it makes sense to first assess the degree of residual nonattainment in each estimate. Unlike with ozone, the PM RIA does not provide a good common metric for estimating the amount of further reductions needed. There are two possibilities. The first is to compare the number of counties out of attainment before and after the controls are applied. The second, which would be more like the concept of residual tons to reduce for ozone, would be to use the residual and initial $\mu g/m^3$ of nonattainment over all of the areas to determine how much progress there is towards full attainment. In the case of PM, EPA has not released the necessary information to perform the latter with much precision. Thus, for purposes of comparison across various cost estimates, PM cost estimates were normalized for their degree of attainment using the former definition based on counties that achieve attainment.

An additional adjustment is necessary before the estimates can be compared. Some of the estimates in Table 1-3 are based on a list of nonattainment areas as defined by EPA's air quality model. Later, EPA limited the areas that need to spend money to achieve attainment to only those areas that both the model shows to be in nonattainment in 2007, *and* where there is sufficient current monitoring data to calibrate the model with local air quality information. This had the effect of cutting the number of areas that would require control action costs by about one-half; it also reduced total control cost estimates. To account for this other key difference, the various cost estimates are also adjusted to a "per initial nonattainment county" basis.

Figure 1-5 plots the resulting costs using the adjustments just described to improve their comparability. One finds that there does appear to be a roughly increasing cost per county with increasing degree of attainment. One also finds that the earlier EPA cost estimates are in fact *lower* in overall costs after accounting for the decision to only attribute control actions to the needs of counties that currently have good monitoring data. Based on a reading of the other modeling adjustments between the draft and final EPA cost estimates, there is good reason to believe that the main reason for the underlying increase in cost per county is related to massive adjustments to reduce the emissions inventory for dusts.[23]

Unfortunately, these cost estimates do not provide strong evidence for how to extrapolate to the costs of full attainment. Almost any value could be obtained based on the fitting of a range of linear to highly nonlinear curves through these points and then estimating where this curve would cross the vertical axis. More information is needed from additional sources on how marginal costs may increase. Although they are not to be found in the PM RIA, EPA has itself generated two estimates of the full attainment cost, which are listed as G and H in Table 1-3. (These correspond to a \$19 billion and \$8.7 billion per year estimate, respectively).

Table 1-3. PM Cost Estimates Cost of compliance with proposed $PM_{2.5}$ NAAQS (Cost expressed in 1990 dollars)

---

[23] Based on analysis of model calibration problems, EPA determined that the dust inventory should be reduced by a factor of 4. The initial reaction is that this would decrease costs. However, as can be seen in Figure 1-4, the opposite effect is more likely. The direct effect of this modeling action is to substantially reduce the cost-effectiveness of all dust-control measures. Thus, to achieve attainment requires the use of other, more costly measures not related to dust.

Label	A	b	B	C	D	E	F	G	H
Baseline w.r.t. Implementation of CAA Control Requirements									
• Incremental to CAPI (i.e., 50% reduction in utility SO_2 emissions beyond Title IV rqmts)		X							
• Incremental to full implementation of CAA control requirements by the year 2007	X			X	X	X	X	X	X
• Incremental to full implementation via CAPI (i.e., 50% reduction beyond CAA rqmts)			X						
Baseline w.r.t. PM NAAQS Implementation									
• Incremental to the current PM_{10} NAAQS as of the year 2007	X	X	X	X	X	X	X	X	X
Alternative Analyzed									
• $PM_{2.5}$ 15 ug/m3 annual							X		
• $PM_{2.5}$ 15 ug/m3 annual, 50 ug/m3 24-hour	X	X	X		X	X		X	X
• CAPI (i.e., 50% reduction in utility SO_2 emissions beyond Title IV rqmts)				X					
Level of Attainment									
• Cost corresponds to partial attainment	X	X	X		X	X	X		
• Cost corresponds to "full" attainment								X	X
(Marginal costs used to model "full" attainment may represent controls that do not exist)									
Exogenous Limits on Cost Effectiveness									
• Set cap on control measure cost at $1 billion per ug/m3 reduced	X	X	X		X	X	X		
• Set cap on control measure cost at $2 billion per ug/m3 reduced									
• No cap on control measure cost								X	X
Identification of Initial Non-Attainment Areas									
• From subset of 470 counties with PM_{10} monitoring, predict $PM_{2.5}$ exceedences	X	X	X	X				X	X
• Perform concentration modeling for all counties					X	X	X		
Regionwide/Local Control Measure Constraints									
• In areas exceeding the standard, attainment is sought through ...									
• ... control measures within that nonattainment area only (constrained)					X				
• ... nonutility control measures within area only, utility control measures regionwide									
• ... control measures throughout the region (unconstrained)	X	X	X			X	X	X	X
Results									
• No. of Initial Non-Attainment Areas (i.e., counties)	126	126	126	126	510	510	438	126	126
• No. of Residual Non-Attainment Areas (i.e., counties)	57	53	53	97	378	216	168	0	0
• Percent Residual Non-Attainment (%)	45	42	42	77	74	42	38	0	0
• Implementation Cost (billion $/year)	6.3	4.3	8.9	4.6	11.3	17.1	17.1	19	8.7
• Implementation Cost (billion $/year per nonatt. area)	0.05	0.03	0.07	0.04	0.02	0.03	0.04	0.15	0.07

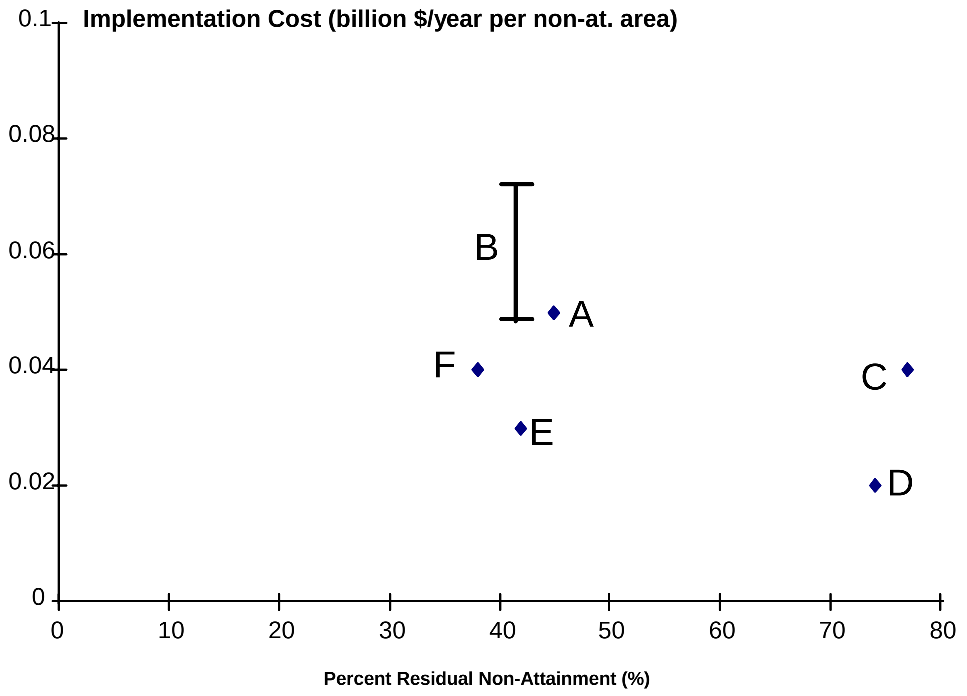
References
A ... EPA's December 1996 "RIA for Proposed PM NAAQS" ... pages 7-9 & 7-12
A ... Pechan's September 1996 "Addendum to Complemental ...." ... page 6
b ... EPA's December 1996 "RIA for Proposed PM NAAQS" ... pages 7-19
B ... EPA's December 1996 "RIA for Proposed PM NAAQS" ... pages 7-17 & 7-19
C ... EPA's "Acid Deposition Standard Feasibility Study Report to Congress"
D ... Pechan's May 1996 "Complemental National Cost Analysis ...." ... page 10
E ... Pechan's May 1996 "Complemental National Cost Analysis ...." ... page 28
F ... Pechan's January 1996 "Supplemental National Cost Analysis ...." ... page 30
G ... EPA Fact Sheet for PM RIA
H ... Vatavuk's November 1996 memo "Full Attainment Cost Estimates"

Estimate H was found in the EPA PM Docket and does not appear to have been cited by EPA in any public communications. DFI reviewed the basis for this calculation and determined that the method of extrapolation is flawed. The fact that EPA has not made use of this number probably indicates that EPA also understands the flaws.[24] Because of the flaws, this estimate is not used or referred to further in this analysis.

---

[24] The source of H is a November 22, 1996 memo from W. M. Vatavuk to the Docket, (Docket number A-95-54, II-F-3). The key problem is that the extrapolation attempts to estimate marginal costs for the residual nonattainment areas in the 15/50 standard by looking at how the average cost increases when additional new nonattainment areas are brought into the cost estimation for the more stringent 12.5/50 standard. The increased cost of the 12.5/50 standard is tied to the *lower* costs of areas that have a lesser control problem, rather than to increasing control effort on the part of the residual nonattainment areas that are of concern for the 15/50 standard.

Figure 1-5: EPA's Estimates of Implementation Cost for Proposed PM NAAQS and Corresponding Levels of Non-Attainment



The other EPA-generated full attainment estimate (estimate G) appears in EPA's 5-page *Fact Sheet on EPA's Regulatory Impact Analysis for the PM$_{2.5}$ Standard*. It does not appear in the RIA itself, and seems to be completely undocumented. However, the RIA does provide a table showing low, high, and average concentrations over all the 57 residual nonattainment counties before and after implementation to partial attainment.[25] The residual nonattainment information in that table is reproduced here in Table 1-4. If one sums the *average* concentration in each region, the result is 13 µg/m^3. This is a fairly meaningless number since there are actually 57 residual nonattainment counties, each with its own µg/m^3. However, EPA's marginal cost for each of the 57 counties at the cost "stopping point" was $1 billion per µg/m^3. If this marginal cost is multiplied by the 13 µg/m^3, and added to the $6.3 billion, one obtains $19 billion. Thus we assume that this is the EPA extrapolation method. EPA asserts in its *Fact Sheet* that this $19 billion per year is thought to be an overestimate of the likely full attainment cost for the proposed PM standard. Several other groups have noted the flaws in the EPA approach. We have added a few to the list:

- The marginal costs *in any single county* increase dramatically to levels such as $20 billion or $30 billion per µg/m^3.[26]

---

[25] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard*, December 1996, Table 7-4.

[26] This fact was demonstrated for Philadelphia and Denver in a letter from Erica Laich, E. H. Pechan & Associates (the EPA contractor on the cost modeling) to Mr. Bill Vatavuk, EPA, November 22, 1996 (Docket number A-95-54, II-F-9).

- The total cost before all controls are exhausted is \$19.6 billion in the Midwest/Northeast region and \$3.4 billion per year in the Rocky Mountain region.[27] There are five more regions unaccounted for.

- There are up to 17 nonattainment counties in most of the regions. Although these counties may all be linked as a single nonattainment area, EPA provides no information at all on their identity or geographical relationships.

- The 13 μg/m^3 is only an average over all of the nonattainment counties in each region. In fact, the residual μg/m^3 of nonattainment is much higher than the average in some regions. (If the worst county's residual μg/m^3 were added up in each county, the 13 μg/m^3 would be 30 μg/m^3.)

Table 1-4. Data Provided by EPA on Residual Nonattainment Associated with its \$6.3 billion per year Cost Estimate (partly from Table 7-4 of the PM RIA)

	Number of		Annual $PM_{2.5}$ Conc. Achieved	
Modeling	Residual Counties		Under Partial Attainment Scenario	
Regions	Monitored	All Modeled	Average	Maximum
	Subset	Counties**	(μg/m^3)	(μg/m^3)
Midwest/Northeast	10	60	17.8	21.8
Rocky Mountain	16	36	17.9	22.6
South Central	1	60	15.1	15.1
Southeast	1	14	15.1	15.1
Northwest	11	21	16.9	19.0
West	17	23	16.2	17.1
California*	1	2	19.4	24.0
Total	57	216		

* Residual counties in coastal California are assigned to the California region, residual counties in the remainder of the state are assigned to the West region.

** Data on number of residual modeled counties is NOT from the RIA. This is associated with an earlier costs analysis that is available in the PM Docket.

The above list of flaws appears to undermine the suggestion that the \$19 billion estimate is a realistic full attainment cost. Table 1-5 shows the range of estimates that have been generated by various groups who have tried to make use of the glimmerings of information that EPA has released regarding the actual degree of residual nonattainment, and of its cost modeling results. In attempting to improve the estimates, DFI made verbal requests to EPA for additional detail on the data regarding where the residual nonattainment counties are, and what the residual μg/m^3 actually is for each of the 57 counties. EPA affirmed that it does not wish to give out any further information. Ultimately, therefore, any extrapolations must be based on only this limited set of information.

Of course, the most appropriate way to determine the full attainment costs would be to simply run the PM Optimization Model without the arbitrary cost cut-off of \$1 billion per μg/m^3 of reduced PM and find out what the total cost might increase to (as well as whether attainment might even be feasible within the currently identified set of controls in the model).

In the case of the ozone full attainment costs, DFI developed estimates that were similar in magnitude to those found by other analysts. Table 1-5 shows that in the case of PM, DFI has concluded that the potential control costs could reasonably be expected to be higher than any of the other cost estimates identified. However, the American Petroleum Institute (API) estimates are stated as lower bound, based only on costs of control options that we know are actually in the database of EPA's cost model. As API

---

[27] Ibid.

points out, this estimate is too low because it does not reflect any additional costs for five of the seven regions. The comments submitted by RAP[28] made the same error as the EPA estimates in assuming that the MC would only need to be applied to a single average county in each region. On the other hand, RAP's choice of marginal cost ($4.28 billion per $\mu g/m^3$) is difficult to justify. It is based on an average control cost for a single city that itself would not have to experience that average cost to achieve its own attainment.

Table 1-5. Ranges of Full Attainment Cost Estimates (Each estimate has the $6.3 billion added into it for a total full attainment cost; many sources report only the incremental cost after the $6.3 billion.)

Source	Method	Full Attainment Cost Estimate ($billion per year)
EPA Fact Sheet	Multiply residual nonattainment for average county in each region by MC cap	$19 billion
API Comments	Take maximum cost that model could produce for each region, knowing it is still insufficient to meet standard	$31.5 billion "+?"
RAP Comments	Multiply residual nonattainment for average county in each region by model's maximum average cost from E. Laich letter (i.e., $4.28 billion per $\mu g/m^3$)	$61.3 billion
DFI "lower bound"	Multiply residual nonattainment for county that needs to make the greatest residual reduction by MC cap	$36 billion.
DFI "reasonable range"	Varying assumptions (see below) regarding interactions among counties within a region in their attainment efforts and the possibility that the actual number of residual nonattainment areas may be as high as that shown by EPA's PM air quality modeling, rather than just based on where monitors with good data currently exist; in all cases, assume conservatively MCs do not escalate beyond the $1 billion per $\mu g/m^3$ cap.	$70 billion-150 billion

The basis for DFI's "reasonable" range of full attainment costs is explained in more detail below. Briefly, it is reasonably conservative because:

- It assumes that marginal costs will not increase beyond the level that they have already reached in the partial attainment scenario. This is like assuming that the control measures not identified and included in EPA's model will be more cost-effective than the control measures that are in EPA's model but are not selected because they exceed a pre-determined marginal cost cap. At the same time, the estimate does not assume that there exist many measures that failed to be identified in EPA's engineering analysis as viable PM control options, yet which will be as cost-effective as those that have been more readily identified.

- Even though this estimate addresses the fact that there may be many more nonattainment counties than EPA has included in its final RIA cost analysis, this cost range is still justifiable on the basis of only the 57 residual nonattainment areas summarized in Table 1-4 above. Consideration of potential additional nonattainment areas only serves to support the judgment that the upper bound is not excessively pessimistic.

- The estimate gives substantial credit in our estimation to the chances that many actions will provide air quality improvements simultaneously to multiple nonattainment areas.

---

[28] Comments on the proposed rule by the Regulatory Analysis Program, George Mason University, prepared by Thomas D. Hopkins of Rochester Institute of Technology, May 1997.

A. DFI's Estimation of Costs of Full Attainment of Proposed $PM_{2.5}$ Standard

To estimate the cost associated with meeting the proposed $PM_{2.5}$ standard, EPA used an optimization model designed to determine the PM precursor control measures that would let each nonattainment county meet the proposed standard at the lowest cost. A critical constraint used in the PM optimization model is the cost cap on control measures, which is set at $1 billion per $\mu g/m^3$ reduced in at least one of the counties not yet in attainment. This means that if all control measures below the cost cap are exhausted in an effort to bring a particular county into attainment, it is assumed that nothing more will be done to help the county meet the standard, thus labeling it a residual nonattainment county.

In estimating the cost of full attainment, a particularly significant source of uncertainty involves control measures which have not been identified but which will become necessary to advance from partial to full attainment. EPA has attempted to shed some light on the cost of pushing residual nonattainment counties from partial to full attainment by noting that the marginal cost of control may be driven down through the emergence of more cost-effective control measures that may be identified in the future.[29] Conversely, EPA points out that the marginal cost of control would run significantly higher than $1 billion per $\mu g/m^3$ in the event that residual nonattainment can be eliminated only by control measures similar to those that have already been identified.

The lack of firm information relating to the cost-effectiveness of these unidentified controls suggest that a reasonable middle ground would be to set marginal cost at the level it reaches in the partial attainment case, but to not let this marginal cost escalate, as it does even among EPA's list of identified control measures. Given that the cost cap in EPA's PM optimization model has been set at $1 billion per $\mu g/m^3$ of PM reduced and that all control measures below the cost cap have been exhausted for those counties in residual nonattainment, it is reasonable to view this marginal cost of control, $1 billion per $\mu g/m^3$ reduced, as a conservative estimate (i.e., more likely to understate cost) for those unidentified control measures that will become necessary to proceed from partial to full attainment, especially if attainment actions must be implemented by 2008 at the latest.

In an effort to arrive at an estimate of the full cost of meeting the proposed $PM_{2.5}$ standard, it is also necessary to establish the degree of residual nonattainment by estimating the additional concentration reduction required to bring residual nonattainment counties into full attainment. EPA very roughly describes the distribution by region of the annual $PM_{2.5}$ concentration achieved in the residual nonattainment counties under the partial attainment scenario (see Table 1-4).[30] These results relative to the proposed 15 $\mu g/m^3$ standard represent the best available information regarding the additional concentration reduction needed to bring the residual nonattainment counties of each region into full attainment.[31]

Estimating the number of residual nonattainment counties once the cost-effective control measures have been exhausted is also critical to estimating the cost of full attainment. By applying its air-quality

---

[29] API Comments, *Appendix G: Comments on RIA's Analysis of the Benefits and Costs of Proposed $PM_{2.5}$ National Ambient Air Quality Standards*, p. 7.

[30] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard*, December 1996, Table 7-4.

[31] EPA has declined requests by DFI for more detail on the nonattainment status of various counties in its cost analysis.

modeling methodology to the subset of counties that are currently monitored as part of the PM_{10} monitoring network, EPA identifies 126 initial nonattainment counties broken down into their respective regions, 57 of which remain as residual nonattainment counties after making use of all control measures below the cost cap.[32] Documented in the PM docket, earlier modeling results for which the scope of analysis is not restricted to monitored counties provide a significantly different picture of nonattainment.[33] Based on air quality modeling applied to all counties in the contiguous United States, reported results indicate that 510 counties initially fail to meet the proposed standard, 216 of which remained as residual nonattainment counties after exhausting all control measures below the cost cap. The number of residual nonattainment counties for each of the individual modeling regions as reported in the referenced documentation, and the corresponding degree of residual nonattainment, can also be seen in Table 1-4 above. The key reason for the rosier picture of initial nonattainment in the RIA is that EPA chose to ignore over half of the counties even though its model, which is being used expressly to assess nonattainment problems, indicated that they too may present nonattainment difficulties.

With these rough estimates of the degree of residual nonattainment, the number of residual nonattainment counties, and the marginal cost of control measures necessary to advance from partial to full attainment, it is possible to develop a range of estimates representing the full cost of meeting the proposed $PM_{2.5}$ standard. For each region, the residual nonattainment county furthest from attainment after exhausting all control measures below the cost cap will require the greatest additional concentration reduction. That is, it must be reduced from the maximum $PM_{2.5}$ concentration achieved under the partial attainment scenario down to the $15\mu g/m^3$ annual standard. Using the information in the last column of Table 1-4 one can see that the total cost to accomplish this for all of the regions, assuming a marginal control cost of \$1 billion per $\mu g/m^3$ reduced, is approximately \$30 billion.

The control measures employed to bring about full attainment for the residual nonattainment county furthest from the standard should reasonably be assumed to produce some collateral concentration reduction for other residual nonattainment counties in the region. In addition, subsequent efforts to bring the remaining residual nonattainment counties into full attainment are also likely to produce some collateral concentration reduction for other residual nonattainment counties in the region. Because it is difficult to gauge the extent to which counties experience collateral benefits due to control measures employed to bring other counties into full attainment, a range of assumptions is considered to help develop a plausible range of estimates representing the full cost of meeting the proposed standard.

As an example, a 50 percent improvement towards attainment may be experienced by other residual nonattainment counties due to control measures employed to achieve full attainment for the single worst case county in the region. Applying a collateral reduction percentage of 50 percent to the remainder of the subset of monitored counties identified as residual nonattainment counties results in a total cost for all of the regions of approximately \$54 billion, again assuming a marginal control cost of \$1 billion per $\mu g/m^3$ reduced. The sum of the cost of partial attainment across all monitored counties (\$6.3 billion, from EPA's PM RIA), the cost of full attainment for the county furthest from the standard (\$30 billion), and the cost of full attainment for the remainder of the monitored counties assuming a collateral reduction

---

[32] U.S. Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Particulate Matter National Ambient Air Quality Standard*, December 1996, p. 7-6.

[33] E.H. Pechan & Associates, *Complemental National Cost Analysis of Alternative Particulate National Ambient Air Quality Standards,* prepared for the U.S. Environmental Protection Agency, May 1996. p. 28.

percentage of 50 percent ($54 billion) leads to a total cost of $90 billion for full attainment of the monitored counties within all regions.

A further step can be taken to address the remaining counties expected to be in residual nonattainment based on air quality modeling applied to all counties. These include those designated by the model as residual nonattainment counties that are not part of the current PM_{10} monitoring network. Like the monitored counties, it is reasonable to expect that nonmonitored counties will experience collateral benefits due to control measures employed to achieve full attainment for other counties in the region. Due to the relatively high number of counties working simultaneously to achieve full attainment if these additional counties are to be considered, a somewhat higher level of collateral concentration reduction may be expected. As an example, applying a collateral reduction percentage of 75 percent to nonmonitored residual nonattainment counties results in a total cost for all of the regions of approximately $60 billion, again assuming a marginal control cost of $1 billion per $\mu g/m^3$ reduced. Adding this to the total cost of full attainment of the monitored counties within all regions ($90 billion) gives $150 billion.

As mentioned earlier, EPA has provided no information that can help estimate the extent to which counties experience collateral benefits due to control measures employed to achieve full attainment for other counties in the region. For this reason, a range of assumptions concerning the level of collateral benefits is useful to help establish a range of estimates representing the full cost of meeting the proposed standard. Table 1-6 contains estimates of the cost of full attainment (including the $6.3 billion annual cost of partial attainment based on EPA's PM RIA) for a variety of collateral reduction percentage applied both to monitored and nonmonitored residual nonattainment counties.

Table 1-6. Cost of Full Attainment as a Function of Collateral Reduction Percentage

		Collateral Reduction Percentage Applied to Non-Monitored Counties										
		50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
Collateral Reduction Percentage Applied to Monitored Counties	100%	154	142	130	119	107	95	83	71	60	48	36
	95%	159	147	136	124	112	100	89	77	65	53	41
	90%	165	153	141	129	117	106	94	82	70	58	47
	85%	170	158	146	135	123	111	99	87	76	64	52
	80%	175	163	152	140	128	116	105	93	81	69	57
	75%	181	169	157	145	133	122	110	98	86	75	63
	70%	186	174	162	151	139	127	115	103	92	80	68
	65%	191	180	168	156	144	132	121	109	97	85	73
	60%	197	185	173	161	150	138	126	114	102	91	79
	55%	202	190	178	167	155	143	131	119	108	96	84
	50%	207	196	184	172	160	148	137	125	113	101	89
	45%	213	201	189	177	166	154	142	130	118	107	95
	40%	218	206	194	183	171	159	147	136	124	112	100
	35%	223	212	200	188	176	164	153	141	129	117	105
	30%	229	217	205	193	182	170	158	146	134	123	111
	25%	234	222	210	199	187	175	163	152	140	128	116
	20%	239	228	216	204	192	180	169	157	145	133	122
	15%	245	233	221	209	198	186	174	162	150	139	127
	10%	250	238	227	215	203	191	179	168	156	144	132
	5%	255	244	232	220	208	197	185	173	161	149	138
	0%	261	249	237	225	214	202	190	178	166	155	143

The cost estimate in the upper, right-hand corner of the table represents the assumption that the control measures necessary to bring the county furthest from the standard into full attainment is sufficient to bring its entire region into attainment. This is the "lower bound" estimate cited in Table 1-5. The cost estimates in the right-most column of Table 1-6 correspond to the assumption that all nonmonitored residual nonattainment counties reach the proposed standard due to control measures employed to achieve full attainment for other counties in the region. Another way of thinking about this is that the right-most column provides the cost estimates that would result if the full attainment extrapolations were to be based solely on the 57 residual nonattainment areas that are monitored, and thus are covered by the cost estimates that EPA presented in its RIA. Even under these assumptions, the full attainment costs could rise as high as $143 billion per year. It should also be noted that Table 1-6 does not show the most extreme cost case where there are less than 50 percent collateral reductions in nonmonitored counties. The cost estimates could thus rise towards $300 billion per year. However, it is only realistic to assume a fairly high degree of collateral PM reductions.

The cost estimates in demarcated in Table 1-6 reflect DFI's view on the likely range of collateral reduction, and reflect the cost range of $70 to $150 billion per year that this analysis has selected. This range assumes that collateral reductions are between 70 percent and 90 percent for modeled residual nonattainment areas, and between 50 percent and 90 percent for monitored nonattainment areas. However, individuals who have alternative viewpoints can determine the cost implications of their own judgments from Table 1-6.

IV. Economic Impact Analysis Results

The cost of control measures to reach full attainment of the proposed $PM_{2.5}$ and ozone standards will have an impact on the overall U.S. economy. To estimate the magnitude of that impact, a national version of the EDFS-53 macroeconomic model produced by Regional Economic Models, Inc. (REMI) was used to characterize important economic indicators such as real disposable income and distributive impacts such as differential impacts across regions and income groups. REMI is a 53-sector model representing interindustry relationships across the various sectors and regions of the economy, as well as behavioral and demographic interactions characterized in economic theory.[34] The model developed for this analysis divided the United States into eight regions, or groups of states that are likely to have common control needs and have similar types of economic bases. The REMI regions and the states in each region are summarized in Table 1-7.

Table 1-7. States in Each of the Eight REMI Model Regions

Region 1. Northeast- Mid-Atlantic	Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut, New York, New Jersey, Pennsylvania, Delaware, Maryland, West Virginia, Virginia
Region 2. Southeast	North Carolina, South Carolina, Georgia, Florida, Alabama, Mississippi, Tennessee
Region 3. North Central	Ohio, Kentucky, Indiana, Illinois, Michigan, Wisconsin, Missouri, Iowa, Minnesota
Region 4. South Central	Arkansas, Louisiana, Texas, Oklahoma, New Mexico
Region 5. NW Central	Kansas, Nebraska, South Dakota, North Dakota, Montana, Wyoming, Colorado
Region 6. West	Utah, Arizona, Nevada
Region 7. Far West	California, Hawaii
Region 8. Northwest	Idaho, Oregon, Washington, Alaska

---

[34] More details on the structure and functioning of this model can be found in *REMI EDFS-53 Model Documentation*, Chapter 1, Volume 1, (Amherst, Mass.; Regional Economic Model Inc., March 1997).

In this analysis, the REMI model was used to obtain some insights about what the economic effects might look like if the United States were to embark on a regulatory program to control precursors of $PM_{2.5}$ and ozone that would have control costs at the level of either \$90 billion per year or \$150 billion per year. Discussion in earlier parts of this report indicated that there are no specific control actions explicitly underlying these cost estimates, because they are based on extrapolations rather than detailed cost modeling. In addition, there is very little information available as to the specific nonattainment areas that would bear these costs.[35] Thus, the economic impact analysis using REMI is intended as a pro forma exercise to try to understand the nature and potential magnitude of impacts of a national program of this order of magnitude.

A. Cost Input Assumptions

In assigning the estimated total costs to specific REMI sectors and regions, a number of relevant pieces of information have been used:

- The control program is likely to have broad regional impacts: combinations of ozone and/or $PM_{2.5}$ nonattainment areas appear in all regions. In addition, the assumptions used in the cost extrapolations relied on the judgment that controls would almost certainly be applied in areas of influence outside of the nonattainment areas. If this were not the case, then the control cost estimates themselves would be significantly higher.

- The control activities would tend to be correlated with sources of NO_x, VOCs, SO_2, and, to a lesser extent, PM_{10}.[36] Thus, costs were first attributed to individual sectors according to the proportion of total relevant emissions accounted for by each sector.[37] For emissions associated with the use of a product, the redesign/reformulationon costs would be borne by the manufacturer, and passed on to the consumer. Thus, in estimating which sectors would bear what portion of total control costs, emissions associated with use were attributed back to the sector that manufactures the product.

- For each individual affected sector, the portion of its costs that would be borne in each region would tend to correlate with how much of that sectoral output occurs within each region. Thus, for example, much of the “control costs” for redesigning motor vehicles to be lower-emitting is concentrated in the North Central region (Region 3), although in the model simulation, the costs from this production are passed back to consumers of vehicles in all regions.

- It was assumed that these control programs would be primarily technological in nature. No attempts were made to reflect lifestyle changes or infrastructure changes, other than to apply costs that would be attributed to road dust control measures to local government spending.

- No changes were made to tax rates.

---

[35] Although EPA has this information and has used it for its own cost analyses, it will not release it publicly.

[36] The \$90 billion per year control costs were fed into the economy as if they consisted of the \$6.3 billion for the PM partial attainment actions, \$25 billion for VOC and NO_x controls to manage ozone, and \$58.7 billion for additional PM controls.

[37] A number of adjustments were made to the 1990 Emissions Inventory data to reflect the fact that these cost estimates have assumed that a regional utility and industrial NO_x control strategy, a national LEV program, and Title IV SO_2 controls would be effective before these incremental costs of the proposed rules are borne.

Table 1-8 presents the resulting cost inputs for each sector associated with the $90 billion per year control measures, and shows what percent of each sector's costs is distributed to each of the eight regions. In the table, one can see that the costs are actually distributed in a manner that is reasonably proportionate to regional population, although population was not used as one of the determining factors. The North Central states appear to bear proportionately more, consistent with their large share of utility emissions and the fact that the motor vehicle industry is centered there. Table 1-9 provides the actual regional level costs associated with these attributions. (The costs in this table are still on an annualized basis.)

Computational resource requirements made it infeasible to do the analysis at the state level. Even an eight region model requires substantial modeling, data development and computing time. Further, these analyses of economic impacts are quite illustrative in nature, and do not have sufficient accuracy to warrant a state-specific modeling effort. However, Appendix 2 provides an example of how the same cost-attribution method could be used to generate state-level cost assumptions. The information in Appendix 2 *was not used as input to any of these REMI analyses* and is only provided to show how the same $90 billion per year of costs might have been allocated to states had we been attempting to perform a state-level analysis of this set of potential control costs.

The inputs to the REMI model are in fact much more detailed than what Table 1-9 may seem to indicate. A quick summary of some of the steps and details are:

- The annualized costs are converted to 1992 real dollars (which is the unit used in the REMI model) and are broken into capital and operating cost components.

- Capital costs are fully spent during the implementation phase (2002 to 2008), while operating costs are phased in gradually between 2002 and 2008, then remain constant (in real terms) over the remainder of the model simulation (through 2025). The annual payments for the capital expenditures are also phased in like the O&M costs. Thus, costs are lower than expenditures prior to about 2007, and then become larger than expenditures post-implementation, while companies pay off the capital costs, and operate equipment.

- Capital expenditures are reflected in the model as increased demand to several construction-related sectors. O&M costs are reflected as increased demand for a combination of materials-related sectors, energy and other public-utility related services, and on-site labor.

- Payments of capital charges and O&M are reflected in the model as nonproductive cost increases for the sectors that must purchase and operate the control equipment, or make other manufacturing changes to alter their products (as in the case of reformulated paints, aerosols, and lower-emitting vehicles). One exception to this rule is that costs related to electric generation are translated into a combination of electricity price increases (which is a model input variable that affects the costs of all electricity users, including households, in proportion to their overall demand for this source of energy), and loss to shareholders.[38]

---

[38] In the results reported here, we assumed that about 50 percent of the cost would be passed through as electricity price increases, and about 50 percent would be absorbed by shareholders. The price pass-through is diminished over time to reflect changing capital stock in years approaching 2025. The price mark-up peaks at 2 percent. A sensitivity case was run where the full cost was passed through entirely as price markup. This created a small increase in the magnitude of the economic impacts reported here.

Table 1-8. Attribution of the $90 billion Illustrative Control Cost Scenarios to Regions and Sectors

			REGION							
		Total	1	2	3	4	5	6	7	8
		% of costs	22%	14%	28%	18%	3%	2%	10%	3%
		% population	26%	17%	23%	11%	4%	3%	12%	4%
REMI Sector No.	REMI Sector Name	Sector Cost	Percent of Sector's Cost by Region							
1	Lumber	$1 billion	15%	23%	22%	10%	3%	1%	8%	18%
2	Furniture	$0 billion	18%	30%	31%	6%	2%	1%	10%	2%
3	Stone, clay, etc.	$2 billion	23%	19%	28%	12%	4%	2%	9%	3%
4	Primary metals	$3 billion	27%	12%	41%	6%	2%	2%	5%	5%
5	Fabricated metals	$3 billion	24%	12%	42%	9%	2%	1%	8%	2%
6	Non-electric machine	$0 billion	23%	13%	38%	8%	3%	1%	12%	2%
7	Electric equipment	$0 billion	25%	15%	23%	13%	2%	3%	16%	2%
8	Motor vehicles	$9 billion	11%	10%	68%	5%	1%	1%	2%	1%
9	Rest of transportation equip.	$2 billion	23%	13%	16%	10%	5%	4%	18%	12%
10	Instruments	$0 billion	39%	8%	20%	5%	3%	2%	19%	2%
11	Misc. manufacturing	$0 billion	38%	10%	24%	7%	2%	4%	12%	3%
12	Food	$2 billion	22%	15%	33%	9%	5%	1%	12%	4%
13	Tobacco manufacturing	$0 billion	33%	53%	14%	0%	0%	0%	0%	0%
14	Textiles	$0 billion	23%	67%	4%	2%	0%	0%	3%	0%
15	Apparel	$0 billion	28%	25%	17%	10%	1%	1%	18%	1%
16	Paper	$2 billion	23%	24%	31%	10%	1%	1%	6%	5%
17	Printing	$0 billion	33%	12%	27%	7%	5%	2%	11%	3%
18	Chemicals	$8 billion	32%	16%	27%	16%	1%	1%	6%	1%
19	Petroleum products	$15 billion	14%	3%	16%	49%	4%	1%	11%	2%
20	Rubber	$0 billion	22%	19%	38%	9%	3%	1%	7%	1%
21	Leather	$0 billion	47%	8%	27%	8%	3%	0%	4%	1%
22	Mining	$1 billion	6%	5%	11%	54%	8%	8%	5%	4%
23	Construction	$1 billion	25%	19%	20%	12%	4%	3%	12%	4%
24	Railroad	$0 billion	na	na	na	na	na	na	na	na
25	Trucking	$0 billion	na	na	na	na	na	na	na	na
26	Local/interurban transit	$0 billion	na	na	na	na	na	na	na	na
27	Air transportation	$0 billion	na	na	na	na	na	na	na	na
28	Other transportation	$0 billion	21%	14%	17%	20%	4%	1%	14%	9%
29	Communication	$0 billion	28%	19%	18%	12%	6%	3%	11%	3%
30	Public utilities (nonelectric)	$3 billion	26%	15%	22%	19%	5%	2%	9%	3%
31	Banking	$0 billion	29%	15%	24%	9%	5%	3%	12%	3%
32	Insurance	$0 billion	28%	15%	24%	11%	5%	3%	11%	3%
33	Credit and finance	$0 billion	42%	10%	18%	9%	4%	2%	12%	2%
34	Real estate	$0 billion	31%	15%	18%	10%	4%	3%	15%	4%
35	Eating and drinking	$0 billion	21%	17%	24%	12%	5%	3%	14%	4%
36	Rest of retail	$0 billion	24%	18%	23%	12%	4%	3%	12%	4%
37	Wholesale	$0 billion	25%	17%	23%	11%	4%	2%	12%	4%
38	Hotels	$0 billion	28%	16%	12%	7%	4%	14%	15%	3%
39	Personal & repair service	$0 billion	23%	17%	22%	12%	5%	3%	15%	4%
40	Private households	$0 billion	na	na	na	na	na	na	na	na
41	Auto repair/service	$0 billion	23%	17%	22%	12%	5%	3%	14%	5%
42	Misc. business service	$1 billion	27%	15%	20%	11%	4%	3%	16%	4%
43	Amusement & recreation	$0 billion	26%	16%	19%	9%	4%	5%	18%	4%
44	Motion pictures	$0 billion	20%	8%	12%	6%	2%	2%	48%	2%
45	Medical	$1 billion	29%	15%	23%	11%	4%	3%	11%	4%
46	Misc. professional services	$0 billion	32%	13%	19%	11%	4%	3%	15%	4%
47	Education	$0 billion	40%	12%	21%	7%	3%	2%	12%	3%
48	Non-profit organization	$0 billion	31%	14%	24%	10%	4%	2%	11%	4%
49	Agri./forest/fish service	$1 billion	16%	17%	17%	12%	7%	2%	18%	11%
50	State & Local	$4 billion	26%	16%	24%	12%	4%	3%	12%	4%
51	Federal, civilian	$0 billion	na	na	na	na	na	na	na	na
52	Federal, military	$0 billion	na	na	na	na	na	na	na	na
53	Farm	$3 billion	26%	16%	24%	12%	4%	3%	12%	4%
54	Consumers	$4 billion	26%	16%	24%	12%	4%	3%	12%	4%
55	Electric utilities	$20 billion	24%	17%	22%	12%	4%	3%	14%	4%

Table 1-9. Regional Costs (Annualized, in 1990 Dollars)

			REGION (in Billions of dollars)							
REMI Sector No.	REMI Sector Name	Full Attain.	1	2	3	4	5	6	7	8
	Total	90.0	19.6	12.2	25.2	15.9	3.0	1.8	9.1	3.1
1	Lumber	0.8	0.1	0.2	0.2	0.1	0.0	0.0	0.1	0.1
2	Furniture	0.2	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0
3	Stone, clay, etc.	2.3	0.5	0.5	0.7	0.3	0.1	0.1	0.2	0.1
4	Primary metals	2.6	0.7	0.3	1.1	0.2	0.0	0.1	0.1	0.1
5	Fabricated metals	3.0	0.7	0.4	1.3	0.3	0.1	0.0	0.2	0.1
6	Non-electric machine	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.1	0.0
7	Electric equipment	0.4	0.1	0.1	0.1	0.0	0.0	0.0	0.1	0.0
8	Motor vehicles	9.1	1.0	0.9	6.2	0.5	0.1	0.1	0.2	0.1
9	Rest of transportation equip.	2.5	0.6	0.3	0.4	0.2	0.1	0.1	0.4	0.3
10	Instruments	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
11	Misc. manufacturing	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
12	Food	2.0	0.4	0.3	0.7	0.2	0.1	0.0	0.2	0.1
13	Tobacco manufacturing	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
14	Textiles	0.3	0.1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
15	Apparel	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
16	Paper	2.0	0.4	0.5	0.6	0.2	0.0	0.0	0.1	0.1
17	Printing	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
18	Chemicals	8.0	2.6	1.3	2.2	1.2	0.1	0.1	0.5	0.1
19	Petroleum products	14.7	2.0	0.5	2.4	7.2	0.5	0.1	1.6	0.4
20	Rubber	0.4	0.1	0.1	0.2	0.0	0.0	0.0	0.0	0.0
21	Leather	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
22	Mining	1.1	0.1	0.1	0.1	0.6	0.1	0.1	0.1	0.0
23	Construction	1.0	0.2	0.2	0.2	0.1	0.0	0.0	0.1	0.0
24	Railroad	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
25	Trucking	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
26	Local/interurban transit	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
27	Air transportation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
28	Other transportation	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
29	Communication	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
30	Public utilities (nonelectric)	3.0	0.8	0.5	0.7	0.6	0.1	0.1	0.3	0.1
31	Banking	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
32	Insurance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
33	Credit and finance	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
34	Real estate	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
35	Eating and drinking	0.3	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
36	Rest of retail	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
37	Wholesale	0.3	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
38	Hotels	0.4	0.1	0.1	0.1	0.0	0.0	0.1	0.1	0.0
39	Personal & repair service	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	Private households	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
41	Auto repair/service	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.0
42	Misc. business service	1.3	0.3	0.2	0.2	0.1	0.1	0.0	0.2	0.0
43	Amusement & recreation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	Motion pictures	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
45	Medical	0.7	0.2	0.1	0.2	0.1	0.0	0.0	0.1	0.0
46	Misc. professional services	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
47	Education	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
48	Non-profit organization	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
49	Agri./forest/fish service	0.7	0.1	0.1	0.1	0.1	0.0	0.0	0.1	0.1
50	State & Local	3.9	1.0	0.6	0.9	0.5	0.2	0.1	0.5	0.1
51	Federal, civilian	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	Federal, military	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
53	Farm	3.0	0.8	0.5	0.7	0.4	0.1	0.1	0.4	0.1
54	Consumers	3.6	0.9	0.6	0.9	0.4	0.1	0.1	0.4	0.1
55	Electric utilities	20.0	4.7	3.4	4.5	2.4	0.9	0.6	2.7	0.9

The rest of this section focuses on the most salient results from the $90 billion and $150 billion per year control cost estimates summarized earlier in the report. The model runs reported here reflect an approximate 90 percent success on the part of federal monetary policy in reducing potential job impacts.[39] The summary to this section also provides estimates of the nature of the impacts in the event that there would be *no* residual net job loss in the economy as a whole (i.e., if monetary policy is fully effective). It is important to note that the most critical of the impacts that are being reported here would remain unchanged in large part even if there were no net job loss on a national scale.

B. Real Disposable Income Impacts Based on Low End of Combined Cost Range

One of the most important measures of the impact on the United States economy of the control costs associated with achieving full attainment of the proposed $PM_{2.5}$ and ozone standards is the change in real disposable income per capita. This is because most of the costs of control will be passed on to consumers, rather than taken from alternative productive investments. Based on the $90 billion per year estimate of the cost of full attainment, Table 1-10 presents the impacts on personal disposable income per capita by year to illustrate the time-dependent nature of the effects. Impacts to real disposable income are softened somewhat in the earlier years by the large capital expenditures that occur during the implementation phase (2002–2008 in our model runs).

Table 1-10. Real Disposable Income Impact Per Capita for $90 billion Scenario (1992 real dollars)

	Modeled Year				
	2005	2010	2015	2020	2025
Real Disposable Income Per Capita	-$209	-$259	-$264	-$271	-$276

The real disposable income per capita impact may vary to some degree across regions. Table 1-11 shows the income impacts by region, ordered from the most adversely affected to least adversely affected region. It can be seen that the impacts for this initial analysis do not vary substantially by region. This is because the programs are likely to have widespread impacts that affect all regions in one way or another.[40]

C. Employment Impacts Based on Low End of Combined Cost Range

Change in total employment in the United States is another measure that is useful in characterizing the impact on the United States economy of control costs. As has been noted, in an ideal world, monetary policy would effectively erase any net national employment impacts. However, there is a good chance that the Federal Reserve would fail to be 100 percent effective in the face of a major program and conflicting policy objectives, if only for a transient period. The results of the model runs presented here

---

[39] Although it is not a realistic assumption for an economic projection, one can run the REMI model with a totally unmanaged monetary policy, where the Fed would make no attempt to offset observed aggregate national employment impacts of any magnitude. In this extreme bounding scenario, it was found that the potential job impacts could be as high as plus or minus 1 million to 2 million jobs.

[40] EPA has not released the information necessary to accurately characterize the specific initial and residual nonattainment areas that its models have identified. If made available, this information would be useful in improving the allocation of costs because the regions with the worst residual nonattainment would bear the brunt of the $90 billion cost estimate. Our costs for the first $6.3 billion do flow to the regions in a manner comparable to the regional cost breakdown in the PM RIA. However, we distributed the remaining majority of the costs according to which sectors are responsible for the emissions, and then distributed those sectoral costs to regions according to the baseline REMI sectoral output per region. It is possible that this approach overstates costs in regions that have high emissions but relatively few nonattainment areas. Future model runs should focus on refining the regional attribution of costs.

are for a situation where monetary policy is about 90 percent effective in attenuating aggregate employment impacts.

Table 1-11. Real Disposable Income Impact Per Capita by Region for $90 billion Scenario (1992 real dollars)

Region	Real Disposable Income Per Capita by Region				
	2005	2010	2015	2020	2025
Northwest Central	-$234	-$289	-$292	-$302	-$308
Northeast-Mid Atlantic	-$213	-$276	-$282	-$290	-$294
Northwest	-$223	-$277	-$279	-$283	-$286
North Central	-$213	-$265	-$276	-$280	-$284
South Central	-$196	-$255	-$256	-$263	-$268
Far West	-$199	-$252	-$249	-$256	-$264
Southeast	-$212	-$234	-$244	-$251	-$257
West	-$188	-$230	-$225	-$227	-$229
Nationwide	-$209	-$259	-$264	-$271	-$276

Again focusing on the low end ($90 billion per year) control cost estimate, the following table presents the employment impacts for three time frames, the years 2002, 2010 and 2014. Employment gains in the year 2002 reflect the initial large increase in demand to a number of sectors associated with implementation of the PM and ozone control measures. Employment impacts in the later years illustrate the potential effects following completion of capital projects, as payments on capital expenditures and maintenance costs begin to outweigh the annual demand increases associated with operating and maintaining the control measures that are fully in place. By 2014, projected employment impacts have leveled off at a net national level of about 200,000 fewer jobs. This represents less than 0.1 percent of the national baseline employment, but the job losses are experienced in disproportionate ways by different groups, sectors, and regions in the economy.

The employment impacts due to the cost of full attainment can be broken down to the various industrial sectors and regions that make up the United States economy. Such distributive impacts would remain (although to a somewhat lesser degree) even if the Federal Reserve were 100 percent effective in balancing aggregate employment impacts. Table 1-12 lists these impacts by sector for 2002, 2010, and 2014 (when projected impacts stabilize). In addition, it provides the regional disaggregation of sectoral impacts for 2014, which shows the potential of 200,000 jobs lost nationally. The sectors are ordered by the most adversely affected to the most advantageously affected (on an aggregate national basis).

As can be seen in Table 1-12, the net job impact is greater in some regions than others. This regional disparity would remain even if Federal monetary measures were able to completely mitigate aggregate national employment impacts. Future analysis efforts should be targeted at further refining the relative regional cost burdens, and it is possible that the disparities between regions would be widened through such more refined regional analyses.

Many readers may be interested in what these employment impacts may mean for individual states. The model used for this analysis does not provide state-level detail. Such modeling detail was infeasible within the various resource constraints of this analysis. In addition, a state-level analysis would have been inadvisable, even if it were feasible, given the informational constraints associated with the full attainment cost estimates. However, Appendix 2 provides some rough estimates of state-level employment impacts that are consistent with the model results for the $90 billion per year control cost scenario in 2014. Readers are cautioned that the material in Appendix 2 is speculative, and is not an output of the REMI model.

Table 1-12. Changes in Available Jobs by Sector and Region for $90 billion Scenario

SECTOR NAME	Total Across All Regions			REGIONS							
				1	2	3	4	5	6	7	8
	2002	2010	2014	2014	2014	2014	2014	2014	2014	2014	2014
Restretail(52-57,59)	-13,789	-171,508	-173,691	-40,889	-30,638	-41,418	-18,452	-8,044	-5,227	-21,269	-7,754
Eating/Drinking(58)	-8,532	-82,680	-87,550	-15,531	-17,694	-19,403	-10,851	-4,203	-2,732	-13,410	-3,725
Non-Profit(83,84,86)	-7,057	-63,261	-70,497	-19,445	-10,776	-17,507	-7,236	-3,531	-1,850	-6,714	-3,436
Education(82)	-5,224	-48,875	-52,255	-19,839	-5,966	-11,499	-4,293	-1,974	-1,246	-5,574	-1,864
Amuse&Recreation(79)	-3,286	-29,904	-32,007	-8,547	-4,632	-5,936	-2,604	-1,528	-1,626	-5,822	-1,313
Priv. Household(88)	-5,530	-31,045	-29,083	-6,857	-5,040	-4,397	-4,486	-1,086	-721	-5,474	-1,022
Construction(15-17)	41,472	-33,804	-26,251	-4,125	-4,296	-7,050	-2,154	-1,491	-1,141	-4,580	-1,416
Per Serv/Rep(72,76)	-754	-18,423	-19,834	-3,564	-3,314	-5,008	-1,865	-874	-565	-3,868	-777
Auto Rep/Serv(75)	-1,476	-12,121	-12,336	-2,004	-2,255	-3,084	-1,509	-695	-503	-1,656	-629
Credit&Fin(61,62,67)	-1,407	-9,220	-9,836	-2,665	-1,106	-2,103	-1,062	-712	-490	-1,083	-615
Food(20)	-1,684	-9,257	-8,948	-1,317	-1,656	-1,930	-1,249	-951	-174	-602	-1,069
Motor Veh(371)	-788	-7,237	-7,700	-298	-1,036	-5,647	155	-283	-147	-376	-69
Banking(60)	-578	-7,166	-7,664	-1,636	-1,313	-2,143	-739	-428	-295	-744	-364
Communication(48)	-1,810	-9,076	-7,242	-1,682	-1,331	-1,597	-948	-404	-256	-748	-275
Furniture(25)	-655	-5,414	-6,266	-869	-2,244	-1,795	-228	-174	-128	-664	-163
Apparel(23)	-988	-5,946	-5,811	-1,259	-1,927	-788	-517	-73	-84	-985	-178
Insurance(63,64)	-1,300	-5,021	-4,926	-501	-855	-1,706	-526	-656	-99	-336	-248
Motion Pictures(78)	-685	-3,921	-4,059	-559	-389	-762	-393	-138	-125	-1,531	-164
Hotels(70)	-203	-3,242	-3,988	35	-861	-1,171	184	-68	-2,375	479	-211
Rest Trans Equi(R37)	91	-1,421	-2,837	-604	-850	-285	-300	16	120	344	-1,278
Agri/F/F Serv(07-09)	73	-2,249	-2,686	-620	-390	-550	-189	-5	-130	-393	-410
Textiles(22)	-159	-2,311	-2,495	-460	-1,761	-88	-52	-11	-14	-87	-23
Local/Interurban(41)	-318	-2,354	-2,487	-997	-255	-556	-144	-97	-80	-259	-99
Misc. Manuf.(39)	-179	-2,069	-2,277	-369	-350	-785	-70	-123	-89	-317	-175
Lumber(24)	1,198	-1,829	-1,681	-384	-251	-691	15	-104	-97	-84	-83
Paper(26)	343	-1,221	-1,637	-978	856	-1,435	286	-159	-53	-229	77
Petro Prod(29)	-107	-1,010	-843	-178	-75	-238	-245	-27	-5	-61	-14
Mining(10,12-14)	1,151	-606	-360	-1	91	-180	-414	16	38	72	18
Leather(31)	-65	-236	-203	-37	-23	-30	-61	-7	-3	-37	-5
Tobacco Manuf(21)	-33	-94	-80	-13	-61	-5	0	0	0	0	0
Railroad(40)	464	750	671	142	113	166	96	80	13	35	26
Air Transp(45)	506	973	747	214	140	-12	140	9	28	217	10
Printing(27)	1,044	2,081	1,811	814	297	76	249	18	44	291	21
Other Trsp(44,46,47)	450	1,981	1,998	539	346	197	242	49	48	467	108
Rubber(30)	2,714	4,646	3,527	596	1,858	-200	815	119	44	311	-16
Trucking(42)	3,333	5,111	4,210	963	1,058	406	923	198	37	484	141
Primary Metals(33)	2,072	6,098	4,691	1,126	750	1,447	534	121	166	253	295
Misc Prof(81,87,89)	52,749	4,629	4,734	3,341	979	-784	1,369	92	123	-494	106
Chemicals(28)	3,136	7,290	5,276	-391	2,999	932	2,938	188	-88	-1,372	69
Misc. Busi. Serv(73)	12,266	15,562	8,883	5,858	1,410	-3,593	2,092	-81	194	3,050	-48
Public Utilities(49)	6,769	10,467	10,621	2,764	1,544	2,088	2,262	581	257	871	253
Instruments(38)	3,045	16,016	14,005	6,443	880	2,449	1,027	572	501	1,868	265
Fabricated Metals(34)	6,566	24,083	21,048	4,572	3,071	8,013	2,962	214	255	1,757	205
Wholesale(50,51)	19,155	30,035	22,468	6,921	4,825	4,080	2,666	1,244	317	1,410	1,006
Stone,Clay,Etc.(32)	4,612	26,659	25,264	5,594	5,188	6,453	3,313	1,040	696	2,209	771

Real Estate(65)	336	37,894	41,347	9,892	8,806	8,042	5,234	1,769	1,542	4,218	1,843
Mach. & Computers(35	17,552	50,778	45,441	9,799	8,310	12,970	2,229	2,292	731	7,734	1,376
Medical(80)	4,103	59,722	58,508	17,937	8,238	12,657	6,021	2,099	1,571	7,920	2,063
Elect. Equipment(36)	16,567	71,425	64,704	15,636	12,375	11,805	10,750	1,835	1,813	9,695	795
Gov't & Farm	7,516	48,765	47,547	14,727	6,908	9,266	7,371	1,250	703	6,455	811
Total	152,676	-147,556	-200,029	-28,706	-30,303	-63,329	-6,714	-14,125	-11,102	-28,629	-17,725

Table 1-13 presents the potential employment impacts in the years 2002, 2010 and 2014 based on establishment size. The change in total employment across the United States for small establishments (less than 100 employees) and large ones is given.

Table 1-13. Employment Changes by Establishment Size Category for $90 billion Scenario
(Small Establishments are <100 Employees)

Establishment Size	Employment Impacts by Establishment Size (jobs/year)		
	2002	2010	2014
Small Establishment	114,000	-166,000	-210,000
Large Establishment	31,000	-30,000	-38,000
Gov't & Farm	7,500	49,000	48,000

Table 1-14 presents the potential employment impacts for a number of broad occupational categories in the years 2002, 2010 and 2014. The changes in total employment across the United States for these occupational types reflect increases in employment for all job categories due to the increased demand for construction and maintenance activities associated with PM and ozone control measures. Employment impacts in the year 2010 illustrate the effects following completion of capital projects aimed at achieving the proposed standards, as payments on the capital expenditures and O&M costs begin to outweigh the beneficial economic impacts associated with control measures. The net job losses stabilize at about -200,000 by 2014. Cross-occupational impacts of this qualitative nature would persist even if the Federal Reserve were 100 percent effective in managing aggregate employment effects.

Table 1-14. Changes in Available Jobs by Occupational Type for $90 billion Scenario

Occupational Type	Employment Impacts by Occupational Type (jobs/yr)		
	2002	2010	2014
Blue collar	52,000	-64,000	-90,000
Clerical/sales	38,000	-101,000	-114,000
All construction related	27,000	1,400	2,500
Professional/management	36,000	15,000	2,300
Total	153,000	-148,000	-200,000

The economic analysis also showed the relative employment effects for jobs in five income ranges. Across all regions the general trend was that jobs were lost from the lower two income quintiles while the higher income quintile ranges either maintained or gained jobs.

D. Personal Disposable Income Impacts Based on High End of Combined Cost Range

An economic impact analysis was also conducted for the high estimate in our combined control cost range ($150 billion per year). This section focuses on results based on this $150 billion per year control cost estimate, which is incorporated into the economy as if it represents $6.3 billion for the $PM_{2.5}$ partial attainment actions, $60 billion for VOC and NO_x controls to manage ozone, and $83.7 billion for additional PM controls. Table 1-15 describes the estimated impacts on personal disposable income by year. As can be seen, the temporal pattern of impacts is similar to that for the low cost scenario, but the magnitude of impacts is increased roughly in proportion to the increase in the overall annualized control cost. Loss in real disposable income stabilizes at a level over $450 *per capita*.

Table 1-15. Real Disposable Income Impact Per Capita for $150 billion Scenario (1992 real dollars)

	Modeled Year				
	2005	2010	2015	2020	2025
Real Disposable Income Per Capita	-$347	-$431	-$443	-$455	-$465

The relative regional pattern in real disposable income per capita is quite similar to the corresponding results for the $90 billion scenario shown in Table 1-11 above. Though the magnitude of the change in real disposable income is correspondingly greater for each region in the $150 billion scenario, the level of impact for a given region relative to the other regions across the United States is consistent between the two scenarios.

E. Employment Impacts Based on High End of Combined Cost Range

As with the evaluation of employment impacts based on the low end of the control cost range, the estimates relating to employment in the $150 billion per year control cost scenario are presented for the years 2002, 2010 and 2014. With about 90 percent effectiveness on the part of national monetary policy in stabilizing national employment impacts, this high cost scenario projects potential job losses by 2014 of about 400,000. Table 1-16 displays the potential employment impacts based on establishment size under the $150 billion control cost scenario for the years 2002, 2010 and 2014.

Table 1-16. Employment Changes by Establishments Size Category for $150 billion Scenario (Small Establishments are <100 Employees)

Establishment Size	Employment Impacts by Establishment Size (job/yr)		
	2002	2010	2014
Small Establishments	193,000	-306,000	-389,000
Large Establishments	52,000	-56,000	-73,000
Gov't & Farm	13,000	84,000	82,000

Table 1-17 shows the potential employment impacts for four broad job categories for the same years 2002, 2010 and 2014. Note that the change in 2010 and 2014 in total employment among the blue collar and clerical/sales occupational categories is a net job loss, while the construction-related and professional/management occupational categories still experience some job gains due to the demand for O&M activities associated with PM and ozone control measures.

Table 1-17. Changes in Available Jobs by Occupational Type for $150 billion Scenario

Occupational Type	Employment Impacts by Occupational Type (jobs/yr)

	2002	2010	2014
Blue collar	89,000	-123,000	-174,000
Clerical/sales	64,000	-179,000	-205,000
All construction related	44,000	380	1,000
Professional/Management	61,00	23,000	-2,400
Total	258,000	-278,000	-381,000

In conclusion, the qualitative nature of both the $90 billion per year and $150 billion per year control programs is quite similar, with the key differences being in the quantitative magnitude of each effect. Although there is a potential for net employment impacts at the national scale that are small in percentage terms, the most relevant and enduring impacts are those associated with losses in real disposable income per capita. Real disposable income declines steadily from the year that implementation is initiated, regardless of any off-setting economic activity due to control measures. The losses in real disposable income are likely to be experienced in all regions, and to fall most heavily on less skilled labor classes and smaller types of businesses. Ultimately, the economic burden of the control costs appears to fall disproportionately on the retail and service sectors, which are the least commonly associated with the emissions that are the target of the control programs.

The cost estimates and associated projections of economic impacts described in this report are the result of a brief initial analysis conducted with minimal information regarding the specific nature of the requisite underlying control actions, and minimal information regarding the specific regions to which they should be attributed. The simulation of how the costs would filter into the economy was performed using reasonable assumptions based on the best available data. A number of sensitivity analyses were performed on the ways that these costs may filter back into the economy as increased demand, and only minor changes in the impacts were observed. However, further analysis is warranted, particularly with regard to alternative ways of attributing the control costs to economic actors, sectors, and regions. A substantial improvement in these assumptions could be achieved if EPA were to release more complete and disaggregated information about the results of the air quality and control cost modeling results that it only summarizes in its PM and ozone RIAs. Also, the potential for requisite lifestyle and infrastructure changes should be considered, and included in sensitivity cases, as well as the potential for changes in the relative amenity values of some locations that may have the worst current air quality levels.

Part 2

Assessing the Benefits of the Proposed Ozone and Particulate Standards

I. Summary

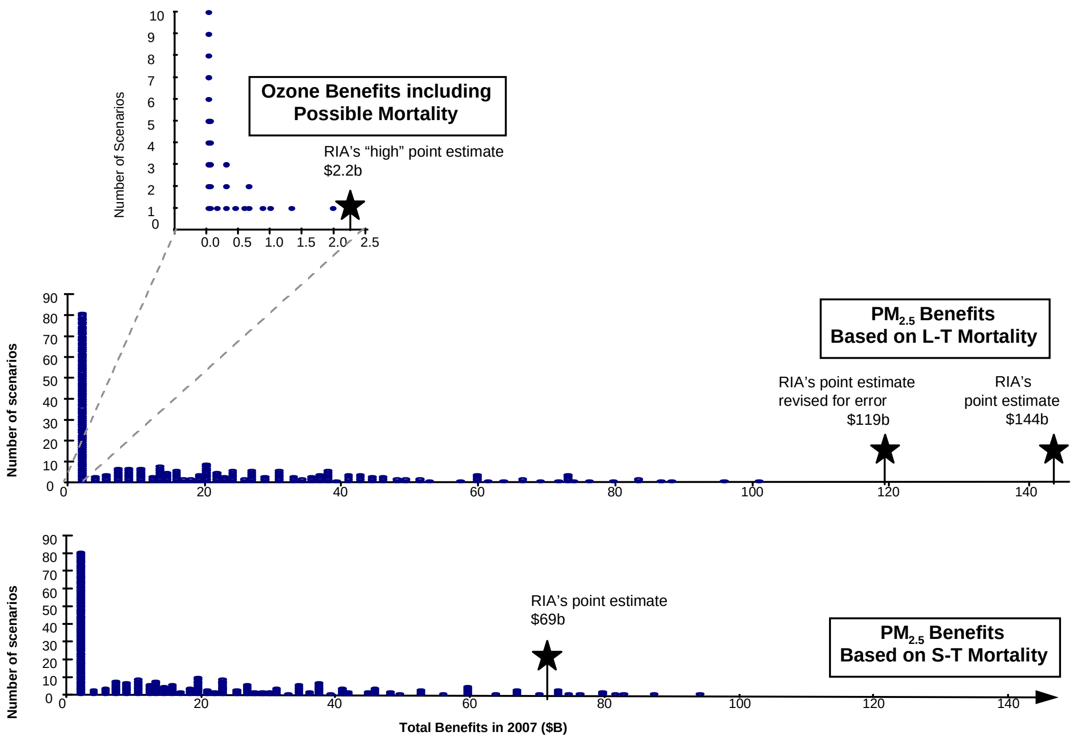
The ozone and PM Regulatory Impact Analyses (RIAs) provide monetized estimates of the national benefits of the proposed ozone and $PM_{2.5}$ standards, respectively. Although there is enormous uncertainty regarding the quantification of health effects from both ozone and $PM_{2.5}$, EPA estimates and communicates about these benefits primarily in point estimate form, with minimal reference even in the text to the nature or implications of the uncertainties. This point estimate representation conveys an unwarranted impression of precision in the numerical estimate. The RIAs suggest that EPA's estimates are not conservative, and that the direction of error is unknown.

This section explores uncertainties in both the ozone and PM benefit estimates, and re-estimates the national benefits under a range of alternative scenarios that are each at least as plausible as the specific point estimates released by EPA. The additional analyses summarized in this section demonstrate that range of possible benefits is very wide for both the proposed ozone and $PM_{2.5}$ standards. Most of scenarios lead to benefit estimates lower than EPA's benefit point estimates, and many of them are much lower. There are also a few alternative interpretations of the available health effects evidence that lead to higher benefit estimates than EPA has published. Overall, presentation of the full range of possible benefits gives a much more informative summary of the current state of scientific knowledge than the point estimates that EPA has provided.

To allow for comparison with the cost estimates developed in Part 1 of this report, this benefit analysis relates solely to the estimated benefits of full attainment of the proposed standards. The benefit estimates are for potential health and welfare benefits that are incremental to achieving the current ozone and $PM_{2.5}$ standards. As with EPA's analysis, benefits are only estimated above the background air concentration level.

Figure 2-1 compares the benefit estimates provided by EPA (the large stars in the figure) with the re-estimated benefits for the many alternative plausible scenarios considered in DFI's benefit analysis (each scenario reflects a separate combination of the key uncertain assumptions).

Figure 2-1. Comparison of Uncertainty Scenarios with Original EPA Benefit Point Estimates



Insights of this benefit analysis, which are observable in Figure 2-1, or otherwise described in this section of the report, include:

- The estimated health benefits from the proposed $PM_{2.5}$ standard range from a value well below $1 billion to a high of about $100 billion per year. Most of the estimates are less than $40 billion per year.

- The range in which the health benefits from the proposed ozone standard are likely to be found is similar to that stated by EPA: from less than $0.05 billion to about $2 billion per year. However, EPA did not clearly communicate that its own "most likely" ozone benefits value is near the low end of this range.

- The ranges of benefit estimates do not change even if one decides to accept the epidemiological findings as a quantified representation of fully causal relationships.

- After accounting for the various uncertainties, the choice of "long-term" or "short-term" mortality in the PM analysis has relatively little impact on the estimated range of benefits, even though the PM RIA suggests that this is a "particular" source of uncertainty.

- There are a substantial number of scenarios in which the welfare (nonhealth) benefits of the standard may exceed the health benefits, for both PM and ozone. (The welfare benefits are included in the benefit estimates shown in Figure 2-1. No uncertainty analysis was performed with respect to the welfare benefits in this analysis.)

- Although EPA argues that its benefit estimates are understatements because of the numerous unquantified or nonquantifiable benefits, there is little evidence that the ranges would be sensitive to addition of these other benefits: the ranges of benefits are determined almost entirely by the potential for avoided adverse health effects, particularly mortality.

- No attempt has been made to combine the ranges for PM and ozone. However, it is unlikely that the top ends of the ranges should be added together. The benefits estimate for ozone is due almost entirely to assuming a mortality effect that is highly confounded with estimates of potential PM mortality. Thus, if one wishes to attribute mortality to ozone, then one must consider reducing the mortality benefits attributed to PM.

This re-assessment of EPA's benefit estimate found it useful to distinguish between (1) errors in, or disagreements about, appropriate benefit analysis assumptions and (2) uncertainties in the underlying scientific research that can affect the benefits estimate, but for which there is little ground for establishing one "correct" value within the range of uncertainty. In re-estimating the benefits, issues of the first type are communicated by showing the national benefit estimate with and without the assumptions and judgments preferred in this analysis. The second type of uncertainty is communicated by displaying the full range of benefit estimate that result from possible combinations of these uncertainties. This analysis makes no attempt to assign probabilities to uncertainties.

This analysis makes adjustments for the following types of errors and disagreements: use of incorrect relative risk estimate for long-term mortality for $PM_{2.5}$; excessively high valuation on mortality through use of "numbers of deaths" as opposed to the economically more valid estimate of "years of lost life expectancy"; incorrect estimation of PM_{10} reductions, and unjustified attribution of benefits to reduction in the coarse fraction of PM_{10}. The uncertainty ranges in Figure 2-1 were estimated after making reasonable adjustments for these considerations. If the reader wishes to accept all of EPA's judgments on the above matters, this report also provides uncertainty ranges that result when using EPA's assumptions.

The ranges shown in Figure 2-1 reflect all the combinations of the following sources of uncertainty: potential presence of an undetectable threshold in epidemiologically derived results; alternative estimates of relative risk across studies; uncertainty ranges on relative risk within the single study selected by EPA for each benefits estimate; uncertainty regarding the degree of confounding, and the potential that there is no causal relationship in epidemiologically derived results. The last of these uncertainties does not affect the ranges that are derived, and detailed results are provided in this report both with and without uncertainty about causality. This is to reassure readers that the lower estimated benefits ranges have not been predetermined by assumptions that the relationships may not be causal.

While there are many more sources of uncertainty, those which have been included in this analysis are the ones that have been demonstrated by EPA to have the largest potential impact on the estimates (i.e., they are the most "sensitive" of the analysis assumptions). Thus, the ranges of benefits presented here are unlikely to be dramatically altered by inclusion of other uncertainties. Again, it is the ranges rather than any specific point estimates that give the most relevant context within which to evaluate the merits of the proposed standards.

II. General Quality Concerns

Before presenting the detailed assumptions and analysis results for $PM_{2.5}$ and ozone individually, it is worth discussing three key concerns that are common to both benefit analyses:

1. the declining quality of oversight and peer review from the underlying science summaries (i.e., the Criteria Documents) through the RIAs;
2. lack of accountability and public access; and
3. the difficulties imposed on benefits estimation when the sole underlying evidence is epidemiological.

A. Poor Quality of Oversight and Peer Review in Benefit estimates

The process of developing a scientific basis for the National Ambient Air Quality Standards has been held up by EPA as an example of "peer review on peer review." Indeed, the underlying summary of the science, called the Criteria Document, does receive an extensive review and oversight by a panel of prominent professionals known as the Clean Air Scientific Advisory Committee (CASAC). Further, it is very difficult for any information or finding to be included in the Criteria Document unless it has first been published in an accepted peer-reviewed journal. Thus, the quality of the Criteria Document is usually considered quite high. The Criteria Document is prepared by EPA's Office of Research and Development.

The Staff Paper, by contrast, is prepared by a different EPA office, the Office of Air and Radiation. It is intended as a bridge from the state of scientific knowledge to a policy interpretation. Although the Staff Paper does undergo a formal public comment period, the only true peer review that it receives is related to its summary of the science. CASAC evaluates the Staff Paper only in terms of whether it properly summarizes the science, and does not comment on its policy interpretations.

The information in the Regulatory Impact Analysis, which is released at the time that a standard is formally proposed, is not peer-reviewed at all. The Regulatory Impact Analysis (RIA), in fact, is not even a part of the formal process for setting a National Ambient Air Quality Standard. Rather, it is required under an Executive Order.[41] Thus, the RIA is generally given substantially less oversight and peer review, yet the information in the RIA often receives the greatest amount of public attention. There are few, if any, procedural mechanisms to assure that the benefits information used in an RIA properly reflect the state of science, or properly reflect the warnings and caveats of the Criteria Document.[42]

As will be discussed in various other parts of this section, this lack of oversight and peer review seems to result in many areas of criticism for the RIA benefit estimates. For example, over 95 percent of the estimated benefits for ozone are based on a single study that was not performed to address ozone mortality, and which was never cited or discussed in the ozone Criteria Document. Similarly, there are many warnings in the PM Criteria Document against using epidemiological results as well-defined

---

[41] Executive Order 12866, Sept. 1993, which superseded a similar requirement under Executive Order 12291, Feb. 1981, which first required a costs and benefit analysis for rules affecting the national economy in the degree of $100 million or more annually.

[42] The same concerns with lack of peer review pertain to the cost estimates in the RIA, which are the subject of Part 1 of this report. However, in the case of the cost estimates, there is no preceding compendium of peer-reviewed information to link to, such as the *Criteria Document* in the case of benefits estimation.

quantitative dose-response relationships; yet that is exactly what has been done in the benefit estimates of both RIAs.[43]

B. Lack of Accountability and Public Access

Lack of peer review is an obviously critical concern. However, this concern is exacerbated by the fact that there also are no apparent mechanisms to encourage that EPA be accountable for performing credible and reproducible benefit or cost estimates. EPA has quite clearly decided not to release major portions of the intermediate computations and data that lie behind its national cost and benefit estimates. Within the limited time frame between the release of the RIAs and the final rule making, it is infeasible to complete the process that does exist to obtain the relevant pieces of information from EPA (e.g., via a Freedom of Information Act request). The public must therefore trust EPA or make do with the small pieces of the puzzle that EPA voluntarily decides to release. Thus, it is impossible for any outside party to actually reproduce any of the national benefit estimates.

Because basic data and assumptions of the RIA are not publicly available, there have been many computational steps in this re-assessment that have required analyst judgment, approximations, and the use of information sources that may not be precisely the same as those used by EPA. Thus, there is an inherent likelihood that EPA would generate different results for each uncertainty scenario. However, at each step of this re-assessment, conservative judgments have been selected (i.e., judgments that can be expected to overstate the health benefits). Thus, one can expect that the picture of uncertainty that is drawn in this analysis would be unlikely to change dramatically if EPA were to allow broader public access to its data, computations, and assumptions.

C. Difficulties with Using Epidemiological Results for Benefit estimates

Despite warnings in EPA's Criteria Documents about the need for great caution in using epidemiological results as the sole basis for quantitative dose-response functions, the vast majority of the PM and ozone benefit estimates are based solely on such results. In the case of $PM_{2.5}$, there is no accepted argument for the biological plausibility that mortality may be affected by changes in low concentrations of particles, and little credible evidence of a toxicological nature either. The lack of supporting scientific understanding has caused numerous scientific experts to suggest that there is not yet even a strong case that these associations are causal in nature. In other words, there may not even be a dose-response relationship for these effects. In the case of ozone, the Criteria Document even states that there is no clear epidemiological evidence of a relationship of ozone with mortality, yet mortality benefits based on epidemiological evidence account for $2.25 billion of the RIA's $2.29 billion "high" estimate of the health benefits of the proposed ozone standard. This last example highlights the types of problems that occur when there is no form of accountability on the part of EPA to ensure that RIA's benefit estimates reflect a consistent view of the state of the science as expressed in the peer-reviewed materials also released by EPA.

---

[43] Examples of such disconnects between the statements of the peer-reviewed *Criteria Document* and EPA PM risk analyses (which are the methodological foundation for the PM benefits estimates) are presented in the written testimony of Anne E. Smith before the U. S. Senate Subcommittee on Clean Air, Wetlands, Private Property and Nuclear Safety on February 5 1997, (copies available from http://www.dfi.com).

There have been several papers published in peer-reviewed journals that explain how epidemiological studies can produce an erroneous or biased estimate of risk relationships.[44] There are also statistical proofs of the potential for bias.[45] Less technical and more intuitive examples can be provided that demonstrate how easy it would be for epidemiological evidence of ambient air quality health impacts to appear consistently in numerous different locations, yet not reflect any true causal relationship at all.[46] The Criteria Document itself recounts some of these problems with using epidemiological evidence. Thus, there is a significant body of evidence that epidemiologically derived risk estimates are subject to error so substantial as to leave open a reasonable doubt as to causality itself. Even stronger evidence is present that there may be substantial bias in the estimated relationships with PM or ozone, such that one or more other unaccounted-for factors may be reflected in the PM or ozone risk estimate. The following uncertainty analyses address the potential impact of these concerns on potential benefits from the proposed ozone and $PM_{2.5}$ standards.

III. Benefits Of The Proposed $PM_{2.5}$ NAAQS

A. Current and Proposed Standards

The current particulate matter standard is based on PM_{10}, or particles less than 10 microns in diameter. The standard is a maximum of 50 $\mu g/m^3$ annual mean, averaged over 3 years, and 150 $\mu g/m^3$ 24-hour average, with no more than one expected exceedence per year.[47]

The proposed standards would retain the 50 $\mu g/m^3$ annual mean standard for PM_{10}, along with a 24-hour PM_{10} standard of 150 $\mu g/m^3$ at the 98th percentile. Most importantly, new standards for the fine fraction of particulate matter, $PM_{2.5}$, would also be imposed. These would be at the levels of 15 $\mu g/m^3$ annual mean, with a 24-hour standard of 50 $\mu g/m^3$ at the 98th percentile. According to the EPA Administrator, this new combination of annual and peak PM_{10} and $PM_{2.5}$ standards would "protect public health with an adequate margin of safety."[48]

In the proposed rule, EPA affirms that the current levels of the PM_{10} standards are already adequately protective for any effects that might be associated with the coarse fraction. For example, it states that "the clearest community epidemiological evidence regarding coarse fraction particles finds such effects only in areas with numerous marked exceedences of the current PM_{10} standard."[49] EPA also indicates that there is no evidence suggesting that the coarse fraction of PM_{10} might be associated with mortality:

---

[44] One recent journal article that covers these issues in straightforward terms is by S. Vedal, "Ambient Particles and Health: Lines that Divide," *Journal of the Air & Waste Management Association*, vol. 47 (May 1997), pp. 551–581.

[45] See, for example, F. Lipfert and R. Wyzga, "Uncertainties in Identifying 'Responsible' Pollutants in Observational Epidemiology Studies," *Inhalation Toxicology*, vol. 7 (1995), pp. 671–689.

[46] See, for example, A. Smith and N. Chan, *How Statistics Can Mislead PM Policy: A Case of Smoke and Mirrors?*, Decision Focus Incorporated, March 10, 1997, in the PM Docket (copies available at http://www.dfi.com).

[47] 61 Fed. Reg. 65640

[48] 61 Fed. Reg. 65659

[49] 61 Fed. Reg. 65649

"in contrast to fine particles, coarse fraction particles are more clearly linked with certain morbidity effects at levels above those allowed by the current 24-hour standard."[50] Thus, the only change in the proposed rule that is relevant from the perspective of calculating benefits is that associated with fine particles specifically. In the cost and benefit analyses of the PM RIA, EPA correctly first brings all of the areas that are out of attainment with the current PM_{10} standard into attainment, and then estimates benefits (and costs) associated with the new proposed $PM_{2.5}$ standards incrementally from that starting point.

B. EPA's National Benefits Categories and Estimates

EPA's PM RIA develops estimates of the national benefits of the proposed $PM_{2.5}$ standards for a number of health effects categories. In addition, the national benefits estimate includes two nonhealth benefits ("welfare benefits") categories. The RIA develops estimates of the avoided incidence or severity of each of the categories when the proposed standard is applied. It then multiplies each by a monetized value for the respective endpoints, and sums them to achieve an overall estimate of total national benefits in the year 2007. It should be noted that EPA's estimates of avoided incidences in each category, and thus the estimate of total benefits, provide only a point estimate, with no range of uncertainty. The overall list of benefits categories used in EPA's benefits estimate is provided in Table 2-1, along with information on the basis for the studies.[51]

Table 2-1. Summary of EPA's $PM_{2.5}$ National Benefit estimates for Full Attainment of the Proposed $PM_{2.5}$ Standard, and Their Scientific Basis

Benefits Category	Estimated Benefits in RIA ($ millions p.a.)	% of Total	Data Basis	Scientific Basis
Mortality	$22,485 (S-T) $ 97,319 (L-T)	32% (S-T) 68% (L-T)	$PM_{2.5}$	epidem.
Chronic Bronchitis	$43,448	63 to 30%	PM_{10}	epidem.
All respiratory hospital admissions	$63	< 0.1%	$PM_{2.5}$	epidem.
Congestive heart failure hosp. admis.	$35	< 0.1%	PM_{10}	epidem.
Ischemic heart disease hosp. admis.	$49	< 0.1%	PM_{10}	epidem.
Upper Respiratory Symptoms	$1	< 0.1%	PM_{10}	epidem.
Lower Respiratory Symptoms	$3	< 0.1%	PM_{10}, $PM_{2.5}$	epidem.
Acute Respiratory Symptoms	$306	0.4%	PM_{10}	epidem.
Acute Bronchitis	$2	< 0.1%	PM_{10}, $PM_{2.5}$	epidem.
Shortness of breath	$1	< 0.1%	PM_{10}	epidem.
Moderate or Worse Asthma Status	$8	< 0.1%	$PM_{2.5}$	epidem.
Restricted Activity Days	$54	< 0.1%	$PM_{2.5}$	epidem.
Visibility	$1401	1 to 2%	light extinction	physics
Household soiling damage	$931	1%	TSP	econometric
TOTAL	$68,786 (S-T) $143,620 (L-T)	100%		

---

[50] 61 Fed. Reg. 65654

[51] EPA, Regulatory Impact Analysis for the Proposed Particulate Matter National Ambient Air Quality Standards, December 1996, Table 9.11.

The overall national benefits estimate that results is either $69 billion or $144 billion per year. The range depends on what "choice" of mortality estimate is used rather than any form of uncertainty. There are two types of mortality studies:

- One type looks at changes in mortality as the daily levels fluctuate in a single city. This is called "short-term mortality" (S-T) because it is associated with day to day variations, and such deaths, if they are really *causally* associated with the PM variations, would be associated with acute responses to brief but high levels of ambient PM.

- The second type of mortality study looks at changes in average mortality rates from city to city, and associates differences in these average rates with differences in average PM levels between cities. This is called "long-term mortality" (L-T) because it appears to reflect the effect of chronically higher exposures to ambient PM, and does not necessarily capture only acute responses to peak ambient PM episodes.

Assuming that this conceptual construct is a valid one, logic says that "long-term" mortality estimates would encompass "short-term" effects as well as any effects associated with chronically higher exposures. Thus, one should not add short-term and long-term mortality benefits. EPA therefore reports two estimates of total benefits, one which uses short-term mortality, and one which uses long-term mortality.

The higher national benefits estimate of $144 billion is based on long-term mortality. EPA cites the fact that it is higher than the short-term estimate as evidence that there is probably an incremental chronic mortality effect in addition to an acute response to peak ambient levels of PM. However, as this analysis will demonstrate, when uncertainty and errors are accounted for, there is actually quite little difference between the two types of mortality estimates.[52]

For either estimate of mortality, the combination of mortality and chronic bronchitis collectively sum to over 95 percent of the total benefits. Because mortality and chronic bronchitis are by far the most dominant components of the total benefit estimates, this analysis focuses on the range of uncertainty and sensitivity brought about by uncertainty in these two effects categories. Additional uncertainty is also present in incidence or valuation of other benefits categories, but it is highly unlikely that these uncertainties would substantially change the ranges of benefits. It is, however, interesting to note that:

- The basis for almost all of the benefits is epidemiological studies. Not one of the health effects risks appears to be founded on evidence of a clinical or laboratory nature. Thus, all of these health estimates are subject to the potential biases and causality uncertainties described in the preceding section.

- Many of the underlying dose-response relationships were derived from studies using PM_{10} (or worse, TSP) rather than $PM_{2.5}$. The attribution of the effects observed in most of these studies to the fine

---

[52] Recently, EPA has acknowledged an error in the epidemiological study underlying the long-term mortality estimate (EPA press release, April 2, 1997), and revised its benefits numbers downward 25 percent, which would imply a revised total benefits estimate of $119 billion, of which $73 billion is mortality. This correction is incorporated into the following analysis, along with other sources of uncertainty.

fraction of PM is *postulated* by EPA, rather than supported by the underlying epidemiological studies themselves.

These points alone should serve to highlight the degree of uncertainty that is inherent in EPA's benefit estimates. However, it is still useful to explore these uncertainties in a quantitative fashion, both with and without consideration of the problematic issue of whether there is a causal relationship between these potential benefits categories and current levels of ambient $PM_{2.5}$.

Figure 2-1 has already provided a summary of the overall quantitative results of this exploration of uncertainties in the benefit estimates. The rest of this section will provide a description of the analytical approach used to derive these results, and will provide more detailed sets of results that underlie Figure 2-1 for PM. This section is followed by a similar section that focuses on the uncertainty analysis of EPA's ozone benefit estimates.

C. Overview of Analysis Methodology for PM Benefit Re-Assessment

This analysis focused on developing an understanding of the major uncertainties in EPA's national benefit analysis which could impact the overall benefit estimates. In addition, several of the assumptions underlying EPA's analysis were revisited, and in some cases alternative assumptions were developed which the authors viewed as either more correct or more appropriate. The ultimate product of this analysis is a set of national benefit estimates (both in terms of both incidence and monetized) which reflect a plausible *range* of outcomes if the proposed rule were to be fully implemented. No single point within any of the ranges is viewed as "most likely," but the range itself, and the bulk of the individual alternative scenarios, provide more accurate and useful information than the single point estimate provided by EPA. The results presented here are thus more relevant for informing the policy making process.

The analysis that is reported in EPA's RIA calculates benefits on a county level, then aggregates to national estimates. However, the details of the underlying county-level data are not publicly available. EPA does not even report the identity of the counties that are viewed as being in nonattainment before or after controls on PM precursors are applied. This makes it impossible for outside parties to exactly replicate EPA's numerical results, or to check the accuracy of EPA's own calculations. Even aspects of the dose-response formulas are insufficiently documented.

DFI made verbal requests to EPA for relevant pieces of supporting data.[53] EPA consistently refused to provide underlying data on the basis of such requests. However, most queries regarding how the calculations were actually performed were addressed well enough for DFI to develop an equivalent set of benefits computations for a few individual cities, and for a few "representative" hypothetical cities. The sensitivities of impacts estimates in this set of real and hypothetical cities were assessed, and used to estimate the aggregate sensitivity of the national-scale impacts estimates. Where EPA refused to release certain source and intermediate-results data necessary to replicate its methodology, DFI made use of external data or technical judgments, which are noted in this report. Obviously, the following assessment

---

[53] There was insufficient time in this policy review period to go through the Freedom of Information Act request process, and no attempts were made to obtain information via that route.

of uncertainties could have been much more rigorous if EPA would release more specific supporting information rather than just a national aggregate result.

The following steps were undertaken in this analysis. Succeeding sections provide more discussion of each step.

- We reviewed EPA assumptions and adjusted for methodological errors and inappropriate valuations.
- We investigated key scientific and epidemiological uncertainties which could affect benefits, and developed reasonable ranges for uncertain parameters.
- We determined sub-populations which receive benefits, and developed a methodology for aggregating to national estimates.
- We assessed the sensitivity of health effects incidences to the key uncertainties.
- We aggregated incidences to determine changes in EPA's national incidence estimates.
- We applied values per incident to develop ranges of national monetized benefits.

In the discussion, occasional references are made to specific health effects studies that are used in the benefits estimation process. These studies are referred to by first author and date. Appendix 3 provides the full reference for each of these studies.

D. Adjustments to Correct for Errors and Inappropriate Valuation

There are two basic types of problems with EPA's PM benefit estimates. The first type is the use of assumptions and judgments that the authors believe are unjustified or erroneous. The second type is pure uncertainty that remains in the evidence being used to derive benefit estimates. In the first step, DFI made adjustments to reflect errors in assumptions and judgments that a large number of public groups who submitted formal comments to EPA agree are inappropriate. The result is an alternative point estimate that is denoted as the "DFI valuation/assumptions baseline" from which uncertainty analysis scenarios then proceed. The rationale for specific changes to the valuation or assumptions is detailed in this section. Their impact in changing EPA's nominal benefit estimates (before any sensitivity analysis is applied) is also discussed. Figure 2-2 shows the progression of changes in the nominal estimates as assumptions are changed from EPA to DFI's baseline.

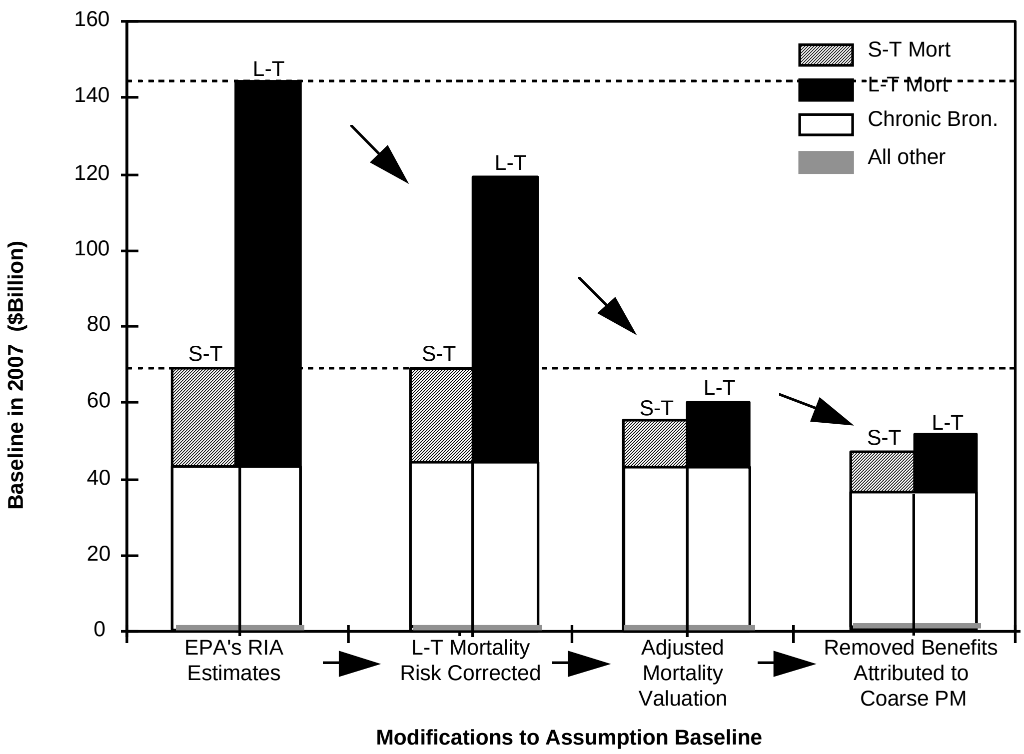
PA's estimate of benefits in the RIA. As was discussed above, Table 9.11 of the PM RIA estimates full attainment benefits using two different measures of mortality, short-term (S-T) and long-term (L-T). EPA's point estimates for annual national benefits in the RIA (after rounding to the nearest billion) are:

Total Benefits of full attainment, counting S-T mortality:	$69 billion
Total Benefits of full attainment, counting L-T mortality:	$144 billion

Correction of L-T mortality risk calculation. EPA has acknowledged an error in its L-T mortality estimates, stemming from an error in its interpretation of the underlying epidemiological study (i.e., Pope *et al.*, 1995). That study developed its risk estimates relative to median concentrations of $PM_{2.5}$, rather than mean concentrations. EPA's benefits estimation for L-T mortality used the relative risk results from this study as if they applied to mean concentrations. Roughly speaking, the mean concentration in ambient PM data is about 25 percent higher than the median concentration (reflecting the fact that ambient concentrations tend to be somewhat skewed in distribution, rather than normally distributed).[54] EPA has publicly announced that correction of this error will result in an approximate reduction of the avoided L-T deaths from 20,000 to 15,000—a 25 percent decrease.[55] The uncertainty analysis in *this* report is based on the corrected estimate for L-T mortality. After applying this 25 percent to the L-T mortality benefit estimate in the RIA ($97 billion), the aggregation benefits estimate (shown as the second set of bars in Figure 2-2) becomes:

Total benefits of full attainment, counting S-T mortality:	$69 billion
Total benefits of full attainment, counting L-T mortality:	$120 billion

Figure 2-2. Point Estimate Benefits with Progressive Adjustments to Assumptions



We also incorporate this correction into the EPA point estimates which appear throughout the remainder of this section on particulate matter benefits.

Adjustment to Value of Life estimates. EPA uses $4.8 million per estimated reduction in mortality. There are a number of reasons to believe that this is an overly high value. Economists have long

---

[54] K. Jones, *Is EPA Misleading the Public About the Health Risks from $PM_{2.5}$? An Analysis of the Science Behind EPA's $PM_{2.5}$ Standard*, report prepared for Citizens for a Sound Economy Foundation, Washington, D.C., May 1997, p. 6.

[55] "Statement of Mary Nichols, EPA Assistant Administrator, Office of Air and Radiation," EPA press release, April 2, 1997.

advocated estimating benefits on the basis of "years of lost life" or "quality adjusted loss of life-years" rather than on "numbers of lives lost," simply because this is the only way to appropriately reflect the fact that some forms of life risk are clearly of greater concern than others. This preference among economists is reflected in key current-Administration communications on this issue:

- Expert economists reviewing EPA's draft report *The Benefits and Costs of the Clean Air Act, 1970-1990* (the "Retrospective Study") have argued that mortality impacts in that study should be valued according to expected years of lost life rather than numbers of lives lost.[56]

- The Office of the President's guidelines for economic analysis in RIAs also suggest the importance of considering value based on expected lost life-years in contrast to value based on a random "statistical life."[57]

The problems of using "numbers of lives lost" are highlighted in the case of PM. All attempts to develop an argument for biological plausibility that PM can cause mortality have relied on the idea that the affected individuals are severely ill, and on the verge of dying due to pre-existing disease or age; elevated PM effectively becomes the "last straw" rather than a specific precipitating event. Thus, even by EPA's judgment, any deaths that might (temporarily) be avoided by the proposed regulation, would accrue disproportionately to the elderly or very ill. However, the valuation estimate used by EPA reflects a randomly lost life, and encompasses risks that might involve a much greater shortening of lifespan than appears to be justified for PM mortality impacts. For this reason alone, there is an argument for using a substantially lower value per mortality incident in the PM benefits estimate.

In addition, some have suggested that the $4.8 million per "statistical life lost" may itself be too high. One criticism is that EPA's value-of-life figure is based partly on "contingent valuation" studies rather than market-based behavior. There are many sources of market-based information about willingness to pay to avoid a loss of life, and these studies also find a lower value than that produced by the hypothetical and nonbinding survey approach that contingent valuation relies on. Even market-based estimates, however, should be carefully scrutinized for the impact of age on the estimate, and should be converted into a value per year of lost life expectancy before being applied to the PM situation.

One set of comments submitted to EPA on the PM RIA noted two alternative lower values that may be more appropriate, but which also appear to overstate the benefits if one were to account for likely differences in years of lost life expectancy. These are: $2.7 million per statistical life from the Department of Transportation (which would then need to be adjusted for the lesser average years lost for pollution rather than transportation risks), and $1.3 million for an average of 12 years of lost life from the National Research Council.[58] This information would suggest that an equivalent value, after adjusting for a risk that would imply only a few years of lost life expectancy, might be in the range of $1 to 2 million.

---

[56] Letter from Dr. Richard Schmalensee, Chair of EPA's Advisory Council on Clean Air Compliance Analysis, to Carol Browner, EPA Administrator, dated October 23, 1996 (Docket Number EPA-SAB-COUNCIL-LTR-97-001).

[57] White House, *Economic Analysis of Federal Regulations in Executive Order 12866*, June 11, 1996.

[58] T. Hopkins, *Can New Air Standards for Fine Particles Live Up to EPA Hopes?* Policy Brief 180, Center for the Study of American Business, April, 1997. This Policy Brief is based on formal comments submitted on the proposed PM rule by the Regulatory Analysis Program of George Mason University, which can be found in the PM Docket.

Although the single "correct" value to use is ultimately a matter of judgment, there appears to be substantial evidence that the $4.8 million value in EPA's analysis is inappropriately high for application in the case of PM-related benefits. The main reason it may be too high is that it does not account for the much briefer life shortening that appears to be likely for any potential PM-related deaths. A supporting but more minor reason is that this estimate does incorporate values based on contingent valuation, even though there are a substantial number of market-based value estimates available. Comments filed in the PM Docket include a substantial effort by the EOP Group, Inc. to develop and apply an estimate of the PM mortality benefits using the more desirable "life-year" analysis, that reflects the expected years of life lost rather than numbers of deaths.[59] EOP Group Inc. uses this measure and specifically re-analyzes EPA's PM mortality benefits. Their approach results in an effective adjustment to the $4.8 million value per "statistical life lost": while the dollar value assigned to each estimated PM-associated "death" is lower than $4.8 million, the underlying value per random statistical life remains at $4.8 million, just as EPA has used. EOP Group Inc. analyzed S-T and L-T benefits separately, and their estimates of total mortality benefits were:

For S-T mortality: RIA estimate $22.5 billion ⇒ EOP estimate $9.2 billion (59% less)
For L-T mortality: RIA estimate $97.3 billion ⇒ EOP estimate $18.6 billion (81% less)

Thus, the valuation suggested is not the $4.8 million per death of a random individual in the entire population, but reflects the probably substantially lesser life-years saved for the particular population which will be accruing benefits under the proposed standard. The implicit value per statistical life lost *due to PM impacts* would thus be $0.9 million for L-T mortality and $2.0 million for S-T mortality.[60] These estimates are clearly within the range of other valuations suggested above, once those would also be adjusted for an even lesser life-shortening.

Finally, because of the aforementioned peer-review comments on EPA's "Retrospective Study," recent revisions to that report have incorporated sensitivity cases that purport to consider a life-years-lost approach to valuation. While it was not possible to review the new EPA method as part of this study, it appears that the effective valuation for lives estimated to have been prolonged due to all air quality improvements is about 50 percent of the $4.8 million per statistical life lost, or somewhere in the range of $2.4 million.

Overall, it appears more appropriate to use the implicit values developed by EOP Group Inc. rather than the $4.8 million per statistical life in the RIA. These estimates were founded on a detailed analysis of the actual studies for PM, are clearly documented, and are consistent with estimates that have been suggested by a range of others. EPA's own approach in the "Retrospective Study" may result in somewhat higher values per life-year lost, but (a) it was not possible to review them during this study, and (b) they apply to all forms of mortality associated with the past 20 years of air quality improvement, rather than having been based specifically on the PM studies in question in the PM benefit analysis.

---

[59] The EOP Group, Inc., *Life-year Analysis Of Premature Mortality Benefits In The December 1996 Particulate Matter Proposed NAAQS*, February, 1997 (available in the PM Docket)

[60] S-T deaths occur in a particular year, whereas the L-T value reflects the shortening of the expected lifespan, but not necessarily mortality in a particular year. Since avoiding a L-T mortality means avoiding a premature death over multiple years, while avoiding a S-T mortality means avoiding a death *within the next year*, the value of avoiding a S-T mortality is higher.

The third set of bars in Figure 2-2 show the impact of using the EOP Group Inc. life valuation on the aggregate benefits estimate. With this change, the "baseline" benefit estimates (i.e., without yet accounting for uncertainties) become:

Total benefits of full attainment, counting S-T mortality:	$56 billion
Total benefits of full attainment, counting L-T mortality:	$60 billion

Interestingly, this adjustment has caused the difference between the L-T and S-T mortality estimates to be narrowed. This reflects the fact that the larger numbers of estimated "long-term" mortality are actually accrued over several years, while any "short-term" mortality would be entirely accrued in a single year. It is also interesting to note that morbidity impacts (specifically chronic bronchitis) now appear to account for the majority of the total benefits estimate.

Correction in Estimation of Benefits Associated with Changes in the Coarse Fraction of PM. Several of the categories of impact listed in Table 2-1 are based on studies of PM_{10} rather than on $PM_{2.5}$ specifically. This presents an interesting dilemma for the PM benefits assessment. On the one hand, it seems more appropriate to apply these risk associations to the original measure of air quality from which they were derived. On the other hand, EPA claims quite clearly in its the *Federal Register* notice of the proposed rule that it believes that the current PM_{10} standard *does* adequately protect the public health from the various morbidity impacts of the coarse fraction of particles. For example:

> *the current annual PM_{10} standard offers substantial protection against both long- and short-term effects of coarse fraction particles...qualitative evidence of other long-term coarse particle effects...does not provide evidence of effects below the range of 40–50 $\mu g/m^3$.... The main quantitative basis for a short-term [PM_{10}] standard...provide no basis to lower the level of the [24-hour PM_{10}] standard below 150 $\mu g/m^3$....retention of a 24-hour PM_{10} standard at the level of 150 $\mu g/m^3$....would provide adequate protection against the short-term effects of coarse particles that have been identified to date.*[61]

The appropriate interpretation would be that the only incremental benefits to assess after the PM_{10} standard has been applied would be those associated with the fine fraction, $PM_{2.5}$. Nevertheless, in the RIA, all of the benefits categories identified in Table 2-1 as being based on PM_{10} data were estimated assuming that there are benefits associated with reductions in PM_{10} even where PM_{10} is already below the "adequately protective" PM_{10} standard. This portion of the benefits should be removed from the estimates.

In addition, there is a more direct error in the analysis relating to how the coarse fraction was handled. Rollback percentages are based on model outcomes for $PM_{2.5}$. The benefit analysis then assumes that whatever rollback percentage is estimated for $PM_{2.5}$ can also be applied to PM_{10}. However, most of the control measures being considered in the RIA apply to precursors of secondary PM, and these measures will not affect the coarse fraction in any substantial way. Thus, the rollback for PM_{10} would be a smaller percentage than the rollback for $PM_{2.5}$. Thus, not only is EPA attributing benefits to reductions in the coarse fraction that are inconsistent with its statements that the culprit is in the fine fraction, but it is also

---

[61] 61 Fed. Reg. 65661-2

overstating the degree to which the coarse fraction would be reduced when fine particle control measures are applied.[62]

To adjust for this error, each category which uses PM_{10} in its benefits calculations is multiplied by the fraction of PM_{10} that is made up of $PM_{2.5}$. The Natural Resources Defense Council reports that $PM_{2.5}$ as a fraction of PM_{10} ranges from 55 percent to 80 percent.[63] The more conservative 80 percent factor was chosen to avoid the chance that this adjustment to the "benefits baseline" would be overly large. As can be seen in Figure 2-1, the overall adjustment is small. However, it would be increased substantially if one were to assume that $PM_{2.5}$ were closer to 55 percent than 80 percent under ambient conditions, since this adjustment affects the chronic bronchitis benefits, which are now the largest portion of the aggregate benefits.

Benefits categories in the RIA which use PM_{10} as the indicator include congestive heart failure, Ischemic heart disease, chronic bronchitis, upper respiratory symptoms, any of 19 acute respiratory symptoms, acute bronchitis, and shortness of breath, with total estimated benefits of $45 billion. Reducing this portion of the benefits by 20 percent gives:

Total Benefits of full attainment, counting S-T mortality:	$47 billion
Total Benefits of full attainment, counting L-T mortality:	$51 billion

The latter benefit estimates reflect what DFI believes are the most appropriate assumptions and valuations, and thus form the baseline around which the evaluation of uncertainties takes place. Note that there are specific incidence estimates underlying these monetized statements. The following uncertainty analysis is actually applied in terms of the physical incidence estimates, and the uncertainty ranges on the monetized benefits that have been reported thus far are built up from the uncertainty in each type of morbidity or mortality incidence. Thus, it is possible for readers to apply alternative judgments about appropriate valuation and still have access to the uncertainty ranges that result. Although the results presented in the summary section *are* based on the baseline adjustments for value of mortality described above, this section also provides uncertainty ranges using EPA's original values. The fact remains that there is a far more policy-relevant story to be obtained from the *range* of possible benefits than from EPA's point estimate alone.

Adjustments to Chronic Bronchitis Benefits. Several commenters have noted another potential error in EPA's benefits estimate for chronic bronchitis, where it was believed that a higher *prevalence* rate was being valued as if it reflected a higher number of new cases *annually*. The net effect of such an error would be an over-valuation of the chronic bronchitis benefits on the order of a factor of 10–15. If this

---

[62] For example, suppose $PM_{2.5}$ is 60 percent of PM_{10}, and suppose full attainment of the PM_{10} standard has been achieved at 50 $\mu g/m^3$ annual average. The $PM_{2.5}$ concentration is then $0.6 \times 50 = 30$ $\mu g/m^3$. To reduce $PM_{2.5}$ to full attainment of its proposed standard at 15 $\mu g/m^3$ would require a 50 percent rollback above background. When $PM_{2.5}$ is reduced in this way, total PM_{10} also comes down by the same 15 $\mu g/m^3$, to 35 $\mu g/m^3$, which is only a 30 percent reduction. EPA's methodology, by contrast, assumes that PM_{10} would be rolled back by the same *percentage* (50 percent), to 25 $\mu g/m^3$.[62] The RIA analysis apparently applies PM_{10} benefits to the difference of 50 – 25 = 25 $\mu g/m^3$. However, the only benefits that should be realized are from the fine fraction, which has declined 15 $\mu g/m^3$. Thus, the benefits would be overstated by a factor of 25/15, or 1.67, even if one *does* want to attribute benefits to the coarse fraction despite EPA's language in the Proposed Rule.

[63] Natural Resources Defense Council, *BREATH-TAKING: Premature Mortality due to Particulate Air Pollution in 239 American Cities*, May 1996.

were indeed an error in EPA's analysis, then the estimated baseline benefits would be reduced to as low as $15 billion to $20 billion per year. DFI's efforts to confirm or refute this potential problem through discussions with EPA, have been equivocal. In the interests of conservatism, this possible error associated with the estimation of the chronic bronchitis valuation has *not* been incorporated into the adjusted benefits baseline described above.

On the other hand, in attempts to obtain proper documentation of the chronic bronchitis risk analysis, we discovered that the single study on which the chronic bronchitis benefits were based (Schwartz, 1993) was not deemed acceptable for use in EPA's "Retrospective Study" mentioned above. Another chronic bronchitis study (Abbey *et al.*, 1993) has been substituted in the "Retrospective Study." EPA has confirmed that it now also intends to use the Abbey study in the revised PM RIA that will be released at the time that it announces the final rulemaking decision in July 1997.[64]

Without the detailed county data, and without a complete documentation for how the original chronic bronchitis benefits were computed, it is impossible to estimate with any accuracy what the effect of using the Abbey *et al.* study would be on the baseline benefits estimate. More importantly, however, one should note that the change in choice of study was a direct result of the peer-review process that the "Retrospective Study" must go through, but which the RIA does *not* go through. If there had not been another benefit analysis effort that *was* subject to peer review, it is unlikely that there would have been any change made to the PM RIA's benefit estimates for chronic bronchitis. Overall, this situation highlights the problems that occur when a major and important policy-relevant document is produced with little accountability for accuracy or quality:

- The chronic bronchitis benefit estimates account for about $40 billion of EPA's benefit estimates, yet they were not even mentioned in earlier risk estimates leading up to the PM RIA, and first appeared in the RIA itself.

- The chronic bronchitis benefits are based on a single study that appears to have been arbitrarily selected from the record; any dose-response estimates from that study has minimal quantitative accuracy, as the study controlled only for smoking and not for any other environmental consideration, including potentially confounding pollutants.

- The original chronic bronchitis study did not provide annual incidence risks; and the method by which EPA derived annual incidence from it (or possibly failed to do so) is not documented in any public record.

At this point, initial evidence indicates that the substitution of the Abbey *et al.* study may reduce the chronic bronchitis benefits by 25 percent or more. But how this study will be used, and what its own quality is, are also the subject of some concern. These "shifting sands" are indicative of the problems that can occur when a major document such as the RIA both (1) escapes the rigors of peer-review, and (2) is not held accountable to supply sufficient documentation to ensure that outside parties can reproduce its results.

E. Epidemiological Uncertainties

---

[64] Ron Evans, EPA OAQPS, personal communication, May 13, 1997.

The adjusted baseline described in the preceding section reflects alternative estimates of the benefits after accounting for methodology errors and inappropriate judgments. In contrast, the uncertainty analysis around the adjusted impact estimates is intended to address underlying scientific and statistical uncertainty in the epidemiological studies of health effects for which it would be very difficult to suggest that one assumption is any more valid than another. The uncertainties that are addressed here derive primarily from the fact that the PM benefit estimates are almost entirely based on epidemiological studies. The inherent difficulties and uncertainties that this situation creates were discussed in the introduction to this section. At this point, we will illustrate how these uncertainties actually affect results. EPA's RIA and supporting documentation do mention the uncertainties in the dose-response parameters, but none of these uncertainties are reflected in the RIA's national benefit numbers.

Epidemiological studies are subject to various types of errors or uncertainties, ranging from nonrepresentativeness of the air quality monitors in gauging individual exposure; to "confounding," where multiple pollutants may be indistinguishable in their effects. Based on review of the available scientific literature on the problems associated with epidemiological results,[65] discussion of the impacts of these potential errors on parameter values in EPA's *Criteria Document* and *Staff Paper,* and DFI's own previous sensitivity analyses,[66] three key uncertainties were identified to be the focus of this analysis. The three types of uncertainty are: dose-response slope (for each of three health endpoints), in the threshold cutpoint, and in the degree of potential bias in epidemiologically based slopes. Each of these parameters is subject to considerable uncertainty even when taking into account the results of many different published studies, and these uncertainties have a direct impact on national benefit estimates. A range of reasonable values was developed for each of these parameters, and national benefits were then re-estimated for each combination of these parameters, using the DFI baseline valuations and assumptions described above.

L-T and S-T mortality dose-response slope. One key parameter in determining the incidence of health effects is the slope of the dose-response relationship between a particular measure of pollution (e.g. annual average $PM_{2.5}$) and a particular health endpoint (e.g. incremental annual mortality). This is also known in various studies as the "risk ratio," "odds ratio," or "slope parameter." The term "relative risk" is also commonly used to describe the results of these studies, and this measure can be readily converted into the slope parameter with a simple numerical manipulation.[67]

Despite EPA's repeated statements that the PM health effects are supported by dozens of studies, the L-T and S-T mortality risk ratios and ranges used in estimating benefits in the PM RIA are each based on the work of a single study team: L-T is based on Pope *et al.* (1995) and S-T is based on Schwartz *et al.*

---

[65] Two useful references are *Principles for Evaluating Epidemiologic Data in Regulatory Risk Assessment*, Federal Focus, Inc., Washington, D.C., August 1996; and F. Lipfert and R. Wyzga, "Uncertainties in Identifying 'Responsible' Pollutants in Observational Epidemiology Studies," *Inhalation Toxicology,* vol. 7 (1995), pp. 671–689.

[66] Sensitivity of the risk estimates, which are the foundation of the RIA's benefits estimates, was analyzed and documented in A. Smith, *Comments on Risk Analysis in EPA's Draft Staff Paper for a Particulate Matter National Ambient Air Quality Standard*, Comments submitted to EPA PM Docket, June 6, 1996. The potential for serious biases or false attributions to occur in epidemiological results for PM is illustrated in A. Smith and N. Chan, *How Statistics Can Mislead PM Policy: A Case of Smoke and Mirrors?*, Decision Focus Incorporated, March 10, 1997.

[67] A standard logistic regression relationship has Relative risk = $\exp(\text{slope} \times \Delta\text{concentration})$

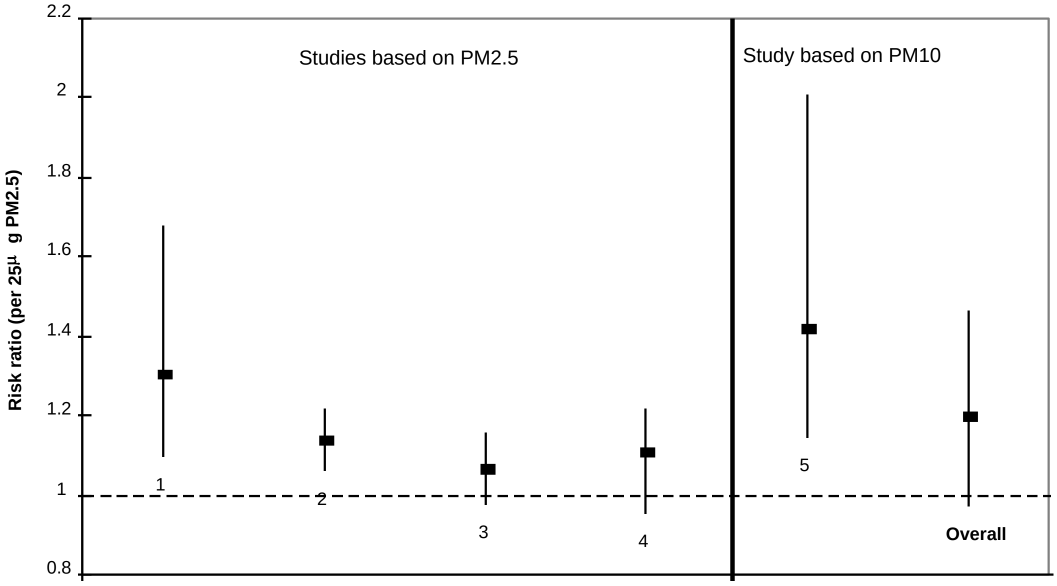
(1996).[68] The PM *Criteria Document* (CD) discusses many additional studies for both L-T and S-T mortality. There is very little explanation for why EPA chose to use only the particular studies that they did. Figure 2-3 shows the ranges of risk ratios for L-T mortality, taken from tables and figures in the CD.[69] Similarly, Figure 2-4 shows the risk ratios in studies available for S-T mortality.[70] Tables 2-2 and 2-3 identify the studies appearing in the figures (and the full references for each study are provided in Appendix 3).

- Note the paucity of studies that were actually based on $PM_{2.5}$. In the case of S-T mortality, $PM_{2.5}$-based studies really only consist of two independent studies (one with 6 cities, and one with 2 cities).

- Also notice that there are a fairly substantial number of studies, both for $PM_{2.5}$ and for PM_{10}, that do not find a significant association with mortality (i.e., the range of uncertainty represented by the vertical bar encompasses a risk ratio of 1.00).

DFI developed a range of uncertainty denoted by the "overall" bar in each figure.[71] This reflects a 90 percent confidence interval (mean ± 1.65 standard deviations) around the mean of means across all of the studies.

Figure 2-3. Range of Risk Ratios across Studies of Long-term Mortality (Study labels are identified in Table 2-2)



---

[68] Formal references to each of the specific health effects studies referred to in this section are provided in Appendix 3 of this report.

[69] L-T mortality risks were extracted from *Criteria Document*, Table 13-5 and Figure 12-9.

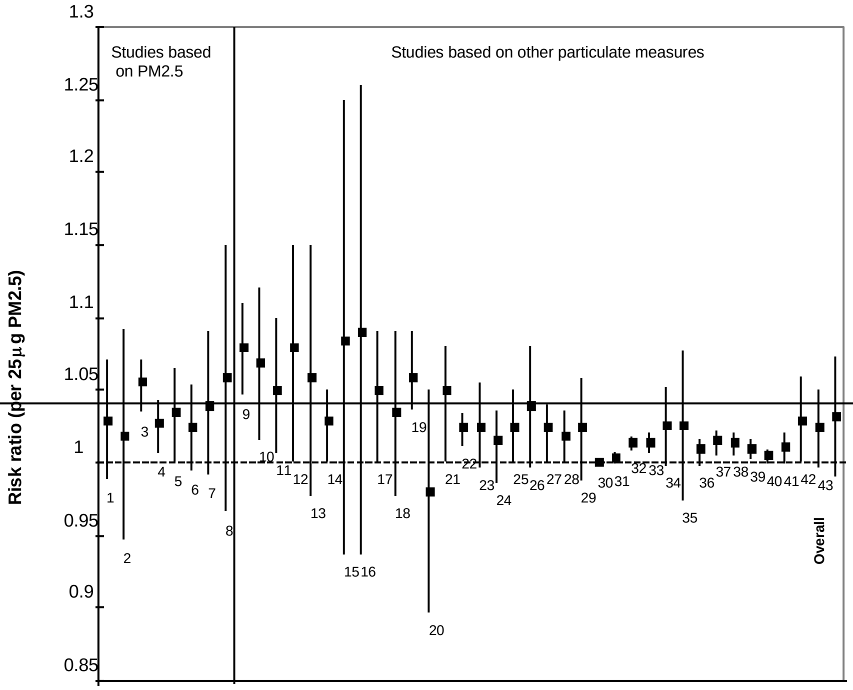
[70] S-T mortality risks were extracted from *Criteria Document*, Tables 12-3, 12-4, 13-3, and 13-4.

[71] Risk ratios were first converted to equivalent $PM_{2.5}$ assuming that 100 µg/m^3 TSP, 50 µg/m^3 PM_{10}, and 25 µg/m^3 $PM_{2.5}$ are all equivalent. See *Criteria Document*, Table 13-5, note (a).

Table 2-2. Long-term Mortality Studies

Number	Author	Reference List Number	Location	Equivalent for 25 µg/m³ $PM_{2.5}$ Risk ratio	Low	High
1	Dockery *et al.* 1993	[16]	Six city	1.3100	1.1100	1.6800
2	Pope *et al.* 1995	[17]	50 Cities	1.1428	1.0760	1.2172
3	Lipfert 1993	[18]	62 SMSAs	1.0700	0.9900	1.1600
4	Ozkaynak & Thurston 1987	[19]	36 SMSAs	1.1100	0.9700	1.2200
5	Dockery *et al.* 1993	[16]	Six city	1.4200	1.1600	2.0100

Figure 2-4. Range of Risk Ratios across Studies of Short-term Mortality (Study labels are identified in Table 2-3)



The ranges that result for the risk ratios when considering all of the studies cited in the CD are:

L-T mortality risk ratio:	1.000	1.203	1.467	(per 25 µg/m³ annual mean $PM_{2.5}$)
S-T mortality risk ratio:	1.000	1.033	1.073	(per 25 µg/m³ 24-hr.-avg. $PM_{2.5}$)

It should be noted that the "medium" values of relative risk are actually higher than EPA uses in its RIA for L-T mortality estimates (compare 1.203 to the Pope value of 1.17 *before* correcting for the error recently found, and 1.14 *after* correcting for that error). The "medium" value for the S-T risk ratio is slightly lower than that in the RIA (compare 1.033 to 1.036). These new values, however, are more representative of the broader set of studies that are cited in the CD.

Although EPA did not estimate uncertainty ranges in the benefit estimates in the RIA, earlier risk analyses that provided the foundation for the benefit estimates did include a "90 percent credible interval" supposedly to account for uncertainty. The latter ranges were based solely on the confidence intervals in the individual studies used for EPA's point estimates. The uncertainty ranges on dose-response slope used in this analysis are *wider* than those that EPA used, since this study accounts for effects estimated over the more comprehensive set of studies.[72] Further, at the same time that the study accounts for a broader set of studies, it incorporates studies that address only PM_{10}. In applying the estimated risks from these PM_{10} studies to $PM_{2.5}$, DFI has attributed *all* of the risk to variations in the fine fraction. This is a conservative assumption. Uncertainty in this assumption is addressed by the "attribution" parameter described below.

Table 2-3. Short-term Mortality Studies

Number	Author	Reference List Number	Location	Equivalent for 25 $\mu g/m^3$ $PM_{2.5}$ Risk ratio	Low	High
1	Schwartz *et al.* 1996	[1]	Portage	1.0300	0.9930	1.0710
2	Schwartz *et al.* 1996	[1]	Topeka	1.0200	0.9510	1.0920
3	Schwartz *et al.* 1996	[1]	Boston	1.0560	1.0380	1.0711
4	Schwartz *et al.* 1996	[1]	St. Louis	1.0280	1.0100	1.0430
5	Schwartz *et al.* 1996	[1]	Kingston	1.0350	1.0050	1.0660
6	Schwartz *et al.* 1996	[1]	Steubenville	1.0250	0.9980	1.0530
7	Dockery *et al.* 1995	[2]	St. Louis	1.0400	0.9950	1.0900
8	Dockery *et al.* 1995	[2]	E. Tennessee	1.0600	0.9700	1.1500
9	Pope *et al.* 1992	[3]	Utah	1.0800	1.0500	1.1100
10	Pope & Kalkstein 1996	[4]	Utah	1.0700	1.0200	1.1200
11	Schwartz 1993	[5]	Birmingham	1.0500	1.0100	1.1000
12	Dockery *et al.* 1992	[6]	St. Louis	1.0800	1.0050	1.1500
13	Schwartz *et al.* 1996	[1]	St. Louis	1.0600	0.9800	1.1500
14	Schwartz *et al.* 1996	[1]	St. Louis	1.0300	1.0050	1.0500
15	Dockery *et al.* 1992	[6]	Kingston	1.0850	0.9400	1.2500
16	Schwartz *et al.* 1996	[1]	Kingston	1.0900	0.9400	1.2600
17	Schwartz *et al.* 1996	[1]	Kingston	1.0500	1.0050	1.0900
18	Schwartz *et al.* 1996	[1]	Portage	1.0350	0.9800	1.0900
19	Schwartz *et al.* 1996	[1]	Boston	1.0600	1.0400	1.0900
20	Schwartz *et al.* 1996	[1]	Topeka	0.9800	0.9000	1.0500
21	Schwartz *et al.* 1996	[1]	Steubenville	1.0500	1.0050	1.0800
22	Ozkaynak *et al.* 1994	[7]	Toronto	1.0250	1.0150	1.0340
23	Kinney *et al.* 1995	[8]	Los Angeles	1.0250	1.0000	1.0550
24	Kinney *et al.* 1995	[8]	Los Angeles	1.0170	0.9900	1.0360
25	Ito *et al.* 1995	[9]	Chicago	1.0250	1.0050	1.0500
26	Styer *et al.* 1995	[10]	Chicago	1.0400	1.0000	1.0800
27	Ito & Thurston 1996	[11]	Chicago	1.0250	1.0050	1.0400
28	Ito & Thurston 1996	[11]	Chicago	1.0200	1.0050	1.0350
29	Ostro *et al.* 1996	[12]	Santiago	1.0257	0.9913	1.0586
30	Ostro 1993	[13]	London	1.0019	1.0018	1.0019
31	Ostro 1993	[13]	Steubenville	1.0049	1.0036	1.0069
32	Ostro 1993	[13]	Philadelphia	1.0143	1.0114	1.0172
33	Ostro 1993	[13]	Santa Clara	1.0149	1.0099	1.0205
34	Dockery & Pope 1994	[14]	St. Louis	1.0269	1.0018	1.0524

---

[72] For comparison, the EPA slope ranges (which were the only uncertainties incorporated into the "90 percent credible interval" estimates of its risk estimates) were 1.09–1.26 for L-T from Pope *et al.* (1995), which is Study 3 on Figure 2-3; and 1.028–1.048 for S-T from Schwartz *et al.* (1996) which pooled 6 separate cities in this single study (the six cities are listed as Studies 33–38 on Figure 2-4).

35	Dockery & Pope 1994	[14]	Kingston	1.0268	0.9784	1.0778
36	Dockery & Pope 1994	[14]	Birmingham	1.0104	1.0021	1.0156
37	Dockery & Pope 1994	[14]	Utah	1.0160	1.0096	1.0224
38	Dockery & Pope 1994	[14]	Philadelphia	1.0150	1.0088	1.0213
39	Dockery & Pope 1994	[14]	Detroit	1.0104	1.0052	1.0167
40	Dockery & Pope 1994	[14]	Steubenville	1.0057	1.0033	1.0082
41	Dockery & Pope 1994	[14]	Santa Clara	1.0114	1.0029	1.0215
42	Moolgavkar *et al.* 1995	[15]	Steubenville	1.0300	1.0050	1.0600
43	Moolgavkar *et al.* 1995	[15]	Steubenville	1.0250	1.0000	1.0500

Chronic bronchitis dose-response slope. EPA's chronic bronchitis risks are derived again from a single study, Schwartz (1993). For the present analysis, DFI chose to use the risk ratio range from the Schwartz study:

CB risk ratio:	1.02	1.07	1.12	(per 25 $\mu g/m^3$ $PM_{2.5}$)

This again, is a conservative assumption for several reasons:

- A review of the Schwartz (1993) study shows that it does not account or control for any environmental factors other than smoking. It warranted only one paragraph of discussion in the CD, and was never mentioned in the *Staff Paper*. The record of supporting studies in the PM Docket indicate that it was not used in any of the original risk analyses, and suddenly appeared in one of the last "updates" of the risk analyses that were delivered just prior to the release of the PM RIA.

- The Schwartz (1993) study is a cross-sectional study, implying that its results indicate overall differences in incidence rates. EPA states that the estimates it has derived from this study are actually supposed to be annual *new cases* of chronic bronchitis. DFI has been unable to obtain useful documentation to determine whether a reasonable conversion was applied. Thus, there is some chance that the estimates from this study substantially overstate the annual incidence. However, this analysis gives the benefit of the doubt that the conversion was done in a reasonable manner.

- In trying to obtain better documentation of how the Schwartz (1993) study was obtained, DFI learned that this study had been removed from EPA's "Retrospective Study" as a result of that study's peer review process. It was replaced by benefit estimates based on another study, Abbey *et al.* (1993), and DFI has learned that EPA is also making the same replacement in its revised PM RIA. The Abbey *et al.* usage also requires some complex conversions to obtain estimates of annual new cases of chronic bronchitis, and EPA's method is not yet documented. However, based on preliminary evidence in a recent draft of the "Retrospective Study," it appears that use of the Abbey results may reduce the dose-response slope by about 25 percent. Because of the highly speculative nature of this estimate, this report continues to use the uncertainty ranges solely from Schwartz (1993), but it should be noted that doing so is probably a conservative step.

Threshold cutpoint. A key uncertainty in the epidemiological studies is whether there exists a "cutpoint" or "threshold," which is a level of the pollutant below which there is not a relationship between pollutant concentration and health effects. This is essentially a "safe level" of the pollutant, and there would be no incremental benefits for ambient reductions below such a level.

Most of the epidemiological studies use a dose-response form which implicitly assumes that there is no such threshold or safe level above zero. That is, the incidence of adverse health effects continues to decline as pollution levels decline, all the way to a pollution level of zero. However, it is well-known that the types of measurement errors that are endemic to all of these studies would be sufficient to mask the presence of any threshold, even when using sophisticated techniques such as quintile-partitioned data, or nonparametric smoothing.[73] Thus, the fact that no threshold has been in evidence does not provide any confidence that a threshold above background does not exist, as EPA acknowledges in a number of locations.[74]

This uncertainty is of prime importance, as acknowledged by EPA: "The single most important factor influencing the uncertainty associated with the risk estimates is whether or not a threshold concentration exists below which PM-associated health risks are not likely to occur."[75] Although EPA obviously understands this point, the magnitude of this uncertainty is not reported anywhere in the benefit analysis. It is, however, incorporated into this analysis of uncertainty.

There are a number of ways that EPA suggests a potential "reasonable" level for the threshold. These are best summarized in the Proposed Rule itself: "The Staff Paper assessment...concluded that the evidence for increased risk was more apparent at annual concentrations at or above 15 $\mu g/m^3$...however, the estimated magnitude of effects [in those studies] may be related to somewhat higher historical concentrations than the affected communities experienced during the time period of the studies; this consideration suggests that a level of 15 $\mu g/m^3$ *would incorporate a margin of safety*" [emphasis added].[76] The point about there being an adequate margin of safety at about 15 $\mu g/m^3$ annual average is reiterated a couple of times in the following pages of the Proposed Rule, along with a suggestion that there is very weak evidence of a short-term effect below 35 $\mu g/m^3$ on a 24-hour average basis.

There is no mistaking that EPA is suggesting that it believes that a threshold may be conceivable somewhere at or even above this level on the annual average. To add to this, a good part of the arguments for the threshold being possibly at or somewhat above 15 $\mu g/m^3$ is based on the Pope *et al.* (1995) study. This is the very study that EPA has since admitted it misinterpreted (see discussion in earlier section on errors in the baseline benefit estimates). When correcting for that error in EPA's understanding of the data in this study, one finds that EPA is actually arguing that there is some suggestion or possibility of a threshold at or slightly above 18.8 $\mu g/m^3$.[77]

---

[73] A demonstration of this point can be found in A. Smith and N. Chan, *How Statistics Can Mislead PM Policy: A Case of Smoke and Mirrors?*, Decision Focus Incorporated, March 10, 1997, pp. 13–15. (This paper was submitted to EPA in formal comments and can be found in the PM Docket.)

[74] For example, the *Federal Register* notice (61 Fed. Reg. 65651) says "While such a threshold has not been demonstrated in studies to date, the potential influence of exposure misclassification serves to increase the uncertainty in the reported concentration-response relationships, particularly for the lower range of concentrations."

[75] 61 Fed. Reg. 65651.

[76] 61 Fed. Reg. 6560.

[77] That is, the figure that EPA uses (in Appendix E of the *Staff Paper*) to argue that a threshold may exist at 15 $\mu g/m^3$ is based on median $PM_{2.5}$ data, rather than mean $PM_{2.5}$ data, as EPA thought. Since the mean is about 25 percent higher than the median (as per EPA's own admission in its press release of April 2, 1997) the threshold that EPA suggests may be visible would be at 1.25 × 15, or 18.75 $\mu g/m^3$ annual average.

In addition to the actual statements by EPA on the matter of a threshold, one of the supporting documents for EPA's RIA is a risk assessment for Philadelphia and Los Angeles by Abt Associates.[78] That analysis investigated various threshold scenarios of up to 30 $\mu g/m^3$ for $PM_{2.5}$ for short-term effects, and up to 18 $\mu g/m^3$ for long-term effects. Consistent with these scenarios and EPA statements, this analysis used the following ranges to reflect the threshold uncertainty:

Cutpoint for L-T effects:	0	15	18 $\mu g/m^3$
Cutpoint for S-T mortality:	0	18	30 $\mu g/m^3$

Attribution of Health Effects to $PM_{2.5}$. As mentioned previously, some epidemiological studies find health effects which their authors attribute to $PM_{2.5}$. Although the study designs should attempt to isolate the effect of this one pollutant, there are inevitable confounding issues which could lead to errors in attributing health effects to $PM_{2.5}$. It is very difficult to determine how much this bias could be. Note that in the estimates for mortality, the range estimated for slope was based on a number of PM_{10} studies, and *all* of the incremental risk in those studies was attributed to $PM_{2.5}$ in that step of this analysis. To the extent that the coarse fraction might still account for an equal share of the risk in those studies, up to as much as half of that risk might actually be attributable to the coarse fraction. Further, measurement error differentials between $PM_{2.5}$ and the coarse fraction could cause the statistical estimation process to falsely attribute risk associated with PM_{10} entirely to $PM_{2.5}$.[79] Thus, even those studies that *were* based on $PM_{2.5}$ could be falsely attributing effects of the coarse fraction entirely onto the fine fraction. These types of problems might be addressed by scenarios that attribute as much as 50 percent of the estimated risk to concerns other than $PM_{2.5}$. This scenario may be thought of as reflecting the potential impact of a moderate amount of bias due to confounding by other pollutants.

Further, it is even possible that some other pollutant or some other environmental factor is at work. This reflects the active debate of whether these associations are even causal in nature. EPA has argued that the case for causality can be made by the fact that the PM association is quite stable over numerous locations. There are many counter-arguments that remain prevalent.[80] Without trying to repeat all of the many counter-arguments, this analysis has attempted to reflect the fact that this uncertainty does exist with a scenario where none of the epidemiologically derived estimates of benefits should be attributed to $PM_{2.5}$.

Given what is known about the types of measurement errors, with the relative exposure misclassification errors for $PM_{2.5}$ probably being small compared to other pollutants, then it is doubtful that there is much potential bias in the other direction. However, it should be noted that the uncertainty ranges on the risk

---

[78] Abt Associates, Inc., *A Particulate Matter Risk Assessment for Philadelphia and Los Angeles*, revised November 1996.

[79] F. Lipfert and R. Wyzga, "Air Pollution and Mortality: The Implications of Uncertainties in Regression Modeling and Exposure Measurement," *Journal of the Air & Waste Management Association*, vol. 47 (April 1997), pp. 517–523.

[80] A recent discussion of the remaining problems associated with asserting causality yet can be found in S. Vedal, "Ambient Particles and Health: Lines that Divide," *Journal of the Air & Waste Management Association*, vol. 47, May, 1997, pp. 551–581. An illustration of how confounding could be going on and still result in stable PM-associations from location to location can be found in A. Smith and N. Chan, *How Statistics Can Mislead PM Policy: A Case of Smoke and Mirrors?*, Decision Focus Incorporated, March 10, 1997, pp. 24–26. (This paper was submitted to EPA in formal comments and can be found in the PM Docket, or at http://www.dfi.com.)

ratio do account for the chances that the actual dose-response slope estimate is higher than that used by EPA.

Thus, for purposes of this analysis, DFI used three alternative values to reflect the attribution uncertainty:

Attribution:	0%	50%	100%

The 0 percent scenario represents the possibility that PM is not to blame at all for the health effects; the 100 percent means that all of the health effects attributed to fine PM in the epidemiological studies are correctly attributed, with no other hidden confounders. 100 percent is the most conservative value, and is the choice that EPA used in its analysis. 0 percent is the most extreme scenario, and since most of the $PM_{2.5}$ benefits are in fact based solely on epidemiological evidence, it will obviously have significant impact on benefit estimates. It is, however, an assumption that is still within the realm of reason.

Some readers may feel uncomfortable with this particular form of uncertainty, or may themselves feel quite confident that causality and bias are not in question. In the uncertainty scenarios that are presented below, ranges are provided both with and without the attribution uncertainty included. One will find that accounting for potential bias or noncausality alters the balance of results, but not the overall range of uncertainty. Since this analysis does not attempt to assign any probabilities to individual uncertainties, the balance of scenarios has little direct import on conclusions of this report.

Scenarios. A scenario is a particular combination of the values of each of the relevant parameters discussed above. For estimates of incidence, there are 27 scenarios. For example, for S-T mortality, the attribution can take on any of 3 values, the dose-response can take on any of 3 values, and the cutpoint can take on any of 3 values. This makes 3^3=27 possible combinations.

When monetized benefits are calculated, incidence of multiple health endpoints are combined. For example, the total monetized benefits including L-T mortality would involve uncertainties both on L-T mortality and chronic bronchitis. These uncertainties are assumed to be independent, so each scenario would consist of selecting one of the three values of attribution, L-T mortality risk ratio, CB risk ratio, L-T mortality cutpoint, and CB cutpoint (five parameters). The total number of monetized benefit scenarios is therefore 3^5=243.

F. Populations Benefiting from the Proposed Standard

EPA's RIA analysis presents national estimates of reduced incidence and monetized benefits. However, EPA will not release sufficient data for any external group to accurately replicate its national estimates. To arrive at comparable national estimates in the present analysis, it is necessary to determine which populations will be affected by the proposed standards, and which sub-populations will receive various levels of air quality improvements.[81]

Affected population. EPA splits its analysis into seven regions, defined in the RIA in Figure 7-1. Table 6-7 of the RIA shows how many counties in each region are considered in EPA's 470-county analysis.

---

[81] This is in contrast with DFI's analysis of the benefits of the proposed ozone standard, where supporting documentation was available indicating EPA's projected nonattainment areas. With this information, it was not necessary to develop assumptions regarding the population affected.

For instance, for the Midwest/Northeast region, 210 counties were considered. Since EPA will not disclose which counties were actually considered, it was assumed that they are the most populous counties in the region. The population in these counties is taken to be EPA's analyzed population.

EPA's RIA summary tables also indicate the number of counties in each region, out of the number that EPA analyzed, that were projected to be out of attainment with the proposed standard in 2007, given implementation of currently mandated controls. These counties will be the primary beneficiaries of the new standard since, under the full attainment scenario, PM$_{2.5}$ concentrations in these counties will be reduced to meet the standard. Since EPA will not release information on exactly which counties these are, it was assumed that they are the most populous counties in each region.

In addition to these nonattainment areas, however, there may be additional indirect benefits to counties which are already in attainment. This is because control measures implemented in nonattainment areas will likely improve air quality in neighboring counties as well, because of the long-range transport of PM$_{2.5}$. EPA evidently counts improvements in attainment areas as part of its national benefits estimate. The authors developed approximate estimates of the population in such areas by using judgmental assumptions regarding the population in areas near nonattainment areas.

EPA's tallies of the number of counties out of attainment are based on their limited 470-county analysis, which encompasses about 60 percent of the national population.[82] In the present analysis, simple scaling and proportionality assumptions were used to develop estimates of the number of affected individuals receiving benefits when the entire national population is considered.

Selection of representative cities. EPA will not release its assumptions regarding air quality in 2007 from which improvements are made to generate health benefits. DFI's approach was to analyze sensitivities to the uncertain parameters in a small set of four representative cities, then use proportionality assumptions to roll-up to a national estimate.

Specific geographical areas in 2007 were categorized according to the extent of 2007 PM concentrations. The PM RIA (Table 6-7) indicates the number of counties projected to violate each of three alternative PM$_{2.5}$ standards. Consistent with this breakdown, this analysis categorized the United States population receiving benefits from the proposed standard into four groups:

Category	**Initial Air Quality in 2007:**
A	Annual average PM$_{2.5}$ >20 μg/m^3
B	Between 15 and 20 μg/m^3
C	Between 12.5 and 15 μg/m^3
D	Under 12.5 μg/m^3
E	Attainment areas that do not experience any PM$_{2.5}$ reductions due to neighboring region control strategies

In the absence of knowing which particular areas or cities are projected to have various levels of PM$_{2.5}$, DFI used external data to select a set of representative cities.

---

[82] RIA, Section 6.4.1.

- The Abt Risk Assessment projects that Los Angeles will not be in attainment of the current PM_{10} standard in 2007. That document analyzes the effect of bringing Los Angeles into attainment of the current standard, and estimates that doing so will lead to an annual average $PM_{2.5}$ concentration of 24.1 $\mu g/m^3$. Therefore, Los Angeles was designated as the representative city for category A.

- Supporting documentation in the PM Docket indicates that the 2007 $PM_{2.5}$ concentration in Philadelphia is estimated at 18.6 $\mu g/m^3$, after implementation of CAA controls.[83] Philadelphia was thus assigned as the representative city for category B.

- No specific information was available on projected air quality in 2007 for any areas in categories C and D. Therefore, two hypothetical "attainment" cities were created, denoted "Hyp. C" and "Hyp. D" which have annual average $PM_{2.5}$ concentrations of 13.5 and 11.5 $\mu g/m^3$, respectively.

G. Sensitivity Analysis for Each Representative City

The goal is to determine the plausible range of *national* benefit estimates. To do that, this analysis first investigated the *percentage* sensitivities in avoided incidence of health effects (not monetized yet) for each of the representative cities described above. As mentioned previously, attention was focused on mortality (L-T and S-T) and chronic bronchitis, since these make up the largest portion of EPA's benefit estimates.

The EPA methodology for determining air concentrations was followed as closely as practicable, given the available data. Gamma distributions were fitted to the annual average and 98th percentile daily $PM_{2.5}$ concentrations, and then 365 daily values of $PM_{2.5}$ were generated.[84] Proportional rollbacks were carried out to reduce concentrations to attain the proposed standard,[85] and logistic dose-response relationships were applied to determine the change in incidence for the health endpoints.

Figures 2-5 to 2-8 show the sensitivity ranges (in percent of the baseline incidence estimate) for a number of different scenarios for each city. The horizontal line at 0 percent on the figures represents the "baseline" scenario consistent with what would be the RIA result (i.e., using the base case risk ratios, zero threshold cutpoint, and the assumption that the level of effect which the statistical studies assign to fine PM is in fact 100 percent due to fine PM). Thus, a sensitivity of 0 percent implies that that scenario for that type of city produces results consistent with EPA's benefit estimates in the RIA. The ranges represented by the vertical lines indicate how much the health effect in question might increase or decrease as each uncertainty parameter is moved (one at a time) to the ends of its range, all else being held equal. The sensitivities are labeled in terms of the health endpoint in question and the parameter being varied. For example, the first bar in Figure 2-5 shows that, for Los Angeles, as the cutpoint scenario for L-T mortality is ranged from 0 (no threshold) to 15 and then to 18 $\mu g/m^3$, the estimated

---

[83] Letter from E. Laich, E.H. Pechan and Associates to B. Vatavuk, USEPA, November 22, 1996, Docket Number A-95-54.

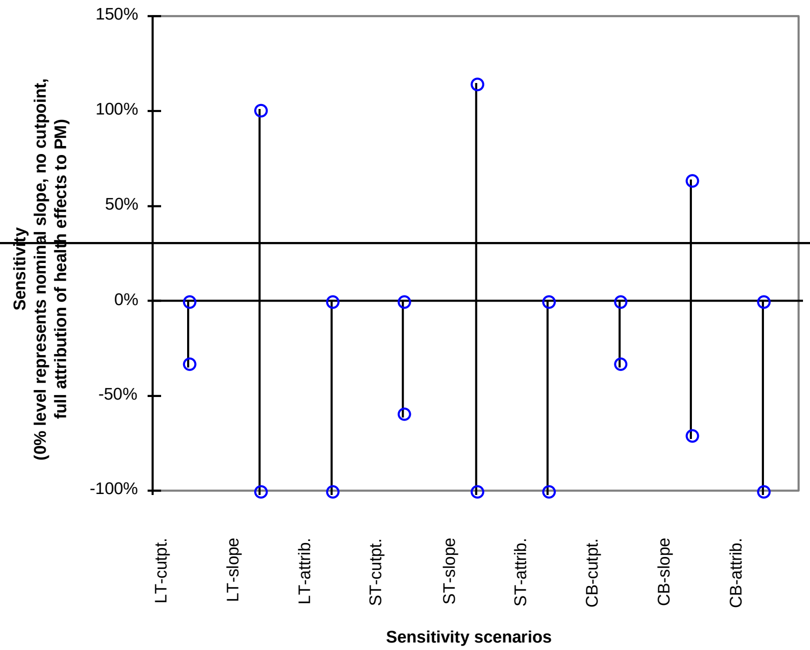
[84] See Abt Associates, *An Analysis of the Monetized Benefits Associated with National Attainment of Alternative Particulate Matter Standards in the Year 2007*, July 5, 1996, Appendix 2.

[85] In projected attainment areas, rollbacks are not necessary to achieve the standard. However, DFI assumed small rollbacks would occur in some of these areas due to indirect effects from controls in nonattainment areas.

avoided incidence (i.e., benefits due to the proposed standard) of L-T mortality drops by about 35 percent.

One can see that the degree of sensitivity tends to increase as the region has lower and lower initial $PM_{2.5}$ concentrations. For example, the sensitivity of the Los Angeles L-T mortality estimate to the threshold cutpoint uncertainty is from 0 percent to about -35 percent. The same uncertainty results in up to a -80 percent effect in Philadelphia. Threshold uncertainty can rise to as much as -100 percent for all the other, cleaner cities. EPA acknowledged this same fact in the Proposed Rule: "Alternative assumed threshold concentrations...result in as much as a three- to four-fold difference in estimated risk associated with PM exposures in Los Angeles County.... In an area with PM concentrations well below the current PM standards (e.g., Philadelphia County), differences in risk...may be even greater."[86] The difference is that this analysis actually estimates and reports that change in sensitivity, and it is shown that the threshold assumption can actually cause mortality estimates to drop to zero in most of the areas of the country. Few areas are as "insensitive" to the threshold uncertainty as Los Angeles.

Figure 2-5. Sensitivity Ranges for City: Los Angeles, CA



---

[86] 65 Fed. Reg. 65651.

Figure 2-6. Sensitivity Ranges for City: Philadelphia, PA

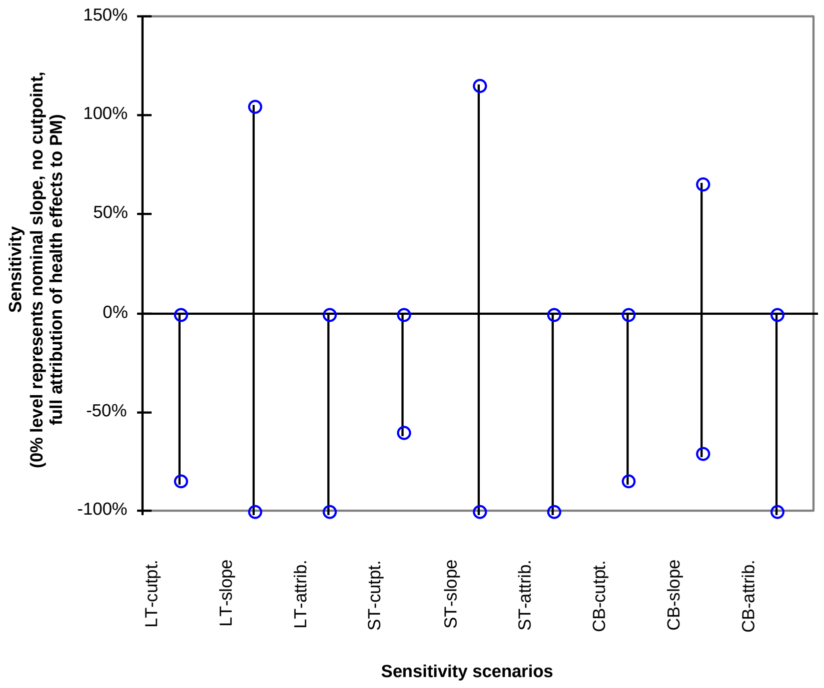


Figure 2-7. Sensitivity Ranges for City: Hypothetical C

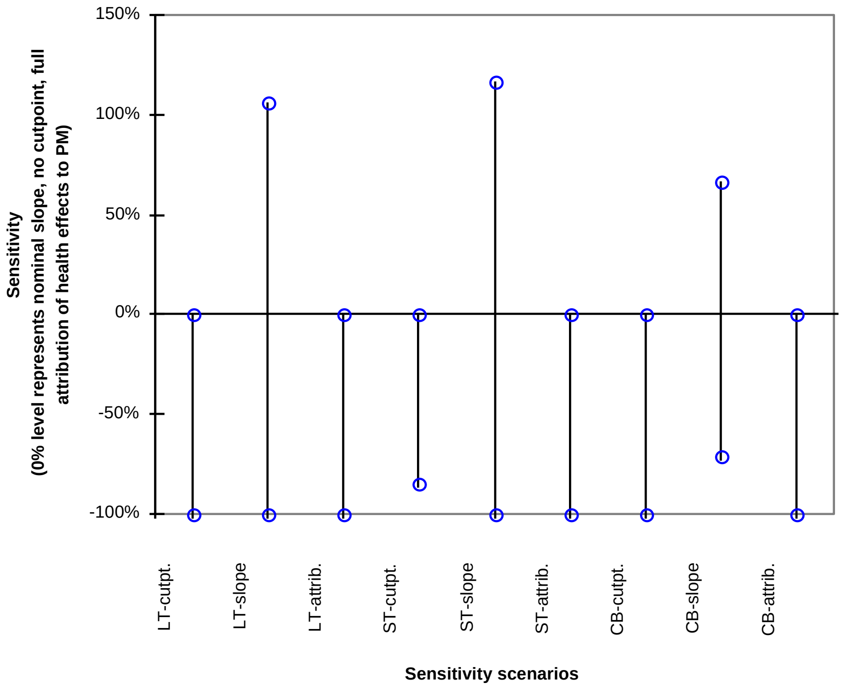
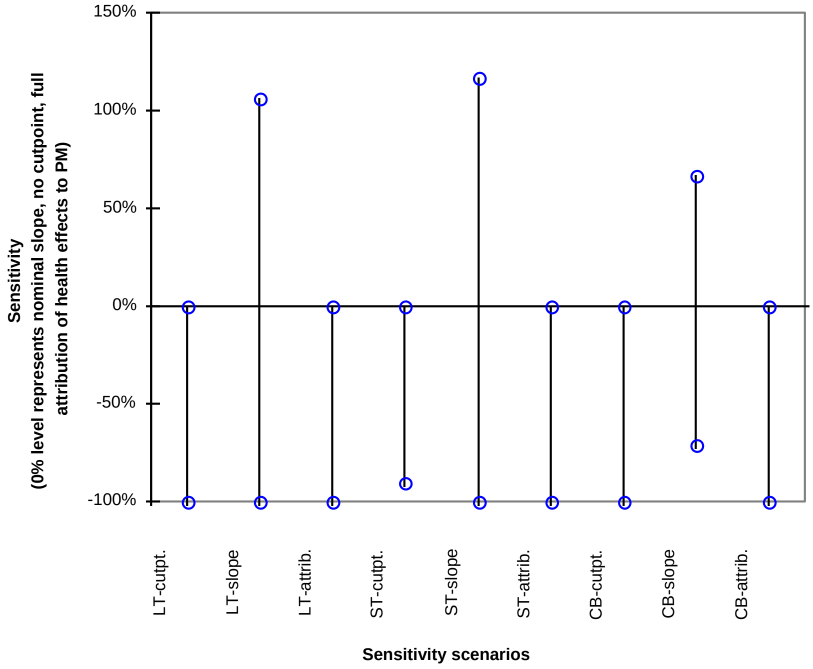


Figure 2-8. Sensitivity Ranges for City: Hypothetical D



Taken collectively, it is evident that each of the cities has quite a high range of sensitivities to the parameters. As has been discussed above, the high and low scenarios are plausible based on information in the scientific record for the PM standard, and based on EPA's own discussions of the evidence in the Proposed Rule and supporting documents. These results indicate that the estimated benefits, in terms of the avoided incidence of health effects, will vary widely as these alternative key parameters are accounted for in the analysis. In some cases the benefits may disappear completely, in some cases the benefits can more than double.

H. National Aggregation of Health Effect Incidences

Given the sensitivity ranges developed for the representative cities, a national aggregate estimate is developed by assigning fractions of the national population to each of the area categories A-E, and disaggregating EPA's overall incidence estimate to the same categories. This was done based on both population and anticipated air quality improvement.[87]

---

[87] The percent of the United States population assigned to each of the types of air quality categories are A: 6 percent, B: 46 percent, C: 15 percent, D: 24 percent, E: 9 percent. These fractions were estimated in such a way as to likely overstate the fraction of populations in the higher PM areas. The disaggregation of EPA's incidence estimate is based on population receiving a particular amount of air quality improvement, which is larger in more severe nonattainment areas. For example, suppose two metropolitan areas each have 1,000,000 population, but one is better represented by category A, with a projected 2007 $PM_{2.5}$ concentration of over 20 $\mu g/m^3$, while another is better represented by category C, with concentration between 12.5 and 15 $\mu g/m^3$. Then, under full attainment of the proposed standard, the "A" city would have a large reduction in concentrations down to 15 $\mu g/m^3$; while the "C" city is already in attainment and would receive only indirect benefits resulting from controls in neighboring nonattainment areas, which would likely be a less significant

With the national incidence estimates thus attributed to individual categories, the sensitivity ranges of the representative cities were applied, then aggregated on a population-weighted basis to form revised estimates of national estimates of the reduced incidence of S-T mortality, L-T mortality, and chronic bronchitis. Figures 2-9 to 2-11 show the outcomes for each of the 27 scenarios (reflecting combinations of three possible values for three variables: attribution, cutpoint, and risk ratio). Figures 2-12 to 2-14 are equivalent but show only the nine scenarios in which full attribution of epidemiological risk is made to $PM_{2.5}$.

For more detail, Tables 2-4 to 2-6 show the equivalent information as in the figures, but in addition allow for identification of the specific scenario corresponding to any particular estimate.

Figure 2-15 illustrates the way that the chronic bronchitis estimates of Figure 2-11 might change once they have been re-estimated using the Abbey *et al.* (1993) study in place of Schwartz (1993). (As discussed above, EPA has decided to make this change in its revised RIA, to be released in July 1997.) One can see that the avoided cases of chronic bronchitis can be expected to drop by about 25 percent. However, these are much more speculative sensitivity estimates since there is almost no useful documentation available on how EPA has actually applied either study. For the remainder of the analysis and discussion, the current RIA's chronic bronchitis estimates will be used. This adds a fair degree of conservatism to the final uncertainty ranges.

---

decrease in concentration. Thus, the benefits (in terms of reduced premature mortality, for example) would likely be greater in the "A" city than the "C" city, even though both have the same population. More detailed discussion of this segregation and proportionality assumptions is available from the authors.

Figure 2-9. Nationwide Short-term Deaths Avoided Per Year

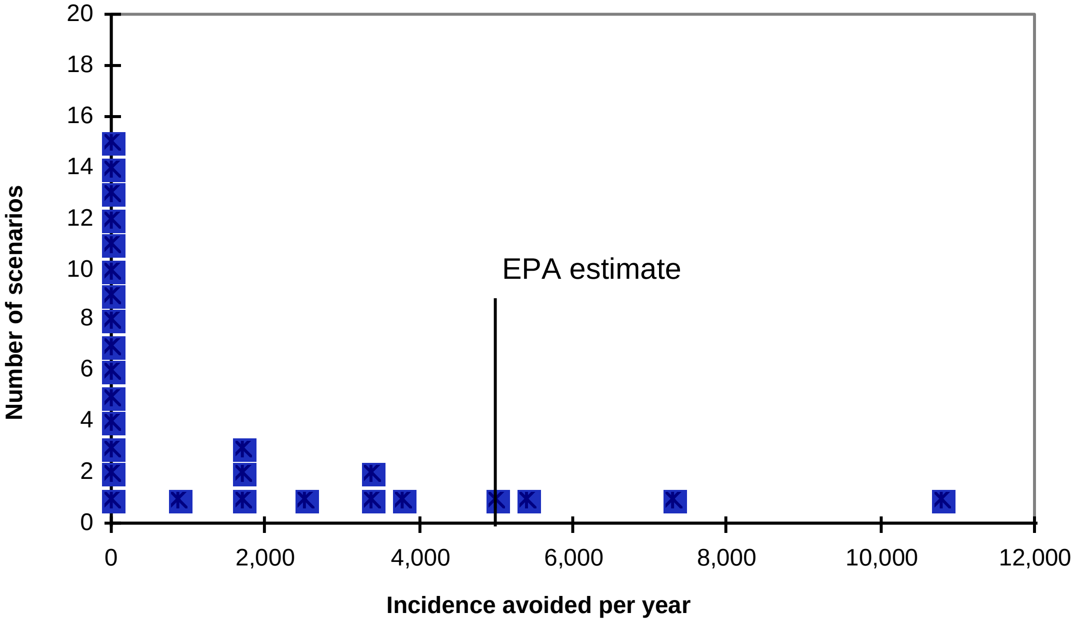


Figure 2-10. Nationwide Long-term Deaths Avoided Per Year

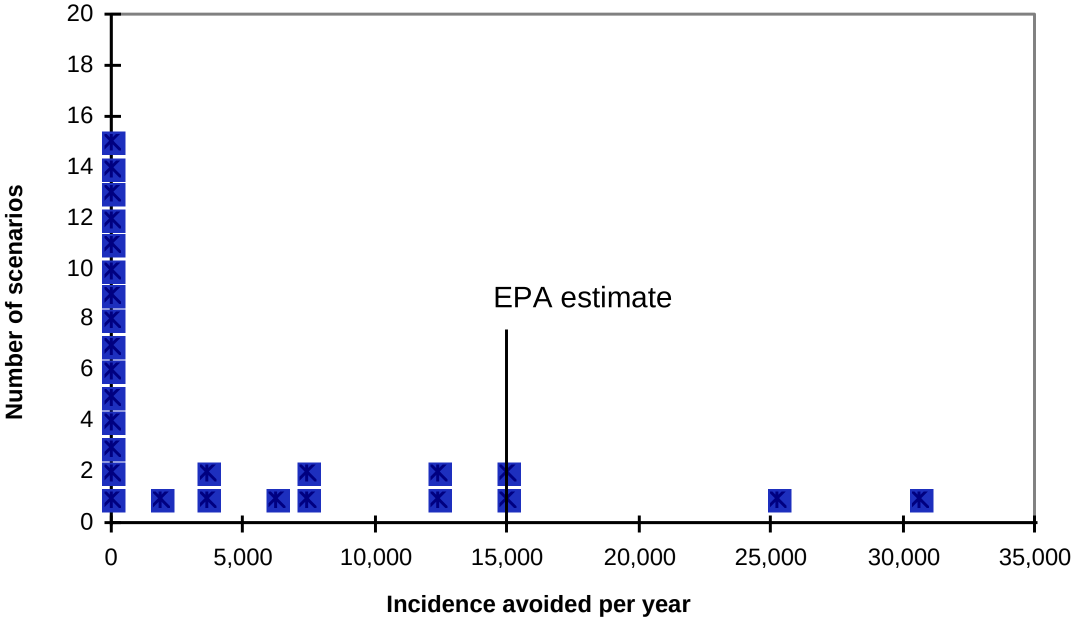


Figure 2-11. Nationwide Chronic Bronchitis Cases Avoided Per Year

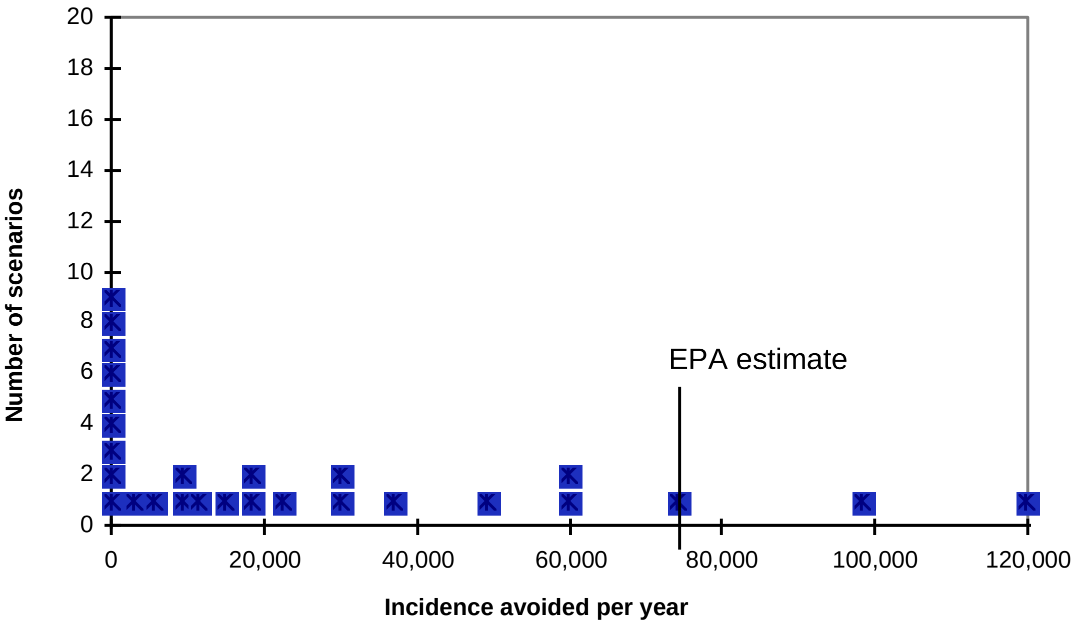
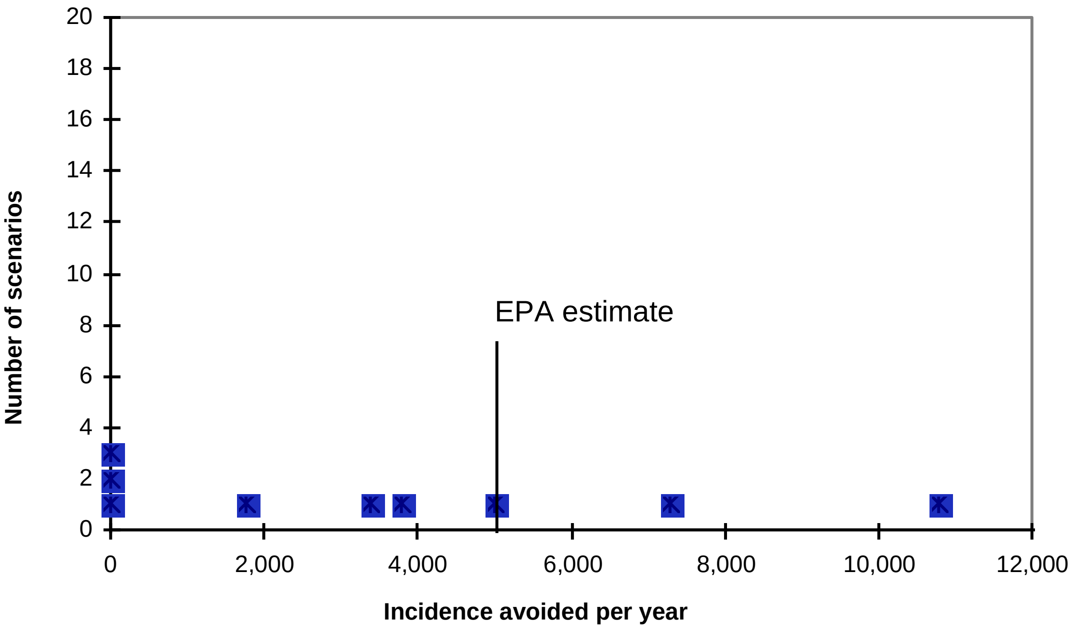


Figure 2-12. Nationwide Short-term Deaths Avoided Per Year, Assuming Full Attribution of Health Effects to $PM_{2.5}$



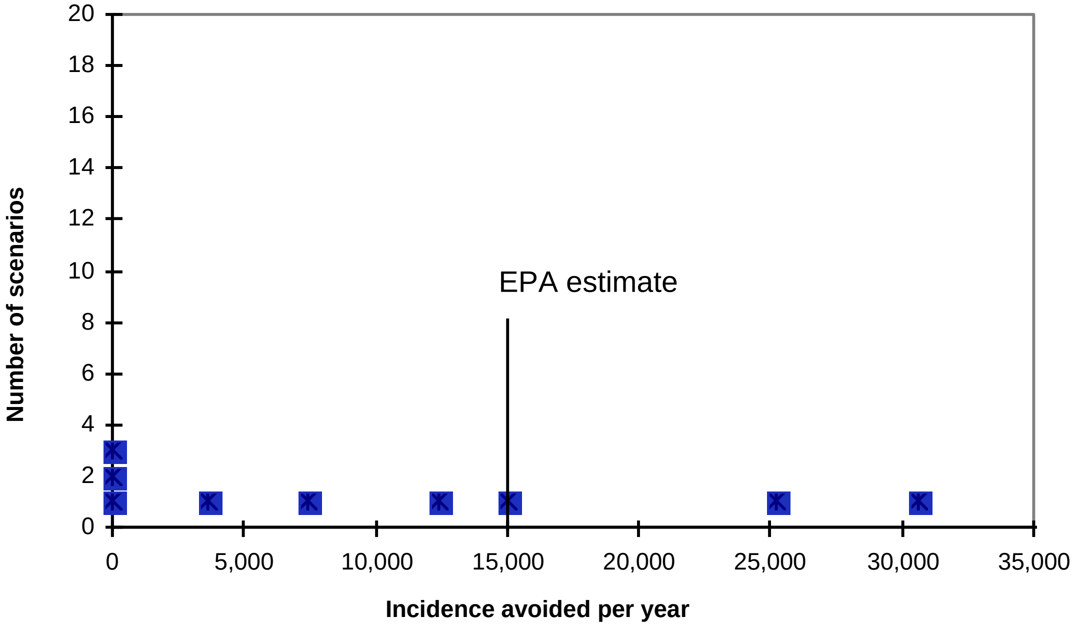


Figure 2-13. Nationwide Long-term Deaths Avoided Per Year, Assuming Full Attribution of Health Effects to $PM_{2.5}$

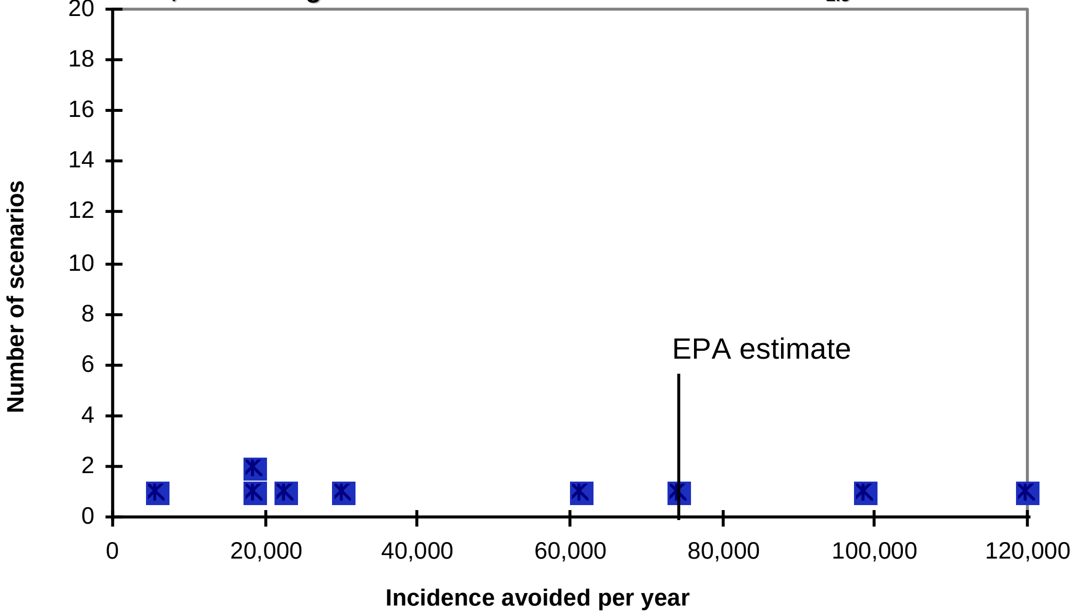


Figure 2-14. Nationwide Chronic Bronchitis Cases Avoided Per Year, Assuming Full Attribution of Health Effects To $PM_{2.5}$

Figure 2-15. Estimated Nationwide Chronic Bronchitis Cases Avoided Per Year if Using Abbey *et al.* (1993) in Place of Schwartz (1993).

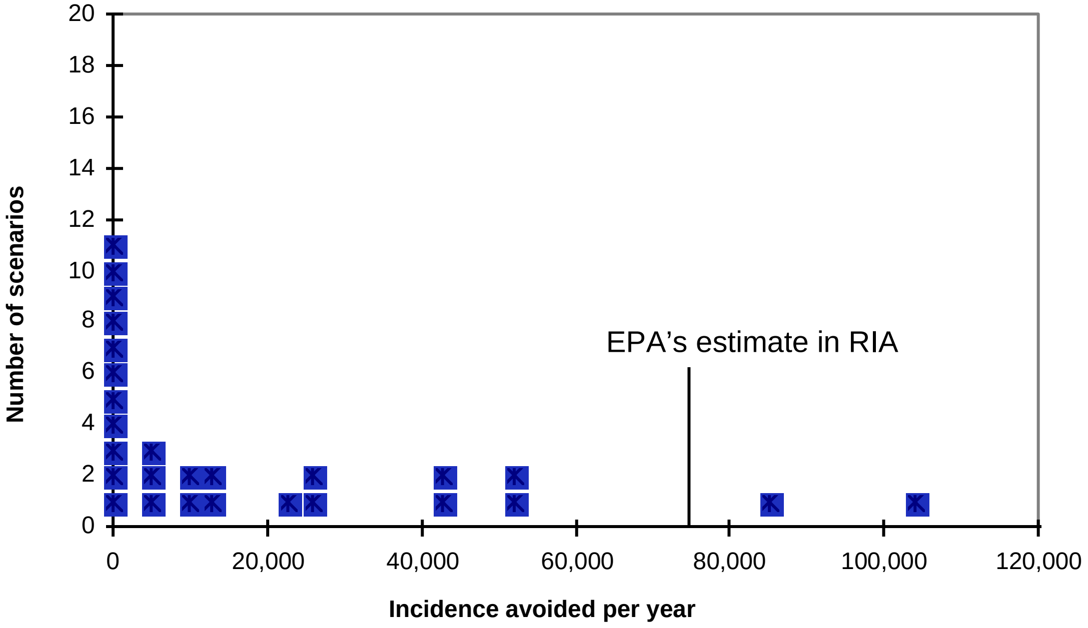


Table 2-4. National Avoided Incidence of Short-term Deaths in 2007, 27 Scenarios
(Shaded block is scenario closest to RIA estimate)

		Risk ratio		
Attribution	Cutpoint	Low	Med.	High
0%	Low	0	0	0
	Medium	0	0	0
	High	0	0	0
50%	Low	0	2,500	5,394
	Medium	0	1,692	3,645
	High	0	880	1,891
100%	Low	0	5,000	10,789
	Medium	0	3,384	7,290
	High	0	1,759	3,783

Table 2-5. National Avoided Incidence of Long-term Deaths in 2007, 27 Scenarios
(Shaded block is scenario closest to RIA estimate)

		Risk ratio		
Attribution	**Cutpoint**	**Low**	**Med.**	**High**
0%	Low	0	0	0
	Med.	0	0	0
	High	0	0	0
50%	Low	0	7,500	15,328
	Med.	0	6,186	12,615
	High	0	1,816	3,718
100%	Low	0	15,000	30,655
	Med.	0	12,373	25,230
	High	0	3,633	7,435

Table 2-6. National Avoided Incidence of Chronic Bronchitis Cases in 2007, 27 Scenarios (Shaded block is scenario closest to RIA estimate)

		Risk ratio		
Attribution	**Cutpoint**	**Low**	**Med.**	**High**
0%	Low	0	0	0
	Med.	0	0	0
	High	0	0	0
50%	Low	11,235	37,000	59,897
	Med.	9,318	30,519	49,151
	High	2,782	9,197	14,943
100%	Low	22,471	74,000	119,794
	Med.	18,636	61,038	98,302
	High	5,564	18,394	29,886

A recent study has suggested that the national L-T mortality estimate of 15,000 deaths should actually be a value "less than 1000."[88] To obtain that estimate, the study assumed that the correct standard (after accounting for the error that EPA made in interpreting the Figure 2 in Pope *et al.*) should be set at 18.7 $\mu g/m^3$ on the annual average. The study also argued that since EPA has stated that this level is adequately protective of the public health, then no benefits should be estimated for any of the cities that are below that standard. It is worth noting that an equivalent to this "less than 1000" mortality estimate would be a scenario that applies a long-term mortality threshold at the level of 18.7 $\mu g/m^3$. The closest approximation here of such a scenario would be the national L-T mortality estimate with a threshold at 18 $\mu g/m^3$ in Table 2-5, for "100 percent attribution" and "medium" risk ratio. One can see that a quite comparable estimate of about 3,600 lives is associated with that scenario. There are a couple of reasons why one would expect the estimate in Table 2-5 to be higher. First, the "medium" risk ratio assumption is higher than the risk ratio used in Pope *et al.* (see Figure 2-3 above). Second, the threshold assumption is lower than that used by Jones, and the estimates are quite sensitive to the threshold in this range. Finally, our estimates for developing a national extrapolation from the four representative cities have been made with conservative assumptions.[89] DFI also investigated a scenario with a cutpoint of 18.7 $\mu g/m^3$ and the Pope *et al.* risk ratio, and arrived at a estimate of 1,930 avoided annual L-T mortality. Generally, given the conservatism in this analysis' methodology, it appears that a fairly comparable estimate to Jones has been derived through a very different estimation process.

I. National Monetized Benefits

With national incidences calculated from the scenarios, the final step is to monetize and add the benefits to get a national total such as that provided in the PM RIA. Consistent with EPA, two totals are calculated, one including S-T mortality and one including L-T mortality. The analysis retains the full range of combinations of scenarios. For example, when deriving the S-T total, there are separate scenarios for S-T mortality threshold and chronic bronchitis threshold. There is not a convincing *a priori*

---

[88] K. Jones, *Is EPA Misleading the Public About the Health Risks From $PM_{2.5}$? An Analysis of the Science Behind EPA's $PM_{2.5}$ Standard*, report prepared for Citizens for a Sound Economy Foundation, Washington, D.C., May, 1997.

[89] For example, we assumed the smallest population possible in areas below the standard, within the range of possibly justifiable estimates of that population.

reason to exclude the possibility that the S-T mortality threshold could be high at the same time that the chronic bronchitis threshold is low. So, whereas the individual health endpoints had 27 different scenarios, the monetized aggregate benefit has 243 scenarios each for S-T and L-T.

The calculation of the monetized benefits for any particular scenario is as follows:

- The appropriate mortality and chronic bronchitis benefits (national avoided incidences) are calculated.
- The incidences are multiplied by the appropriate valuation (depending on the assumptions baseline).
- Other RIA benefits categories which are dependent on PM_{10}, such as respiratory symptoms (see Table 9.4 of RIA) are adjusted for the overcounting of coarse fraction benefits, if the DFI assumptions baseline is used.
- Other RIA benefits categories which are epidemiological, such as hospital admissions, are adjusted if the scenario assumes less than full attribution of the health effects to PM.
- Other RIA benefits categories which are not based on PM_{10} and which are not epidemiological, (e.g., visibility), are added without modification.

This yields the total dollar benefits for one scenario. This is repeated for each scenario, separately for S-T and L-T mortality.

Figure 2-16. Summary Ranges of Benefits of Full Attainment of Proposed PM2.5 Standard

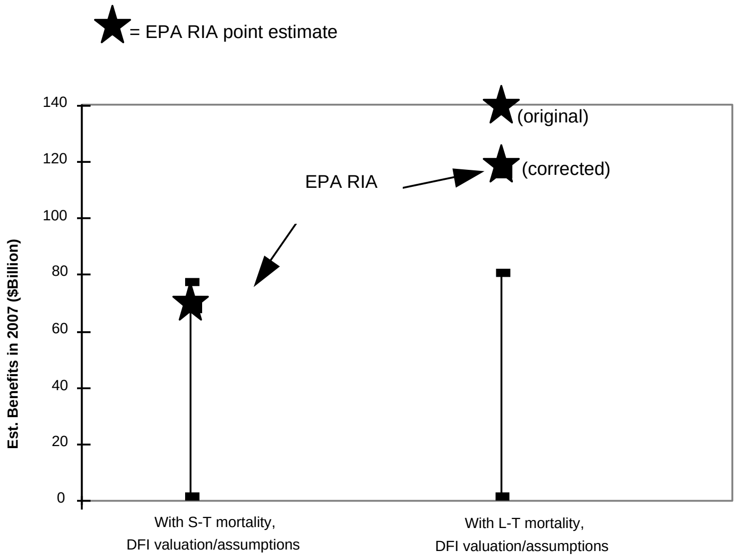
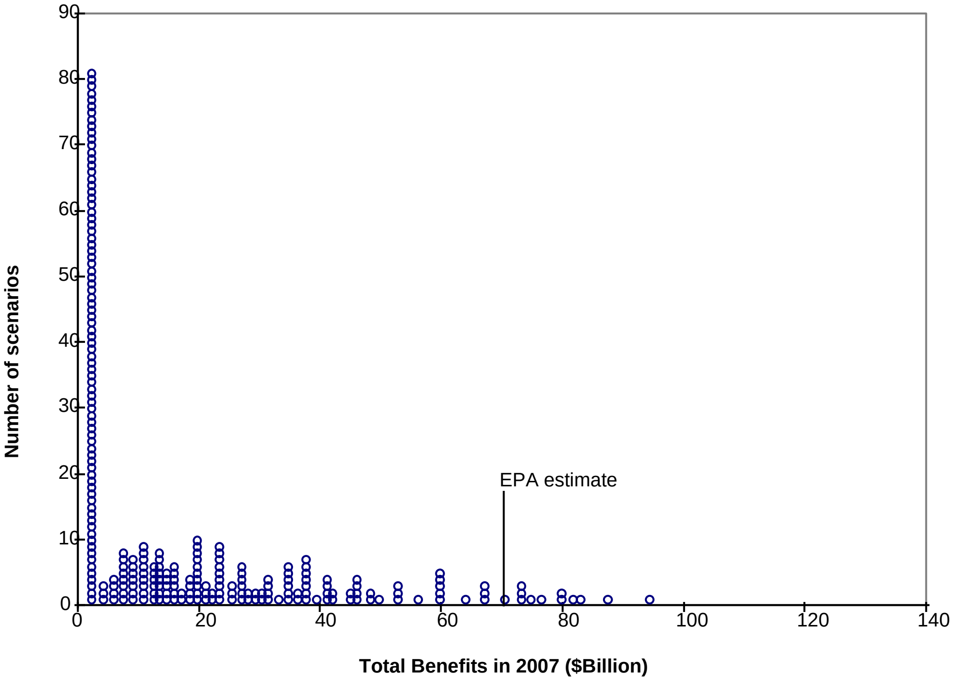


Figure 2-16 shows two estimated ranges of total monetized benefits of the proposed standard, when short-term or long-term mortality is included. The initial RIA estimates, and the ones corrected as per EPA's April 2, 1997 press release, are also shown for comparison. As mentioned previously, it is unclear how EPA arrived at its chronic bronchitis incidences and it is possible that they were computed incorrectly. At this point, EPA says that it will be basing chronic bronchitis estimates on yet a different study. Preliminary indications are that this will make the top end of the ranges in Figure 2-16 decline by about another $10 billion.

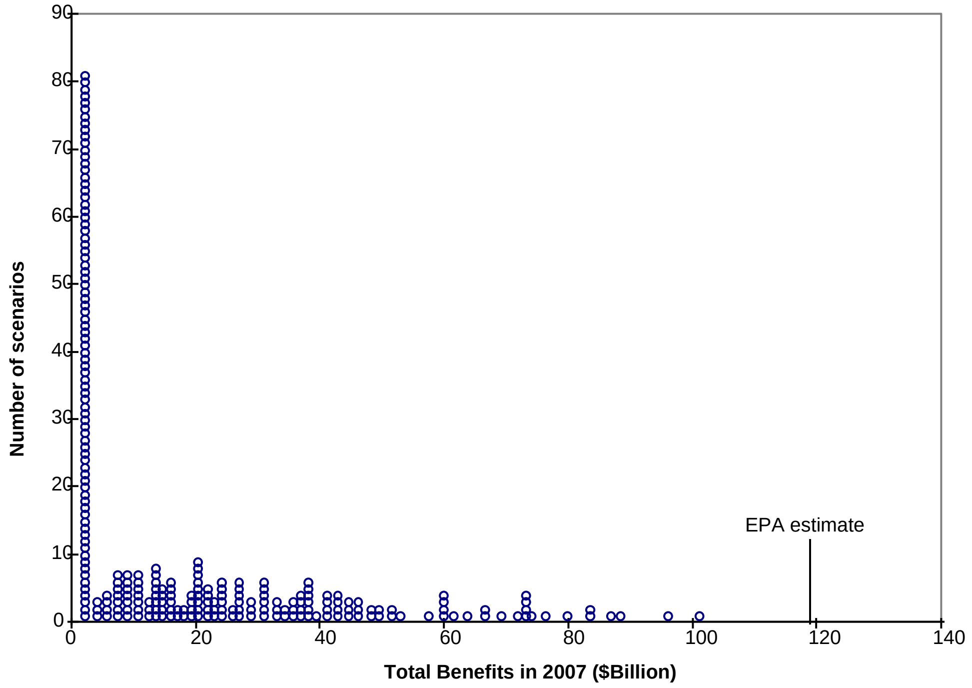
Figures 2-17 and 2-18 provide more detail on specific outcomes within the range, for short-term and long-term mortality, respectively. Each point in the scatter plots represents the outcome from a specific uncertainty scenario.

Figure 2-17. Range of Full Attainment Benefits for Proposed Standard with Short-term Mortality, Based on DFI Valuation and Assumption Baseline



This analysis does *not* assign probabilities to the scenarios, since those are individual judgments that may vary. Thus, the distribution of points in any of the figures contained in this report should not be interpreted as a probability distribution. However, it is usually the case that the most extreme scenarios are the ones with the very smallest probability associated with them. That is certainly the case here since the ranges associated with the risk ratios are themselves only a 90 percent confidence interval on the means of many studies. To avoid overstating extremes when stating a range, one might eliminate a certain number of the top and bottom points. For example, discarding the top and bottom 6 data points would provide a 95 percent confidence interval *if every single scenario has equal probability*. In fact, as we have noted, the top and bottom 6 scenarios should be attributed less than equal probability than more intermediate scenarios. The ranges in Figure 2-16 were created in this way, and thus provide a probably conservative estimate of the 95 percent confidence interval. However, attempts to even approximate an "expected value" within the range would require that the reader personally apply probabilities to each of the three uncertainty ranges and then assess the probability distribution that results for each scenario. Such examples are not provided in this analysis, but can be performed readily.

Figure 2-18. Range of Full Attainment Benefits for Proposed Standard with Long-term Mortality, Based on DFI Valuation and Assumption Baseline

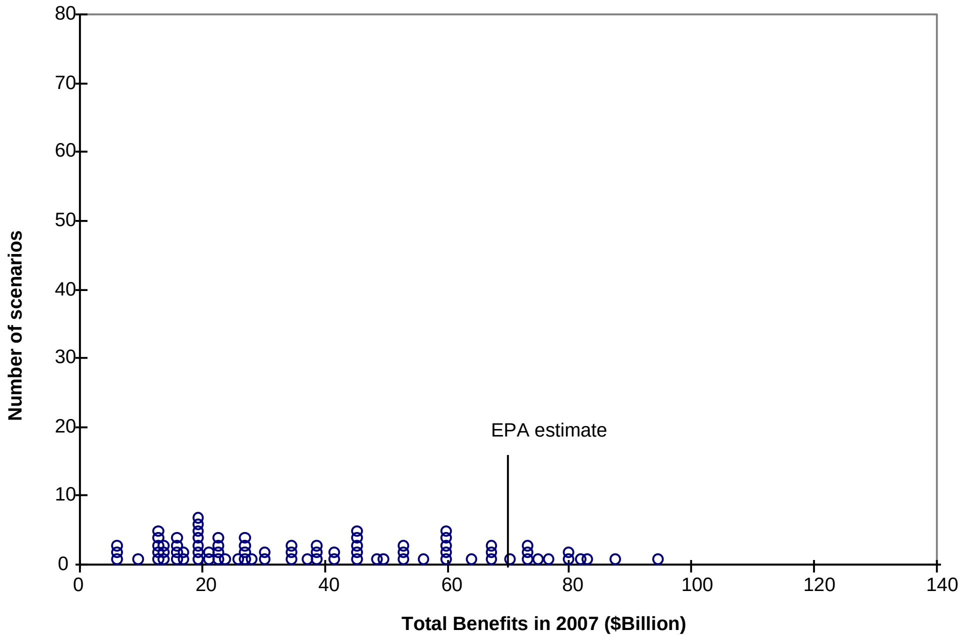


The uncertainties are naturally large, but overall one can see that the national benefit estimates range substantially lower than the EPA estimates, even after correcting for the error that EPA has acknowledged on long-term benefits. DFI's re-calculated benefits range (encompassing 95 percent of the scenarios) is from a low of $2 billion per year to a high of $76 billion when S-T mortality is included, and up to a high of $80 billion when L-T mortality is included. The lower bound of $2 billion consists primarily of visibility rather than health benefits. (The full range, including all scenarios, not just 95 percent of them, leads to a benefits range of $2 billion to $94 billion when counting S-T mortality, and $2 billion to $101 billion when counting L-T mortality.) In contrast, EPA's RIA estimates (corrected for the acknowledged error in the epidemiological study) are $69 billion when counting S-T mortality, and $119 billion when counting L-T mortality. These are near or above the high end of the uncertainty range that has been assessed.

Figures 2-19 and 2-20 show similar scenario results, but only include those scenarios that assume full attribution of the health effects to $PM_{2.5}$. That is, this is what the range of uncertainty looks like if one wants to assume that there is no possibility of confounding, and the epidemiological studies correctly attribute the risk to $PM_{2.5}$. Even with this conservative assumption, total benefits based on both S-T and L-T mortality have the majority of scenarios leading to benefits which lie below EPA's point estimate.

The results presented below have been based on DFI's assumptions and valuation baseline, as discussed above. Some people may wish to reject the mortality valuation and other assumptions that DFI feels are best justified. It is also possible to show the uncertainty in the benefit range using EPA's own baseline valuations and assumptions, but still accounting for the uncertainties due to the epidemiological foundation. This is provided in Figures 2-21 and 2-22. Because EPA's assumptions are used, this range reflects only the epidemiological uncertainties (for which there is underlying statistical uncertainty, not based on judgments or assumptions). Although the ranges now encompass both of EPA's own original dollar benefit estimates, it is clear that the range of plausible benefits is very wide, extending downwards to well less than $5 billion per year. Even with EPA's judgments, most of the estimates fall in the lower end of the range.

Figure 2-19. Range of Full Attainment Benefits for Proposed Standard with Short-term Mortality, Based on DFI Valuation and Assumption Baseline, Full Attribution of Health Effects to PM2.5



J. Conclusions of the PM Benefit analysis

EPA's point estimates of the benefits of the proposed $PM_{2.5}$ standard imply substantial benefits from the proposed $PM_{2.5}$ standard. However, by presenting only a point estimate, without adequate discussion of the uncertainties involved, EPA does not provide the proper context to understand these benefits. The range of potential benefits is so wide that a single point estimate provides little information. This analysis has identified how a number of key uncertainties, which the EPA has acknowledged but not presented in its benefit estimates, can substantially affect the projected benefits of the regulation.

The resulting range of benefits from a number of plausible scenarios is very large, ranging from near zero to significantly larger than EPA's estimate. Although DFI has not attempted to determine which outcome is "most likely," and has not assigned probabilities to the various scenarios, the majority of the scenarios imply benefits significantly lower than EPA's point estimate. The ranges generated from this analysis give a larger and more realistic representation of the potential benefits, and thus provide a more accurate context within which to evaluate the merits of the proposed standard.

Figure 2-20. Range of Full Attainment Benefits for Proposed Standard with Long-term Mortality, Based on DFI Valuation and Assumption Baseline, Full Attribution of Health Effects to PM$_{2.5}$

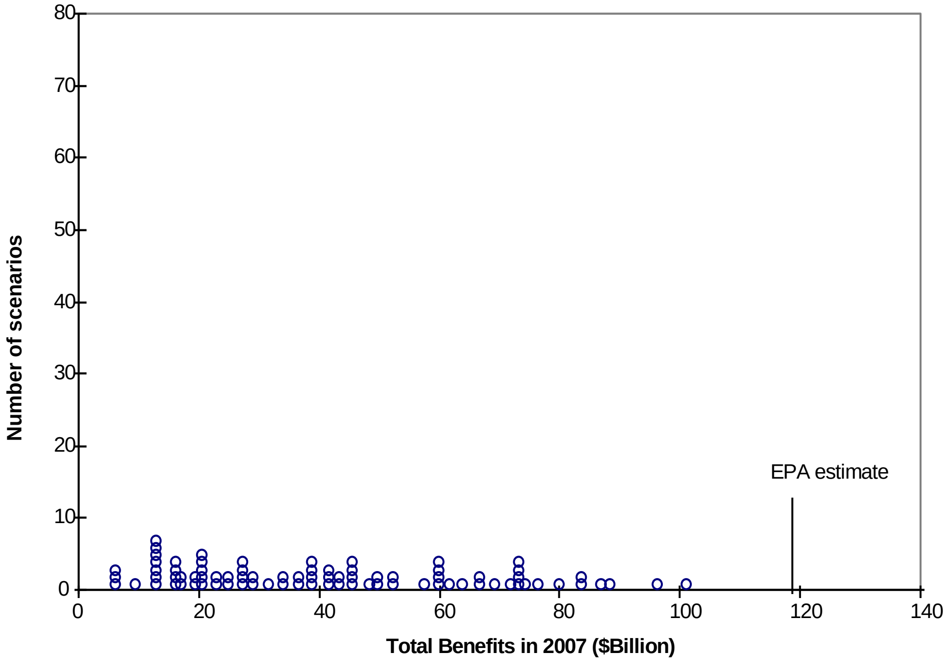


Figure 2-21. Range of Full Attainment Benefits for Proposed Standard with Short-term Mortality, Based on EPA Valuation and Assumption Baseline

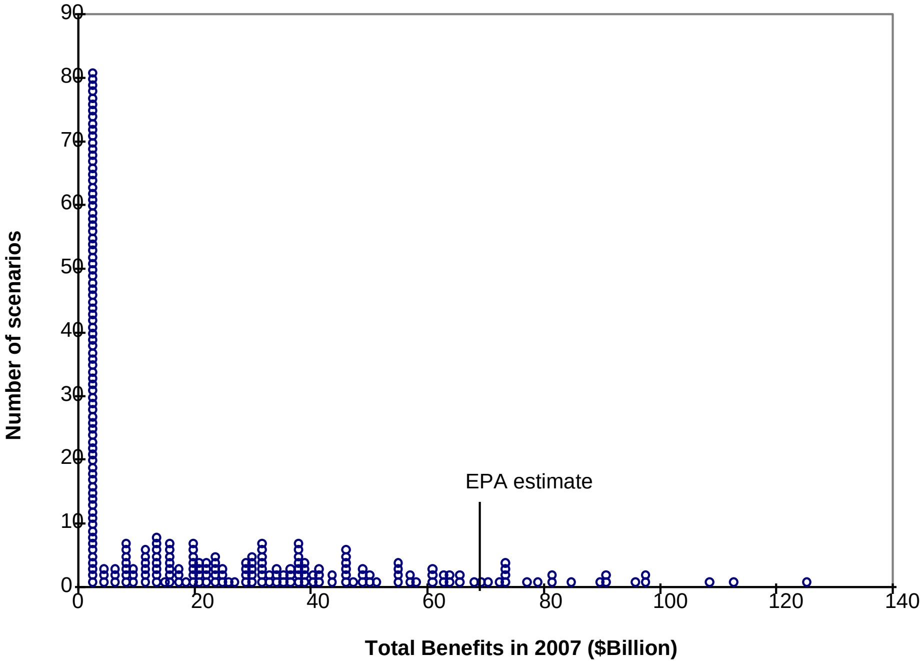
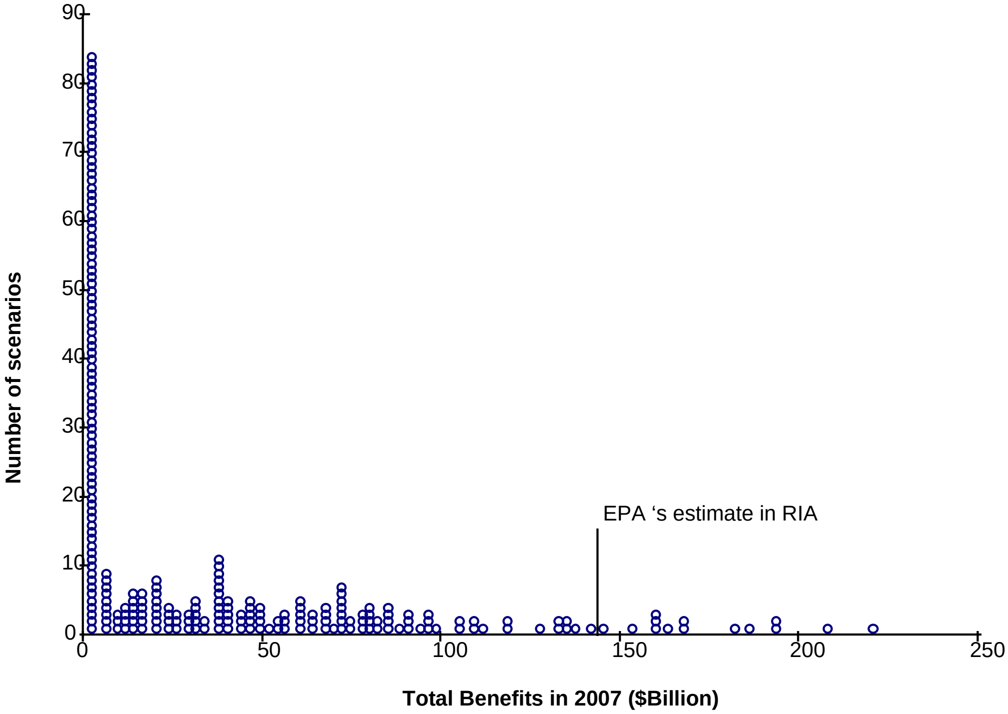


Figure 2-22. Range of Full Attainment Benefits for Proposed Standard with Long-term Mortality, Based on EPA Valuation and Assumption Baseline



IV. Benefits of the Proposed Ozone NAAQS

A. Current and Proposed Standards

The current EPA ozone standard is 120 ppb, measured as the maximum concentration over one hour during a day, with one exceedence of the standard allowed on average per year (averaged over three years). EPA's proposed new standard is 80 ppb, measured by taking the third highest daily 8-hour average concentration in each year, and then averaging that value over three years. The current standard is estimated to correspond to an 8-hour, two exceedence standard of about 90–95 ppb, so that the proposed new standard would require an incremental reduction in ozone levels of about 10 percent beyond attainment with the current standard.

Some U.S. metropolitan areas, such as Los Angeles, have ozone levels far above the current standard. Other areas are in attainment for the current standard, but would be out of attainment under the proposed new standard. The proposed new standard would require those areas now in attainment to carry out additional control measures in order to reduce the emissions of ozone precursors (i.e., volatile organic compounds (VOCs) and nitrogen oxides (NO_x) that react in the atmosphere to form ozone). For the "full attainment" benefits calculations in the RIA,[90] EPA has assumed that all areas will reduce precursor emissions to meet the new standard. (For the Los Angeles area and for some other U.S. metropolitan areas with high ozone levels, it is highly doubtful that feasible methods exist to accomplish the reduction in precursor emissions that would be needed to meet either the current ozone standard or the proposed new ozone standard.)

B. Epidemiological Evidence

Mortality. Ozone-related mortality is suspected from observed association, but multiple uncertainties remain. EPA's Air Quality *Criteria Document* for Ozone,[91] EPA's Ozone *Staff Paper*,[92] and the RIA each state that ozone is not known to cause premature deaths. Epidemiological studies in many metropolitan areas inside and outside the United States have examined the relationship of ozone and other air pollutants with day-to-day fluctuations in observed deaths. Many of the studies show that air pollution is associated with elevated daily mortality. With existing information it is not possible to determine what is responsible, a constituent of air pollution such as ozone, or a factor that is correlated with elevated air pollution but which would not be affected by control measures to reduce emissions. No one knows today whether ozone or other constituents of air pollution at the concentrations found in and downwind of U.S. urban areas cause premature death. If a causal relationship between air pollution and daily mortality does exist, it is not known whether the death should be attributed to ozone, to particulate matter, or to other constituents of air pollution. The Health Effects Institute recently studied the effect of ozone on mortality, and in their report, the authors state: "In summary, although the investigators found an increase in mortality associated with periods during which ambient levels of ozone were elevated, this increase cannot necessarily be attributed to ozone because it was not statistically significant when other air pollutants were included in the analysis...further research is needed to disentangle the effects of the various pollutants and to gain insights into the association of individual pollutants with morbidity and mortality."[93]

Moolgavkar states in his 1995 study (on which the EPA's mortality estimate was based): "Our findings in Philadelphia were similar to our findings in Steubenville: although there was an association between air pollution and mortality, it was not possible to isolate one component of air pollution as being responsible."[94]

If ozone as a component of air pollution does cause premature death, this effect is most likely to occur in individuals whose health is already severely compromised through disease or aging. In such cases, the onset of death may be advanced by a small amount of time (days, weeks, months, or a few years) relative to total life span. In the event that a causal relationship does exist, it is not known whether exposure to

---

[90] United States Environmental Protection Agency, *Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standard*, December 1996, Table E-2.

[91] United States Environmental Protection Agency, *Air Quality Criteria for Ozone and Related Photochemical Oxidants*, vols. I, II, III.

[92] United States Environmental Protection Agency, *OAQPS Staff Paper: Review of National Ambient Air Quality Standards for Ozone: Assessment of Scientific and Technical Information*, June, 1996.

[93] D. Loomis, V. Borja-Aburto, S. Bangdiwala, C. Shy, *Ozone Exposure and Daily Mortality in Mexico City: A Time-Series Analysis* (Cambridge, Mass: Health Effects Institute, October 1996), p. ii.

[94] S.H. Moolgavkar, E.G. Luebeck, T.A. Hall, and E.L. Anderson, "Air Pollution and Daily Mortality in Philadelphia," *Epidemiology*, September 1995, p. 477.

the air pollution at *any* level will hasten death, or whether there is a *threshold***,** below which the effect does not occur.

Morbidity. There is much stronger evidence for ozone-related morbidity impacts, but the extent and severity at ambient concentrations are not well known. At levels in the 70 ppb to 90 ppb ozone exposure range there is no evidence of a threshold for the onset of measurable symptoms or changes in lung function. Clinical experiments on healthy human subjects indicate that ozone exposure during moderate or heavy exercise for periods of four to six hours at levels of 80 ppb cause changes in lung function (narrowing of airways) and inflammation of airway tissue. As a result, EPA is concerned with the effect of ozone on groups that exercise out-of-doors, such as children or outdoor workers. Both the narrowing of airways and the inflammation are believed to last only a short time, a few hours to at most a few days. The health significance of repeated exposure to ozone at these levels, or at higher levels such as occurring in Los Angeles, remains unknown. Scientists suspect that ozone may be associated with increases in asthma attacks, hospital admissions, and premature aging of the lung.

Uncertainty and Peer Review. Extensive discussion of what is known and suspected about the health impacts of ozone exposure is found in EPA's *Criteria Document* (CD) and EPA's OAQPS *Staff Paper*, both of which underwent extensive peer review by the Ozone Panel of the Clean Air Scientific Advisory Committee (CASAC). CASAC is a part of EPA's Science Advisory Board, which is composed of expert scientists from outside of the federal government. CASAC is charged by the Clean Air Act with reviewing available scientific information and making recommendations to the EPA Administrator on National Ambient Air Quality Standards. The letter from CASAC chair George Wolff to EPA Administrator Carol Browner of November 30, 1995, stated the CASAC Ozone Panel's conclusion as follows:

- The Panel felt that the weight of the health effects evidence indicates that there is no threshold concentration for the onset of biological responses due to exposures to ozone above background concentrations. Based on information now available, ozone may elicit a continuum of biological responses down to background concentrations.

- Based on the results... presented in the *Staff Paper*, the Panel concluded there is no "bright line" which distinguishes any of the proposed standards (either the level or the proposed number of exceedences) as being significantly more protective of public health.... Consequently, the selection of a specific level and the number of allowable exceedences is a policy judgment.

The CASAC review as well as the wording in the *Criteria Document* and the *Staff Paper* stress that the health impacts of ozone exposure remain uncertain. There is no known threshold of no effect, or of a serious adverse effect, from ozone at the concentrations occurring in the United States. EPA is charged by law to set a standard that protects health with "an adequate margin of safety." EPA's proposed new standard reducing allowable ozone concentrations is a *policy judgment* about how far, in the face of scientific uncertainty, EPA should go to protect against health effects that *might* be avoided by reducing ozone concentrations.

C. EPA's National Benefits Categories and Estimates

Overview. EPA has calculated the benefits from the proposed new National Ambient Air Quality Standard for ozone. The methodology for the calculation is discussed in the December 1996 *Regulatory Impact Analysis for Proposed Ozone National Ambient Air Quality Standards* (RIA) and in more detail in supporting contractor reports.[95] Estimates of ambient ozone concentrations are calculated using projections of precursor emissions at the county level. Ozone concentrations are projected using the Regional Oxidant Model (ROM) and extrapolating its results from the eastern U.S. to the entire nation. Projections of ozone concentrations under the proposed new standard are made for the year 2007.

Benefits of lowered ozone concentrations are derived by estimating decreases in the following health effects:

- mortality;
- hospital admissions for respiratory illnesses, pneumonia, and chronic obstructive pulmonary disease (COPD); and
- incidences of acute respiratory symptoms and asthma attacks.

In addition, increased worker productivity is considered.[96]

The impact of control strategies in lowering ozone concentrations is assessed in EPA's "full attainment" scenario. A rollback procedure is applied to precursor emissions, independent of the cost and feasibility control measures identified in EPA's cost analysis. This procedure is used to determine how much emissions reduction is needed to meet the attainment criteria of the proposed standard.[97]

The RIA uses dose-response relationships to estimate the incidence of symptoms and mortality, given projected hourly ozone concentrations in each nonattainment area. These are then aggregated to national incidence estimates. EPA has then assigned monetary values to symptoms avoided and to deaths avoided as the result of reductions in ozone concentrations. The benefits ascribed to the change from the existing ozone standard are then estimated as the sum of monetary values from symptoms avoided plus monetary values from deaths avoided. In this manner, EPA has calculated an overall estimate of total monetized national health benefits from the proposed new ozone standard in the year 2007. Welfare benefits are also calculated in the RIA. The welfare benefits are primarily from damage avoided to crops and vegetation.

Basis of EPA's Mortality Estimates. EPA's RIA does not use the exact form of the proposed new standard in the mortality and other benefits calculations (i.e., a third-highest average concentration). Rather, a second-highest average concentration and a fifth-highest average concentration at 80 ppb for the 8-hour daily maximum are used. In its summary presentations EPA presents a range of monetized benefits. This report will focus on the upper end of EPA's range, the second-highest average

---

[95] Mathtech, Inc., *Technical Support Document for Ozone NAAQS Analysis: Benefit Methodology,* November 12, 1996.

[96] RIA, Table E-26, p. E-27.

[97] RIA, p. V-12.

concentration form ("1AX") using the "highest estimate" benefits for the Regional Control Strategy. In this re-assessment, however, DFI directly assesses benefits of the actual proposed form.

The ozone RIA cites four epidemiological studies as the basis for its mortality estimates, but only two of these actually enter into the calculations. EPA's low estimate of zero mortality benefits is based on the Kinney *et al.* (1995) study of Los Angeles.[98] EPA does not give a nominal estimate for mortality; it was "not estimated due to uncertainty considerations."[99] EPA's high estimate is based on a 1995 study by Moolgavkar, *et al.* of Philadelphia.[100] Using the "1AX" form with the regional controls strategies baseline, EPA calculates 470 deaths avoided annually from the new standard compared to the current standard.[101] As for $PM_{2.5}$, EPA has used the figure of $4.8 million as a willingness-to-pay estimate per death avoided.[102] Thus, the "high" mortality benefits estimate is $2.3 billion per year.

This estimate of deaths avoided is the primary basis for EPA's high-end estimate of annual monetized benefits of $2.8 billion[103] in 1990 dollars.[104] Of this amount, only $0.5 billion is attributed to welfare,[105] and only $0.03 billion to nonmortality health effects.[106] The benefit ascribed to mortality is by far the dominant term in the RIA benefit calculation.

D. Overview of Analysis Methodology for Ozone Benefits Re-Assessment

Focus on mortality. The analysis in this report focuses only on the mortality portion of the RIA's estimated benefits. The benefits ascribed to other health effects are less than $50 million, of the order of 0.1 percent of the incremental costs associated with the proposed rule. The RIA estimates that welfare benefits from the proposed new standard are in the range of $195 million to $520 million. *Without including the high estimate for mortality, total health and welfare benefits for EPA's proposed new ozone standard are well under $1 billion.*

This summary of the RIA's benefit estimates was based on the 1AX version of the Regional Control Strategy. This baseline was selected because it was decided in the course of this study's cost analysis (Part 1) that the 1AX version of the Regional Control Strategy was the most appropriate baseline for the cost of the proposed ozone standard. Thus, the ozone benefits estimate described in this section are comparable to the cost estimates for ozone described in Part 1 of this report.

Steps to calculate national monetized benefits. Insufficient information and data was made available by EPA to precisely replicate its methodology. Where data gaps occurred, DFI developed comparable methodology to calculate mortality incidence and aggregate to national monetized benefits:

---

[98] P.L. Kinney, K. Ito, and G.D. Thurston, "A Sensitivity Analysis of Mortality/PM-10 Associations in Los Angeles," *Inhalation Toxicology*, vol. 7, (1995), pp. 59–69.

[99] RIA, p. E-27.

[100] S.H. Moolgavkar, *et al.* "Air Pollution and Daily Mortality in Philadelphia," *Epidemiology*, September 1995.

[101] RIA, p. E-16.

[102] RIA, p. IX-21

[103] Mortality is given as 470 from Table E-15 in the RIA.

[104] RIA, p. IX-35, X-5.

[105] RIA, p. IX-29.

[106] RIA, Table E-26, p. E-27.

- We evaluated EPA's assumptions and valuation, and where necessary, developed alternative assumptions or valuation.
- We investigated key scientific and epidemiological uncertainties which could affect benefits, and developed reasonable ranges for uncertain parameters.
- We determined sub-populations which will experience benefits.
- We calculated the avoided incidence of mortality for each sub-population.
- We aggregated to national estimates of incidence under multiple scenarios of uncertainty.
- We applied values per incident to develop ranges of national monetized benefits.

Succeeding sections provide more discussion of each step.

E. Evaluate and Modify Baseline for Valuation and Assumptions

EPA assumes a willingness-to-pay to avoid a mortality incident at $4.8 million per life. However, this is primarily based on literature studies investigating workplace or accidental deaths. The population most at risk from increased ozone exposure is not necessarily a representative cross-section of the overall population. As with PM, if there is a mortality effect from ozone, those individuals who are physiologically compromised, or over the age of 65 would be the most likely to die from high ozone concentrations, and their lives may be shortened by only weeks, months or a few years. The HEI Mexico City study (described below) examined both total mortality and mortality among persons over 65 years of age. In this latter age group relative risk is increased by about 70 percent to 1.0715 compared to the relative risk of 1.0415 for total mortality.[107]

In this context of greatly skewed distribution of mortality, a valuation of *life-years* saved, rather than lives *per se*, is more appropriate. Further discussion of this point can be found in the PM benefits section of this report. For consistency with the PM assessment, DFI uses the same valuation selected for PM "short-term" mortality and explained in the previous section. Thus, $2 million per ozone-related death avoided is used in the DFI baseline for ozone. The DFI analysis continues to use avoided incidence of mortality as its health effects endpoint, but the multiplication by the lower valuation reflects the life-year perspective applied to the skewed age distribution of effects.

F. Epidemiological Studies Used in This Analysis

In contrast to the EPA *Criteria Document*, the RIA is not peer-reviewed in its use of available scientific information. A number of recent epidemiological studies examining the association between daily mortality and ozone exposure have become available since the EPA *Criteria Document* was produced. These include the Kinney *et al*. (1995) study of Los Angeles and the Moolgavkar *et al.* (1995) study of Philadelphia used in the RIA, and a study of mortality in Mexico City supported by the Health Effects Institute. The RIA used the first two of these studies, and this report will use these two plus the Mexico City study as the main basis for mortality estimates. Some other recent epidemiological studies for other cities will be considered more briefly in the discussion following the presentation of the main results for

---

[107] HEI (1996), Table 15, p. 18.

ozone mortality benefits. Appendix 3 provides a full reference list of all the ozone mortality studies mentioned in this section.

The Moolgavkar *et al.* (1995) study is one of a number of studies that were carried out to examine the relationship of daily mortality in Philadelphia to particulate matter. An association between mortality and ozone was found when ozone, particulate matter (as Total Suspended Particulates, TSP), and sulfur dioxide were considered simultaneously. The association between ozone and mortality was significant only for the highest 20 percent of ozone exposures in the highest exposure season, the summer, when ozone and TSP are correlated.[108] The measure of ozone exposure used was averages throughout each day and for all monitors in the metropolitan area. The authors of the study concluded, "Because the pollution covariates are highly correlated, it is not possible to single out one specific component as being responsible for the observed association between air pollution and mortality."[109]

The Kinney *et al.* (1995) study reexamined a potential relationship between mortality and ozone levels in Los Angeles using new statistical methods and data from 1985–1990. An earlier study by Kinney and Ozkaynak (1991) had examined 1970–1979 data from Los Angeles and had found an association between total oxidants (including ozone) and mortality.[110] The 1995 Kinney *et al.* study examined ozone (measured using one-hour daily maximum concentrations), particulate matter (measured as PM_{10}), and carbon monoxide (CO) for associations with mortality, individually and in combination. Ozone was found to be associated with mortality if the other pollutants were not included, but when all three measures were included, the mortality was associated with CO and PM_{10} rather than with ozone. Ozone may have been acting as a surrogate for particulate matter. The authors wrote, "Definitive conclusions regarding a possible role of O_3 [ozone] in daily mortality cannot be drawn from this small data set, nor from the existing literature."[111]

Mexico City was selected as the site for an extensive investigation of the relation of mortality to air pollution. Mexico City has very high levels of ozone, comparable to those in Los Angeles and far above the current U.S. EPA standard. Philadelphia, by comparison, is representative of many cities in the eastern U.S. that are much closer to attainment of the current United States standard. A team of investigators led by Loomis and Shy were selected by the Health Effects Institute to carry out this investigation, which used advanced statistical methods and considered different indices of ozone concentration: a one-hour maximum level, similar to that used in both Kinney studies, a 24-hour average such as used in the Moolgavkar study of Philadelphia, and two measures similar to the eight-hour maximum in the proposed new EPA standard: an average between the hours of 8 a.m. and 6 p.m. and an 8-hour moving average around the daily maximum. The results of the Mexico City analysis showed that ozone is associated with daily mortality using any of the four indices if ozone is considered alone. However, if other air pollutants (TSP and sulfur dioxide) are also included in the analysis, the finding of an association of mortality with ozone disappears.

In each of these epidemiological studies, the authors calculate a relative risk: the amount by which mortality is observed to increase per unit of increase in ozone level. (The unit of increase is 100 ppb.) In

---

[108] Moolgavkar *et al*. (1995), Table 6, p. 483.

[109] Moolgavkar *et al.* (1995), p. 476.

[110] P.L. Kinney, H. Ozkaynak, "Associations of Daily Mortality and Air Pollution in Los Angeles County," *Environmental Research*, vol. 54, (1991), p. 99–120.

[111] Kinney, Ito, and Thurston, p. 68.

comparing the results, it is important to recognize that the number depends on the index for ozone: whether the daily maximum one-hour average, 24-hour daily average, or daily maximum 8-hour average is used. This report uses a combination of the measures from the Mexico City study similar to the daily maximum 8-hour average of EPA's proposed standard. Comparison of the results from Mexico City with the studies of Los Angeles and Philadelphia shows surprisingly good quantitative agreement in the relative risk for association of mortality with ozone level, given that an association exists. The main uncertainties are whether ozone actually *causes* premature mortality, and whether there is a threshold below which the mortality does not occur.

G. Epidemiological Uncertainties

The analysis of this report captures the major uncertainties present in current scientific studies regarding the effects of ozone on mortality by calculating the benefits of the proposed ozone standard under a set of different scenarios. As with the PM benefits re-assessment, three sources of uncertainty in the extent of mortality are examined explicitly in this analysis: whether ozone is causally related to mortality, the relative risk describing the increase in mortality for a given increase in ozone exposure, and the possibility that ozone causes mortality only above a threshold concentration level. Each of these uncertainties is characterized by three possible values. The resulting 27 combinations give a set of scenarios that can readily be examined to illustrate the implications of uncertainty in current knowledge of ozone mortality.

Relative risk. The association of mortality to ozone alone in Mexico City has been used as the basis for the relative risk. The relative risk estimate and the 95 percent confidence limits are used for the three values to represent the uncertainty. This analysis uses the two intermediate indices of ozone exposure in the Mexico City study, the 8-hour moving average and the 8 a.m. to 6 p.m. average. The values are quite close: the two relative risk estimates are 1.040 and 1.043.[112] The average of 1.0415 is used as the middle value in this analysis. The lower value is 1.02 and the upper value is 1.063. These values approximate the 95 percent confidence intervals reported in the Mexico City study for the 8-hour moving average and the 8 a.m. to 6 p.m. average.[113] Thus, the three scenarios used in this analysis are:

Relative risk: 1.020 1.042 1.063 (per 100 ppb ozone daily maximum 8-hour average)

The Moolgavkar *et al.* (1995) study of Philadelphia used a 24-hour daily average for ozone exposure. Measured against this index of ozone exposure, the study found a relative risk of 1.063 (with 95 percent confidence limits of 1.018 to 1.108).[114] The relative risk in the Mexico City study for ozone alone using a 24-hour average ozone measurement is 1.058 (with 95 percent confidence limits of 1.022 to 1.094).[115] The Kinney *et al.* (1995) study of Los Angeles used a 1-hour maximum for ozone exposure. The relative risk for ozone alone was 1.02 (95 percent confidence limits of 1.00 to 1.05).[116] The Mexico City relative risk using one-hour maximum is 1.024 (with 95 percent confidence limits of 1.011 to 1.039).[117] The

---

[112] HEI (1996), Table 15, p. 18.

[113] HEI (1996), Table 15, p. 18.

[114] Moolgavkar *et al.* (1995), Table 5, p. 482.

[115] HEI (1996), Table 15, p. 18.

[116] Kinney, Ito, and Thurston (1995), Table 2, p. 64.

[117] HEI (1996), Table 15, p. 18.

agreement in relative risk among the epidemiological studies of the three different cities is seen to be close.

Threshold cutpoint. The possible existence of a threshold, a level below which ozone has no mortality consequences, is a key uncertainty in this analysis. There are reasons to believe that a threshold may exist in epidemiological studies of air pollution, even if one cannot be observed in the data. This point was discussed in more detail in the PM benefits section. However, in the case of ozone, the epidemiology itself seems to point to the possibility of a threshold. The three scenarios investigated were:

Threshold:	40	70	100 ppb

40 ppb is equivalent to background concentration level, so that ozone-induced mortality occurs for any exposure elevated over natural background levels. HEI's study of mortality in Mexico City shows evidence of a threshold between 117.3 ppb and 142.8 ppb 1-hr daily maximum, assumed to be at 130 ppb.[118] This translates to approximately 100 ppb using an eight-hour maximum. [119] Finally, 70 ppb corresponds to the midpoint between the low and high threshold values.

Attribution of mortality to ozone. As mentioned previously, there is only equivocal evidence that ozone is a causal factor of premature mortality. Most epidemiological studies have other potentially confounding pollutants which could be underlying the observed mortality. DFI developed three scenarios for attributing the observed mortality association to ozone:

Attribution:	0%	50%	100%

The low scenario is that there is no causal association. The middle scenario is that there is 50 percent attribution of the observed mortality to ozone exposure, so that a reduction in ozone levels would result in 50 percent less decrease in deaths than predicted by the relative risk. The high case is 100 percent attribution; that is, mortality would be reduced as predicted by the relative risk. The 100 percent case is the most conservative and is what is assumed by EPA. This substantial evidence of confounding in the mortality studies provided ample reason to believe that a 50 percent attribution or less could be realistic.

H. Populations Benefiting from the Proposed Standard

The EPA's RIA process first estimates which areas will be out of attainment with the current ozone standard in 2007. These nonattainment areas are the only areas in which incremental benefits are estimated to accrue due to the proposed standard. Supporting documentation from the EPA contractor, Mathtech, Inc., gives a listing of the complete set of these projected nonattainment areas.[120]

---

[118] HEI (1996), Figure 12, p. 18.

[119] HEI (1996), Table 2, p. 10.

[120] This is in contrast to DFI's analysis of the $PM_{2.5}$ standard. For that analysis, EPA did not release which areas were projected to be out of attainment. Therefore, DFI was required to make assumptions to develop estimates of the populations benefiting from the standard. This is discussed in detail in the corresponding portion of the $PM_{2.5}$ benefits section.

Rather than computing avoided mortality for each of the areas listed by Mathtech, DFI selected a set of six representative cities. Each city represents a "category" of ozone problem, which is defined by EPA's nonattainment status. The cities and categories are listed in the Table 2-7 below:

Table 2-7. Representative Cities

Representative City	Current EPA Non-Attainment Classification
Los Angeles	Extreme
Philadelphia	Severe
Baton Rouge	Serious
Dallas	Moderate
Albany, N.Y.	Marginal
Denver	Transitional

To calculate avoided mortality across all of Mathtech's nonattainment areas, DFI assigned each nonattainment area to one of the six categories. The assignment was based on each area's current nonattainment status. So, for example, if Atlanta is a projected nonattainment area for the 1AX Regional Control Scenario, and its current EPA classification is "severe," then it would be assigned to the Severe category and represented by analysis results for Philadelphia. DFI then estimated the total population falling into each of the six categories. These populations receive different levels of benefits (avoided deaths) due to full attainment of the proposed standard.

I. Air Quality and Avoided Mortality for Representative Cities

Projected air quality. Following EPA's methodology, this analysis determined 2007 ozone concentrations based on recent measurement data. The RIA analysis used hourly data for 1990, but these data were not available to DFI. Thus, calculations in this analysis are an approximation to EPA's calculations. This analysis used eight-hour daily maximum ozone concentrations from EPA's Aerometric Information and Retrieval System (AIRS) database for the years 1991–1995. The cities selected had essentially complete ozone concentration measurements for these years. The base year used for calculations is 1994, an average ozone year inthe six cities studied. Neither extremely high concentrations nor extremely low concentrations were observed in comparison to other years in the data base.

The 1994 ozone concentrations were transformed to 2007 concentrations using the same method as in the RIA. The ROM Regional Control Strategy coefficients from the RIA[121] were used in a EPA's linear equation to extrapolate the ozone levels appropriately.[122]

The amount of rollback required to meet the current standard and the proposed standard (eight-hour maximum, 80 ppb, 2 exceedences per year) was determined using a quadratic rollback technique similar

---

[121] RIA, Table IV-1, p. IV-18.

[122] The ROM regression requires population and manufacturing growth rates. The growth rates were derived using BEA Regional Projections of Manufacturing and Population through 2040.

to EPA's technique. This technique lowers the peak ozone days proportionally more than it lowers the low ozone days.[123]

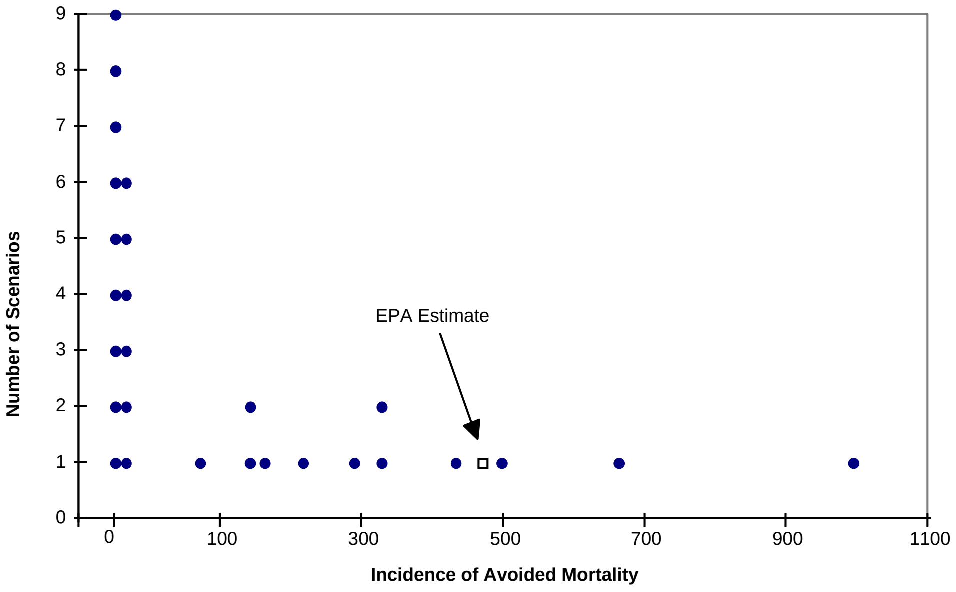
Mortality. Having calculated the daily ozone concentrations for each of the representative cities, the relative risk scenarios and baseline mortality incidences[124] were then applied to calculate mortality under both the current and proposed standards, for each city. The difference between these two is the avoided deaths (benefits) attributable to the proposed standard (above and beyond the benefits of the current standard). These deaths avoided were normalized to deaths per 100,000 population.

J. National Aggregation of Mortality Incidence

With the standardized mortality rate (avoided deaths per 100,000 population due to the proposed standard) for each representative city, and the populations assigned to each of the corresponding six categories, the national aggregate deaths avoided was calculated by simply multiplying the rate by the population for each category, then summing across categories.

The results of the 27 scenarios for deaths avoided are shown in Figure 2-23. The EPA estimate for deaths avoided is approximately bracketed: the highest scenario gives an estimate of approximately twice EPA's figure of 470 deaths. The set of low scenarios show no deaths avoided if ozone exposure does not cause premature mortality.

Figure 2-23. National Incidence of Avoided Mortality Due to Full Attainment of Proposed 80 ppm 8-hour 2-exceedance Ozone Standard



---

[123] Mathtech, Appendix C.

[124] Base (general) non-accidental mortality per 100,000 persons was taken from *Vital Statistics of the United States*, Volume II—Mortality, 1991, Table 8-8.

K. National Monetized Benefits

The valuation per ozone-related mortality incident was applied to calculate monetized benefits of avoided mortality. The range of benefits is from $0 billion to $1.96 billion, as shown in Figure 2-24. The graph also shows EPA's mortality benefits estimate of $2.3 billion. The resulting benefits for each of the 27 scenarios is shown in Figure 2-25. This analysis has used the value of $2 million per death avoided, which, as discussed above, is less than half of EPA's estimate. Since the estimates for the number of deaths range from 0 to twice EPA's estimate of 470 deaths, all of the 27 scenarios fall below EPA's estimate of $2.3 billion. The figure shows that 10 scenarios involve no deaths and no mortality benefits. Fifteen more scenarios fall below $1 billion, for a total of 25 of the 27.

Eighteen of the 27 scenarios have less than 100 percent attribution of mortality effects to ozone. As mentioned previously, EPA's conservative assumption is that all of the risk determined by the underlying epidemiological studies is in fact attributable to ozone (i.e., no hidden confounders). Figure 2-26 and 2-27 show avoided incidence and benefits, respectively, for only the scenarios in which 100 percent attribution is made. Clearly, EPA's estimates still remain at the high end or outside of the range of scenarios.

Figure 2-24. Comparison of EPA Ozone Mortality Benefits Point Estimate to DFI's Range of Ozone Mortality Benefits

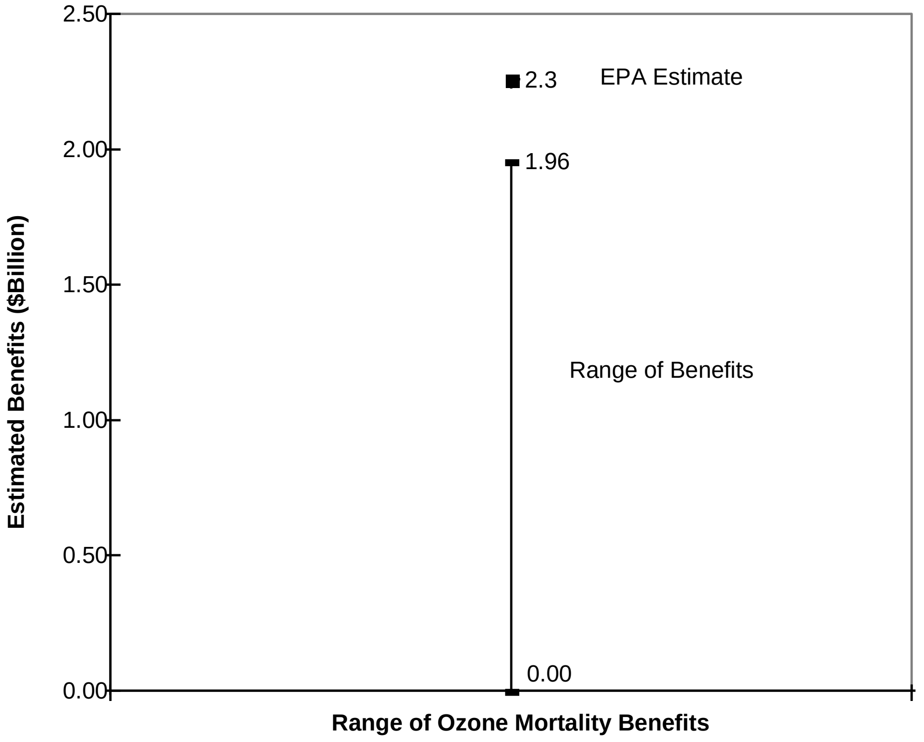


Figure 2-25. National Monetized Mortality Benefits for Full Attainment of Proposed Ozone Standard

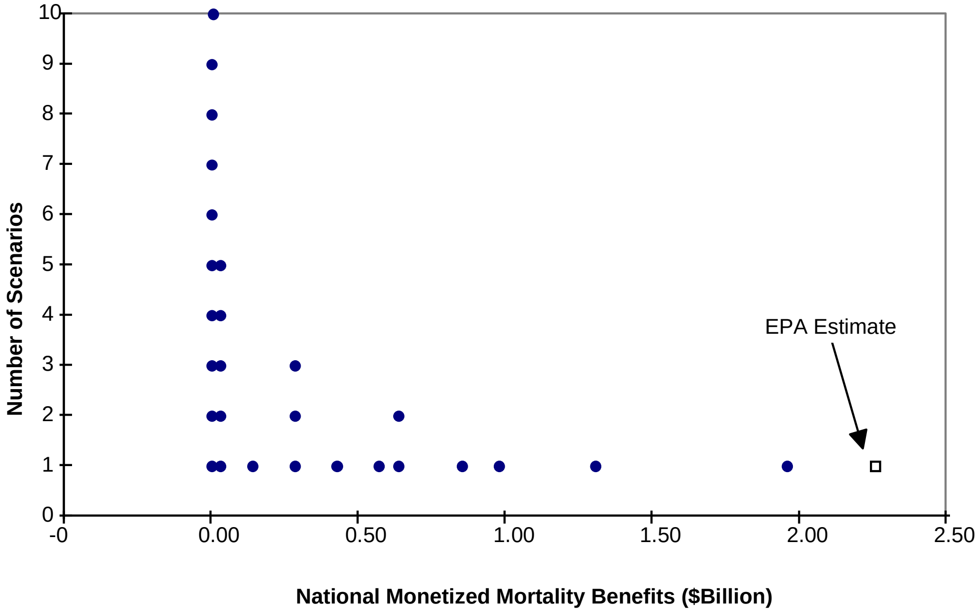


Figure 2-26. National Incidence of Avoided Mortality for Full Attainment of Proposed Ozone Standard, Full Attribution of Mortality to Ozone

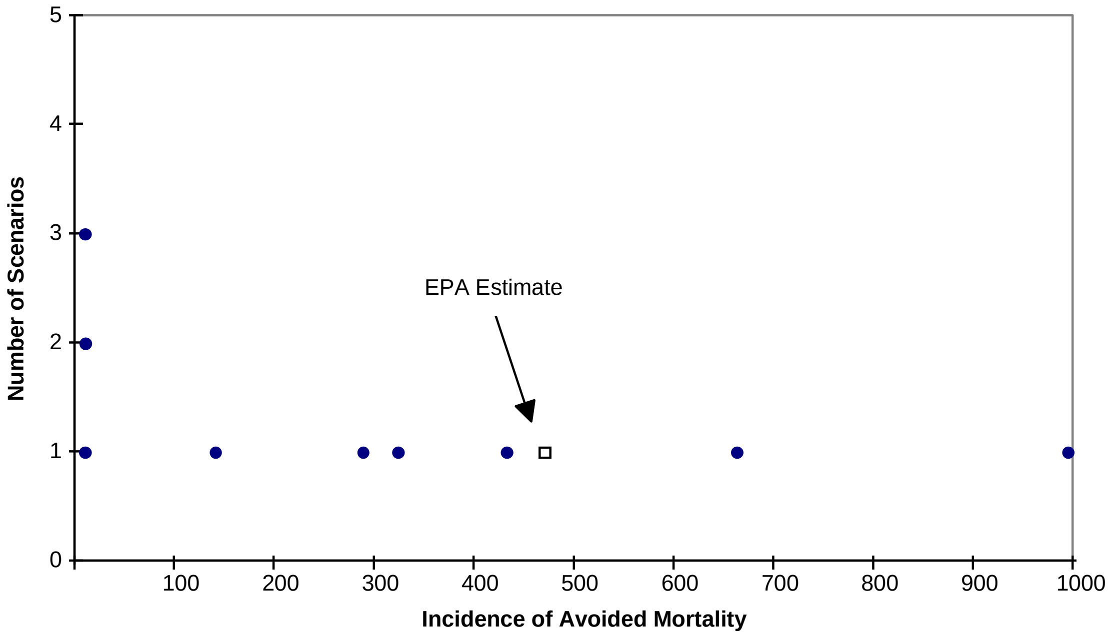
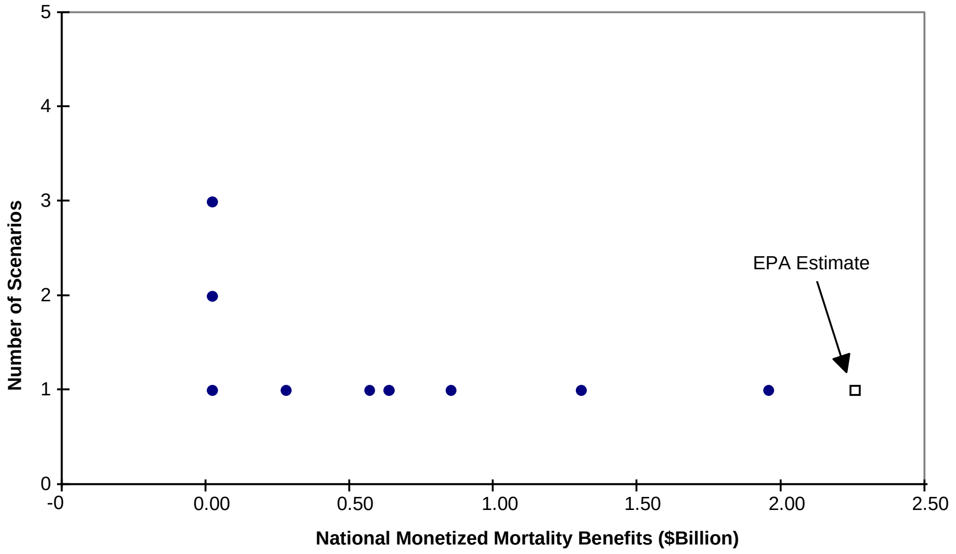
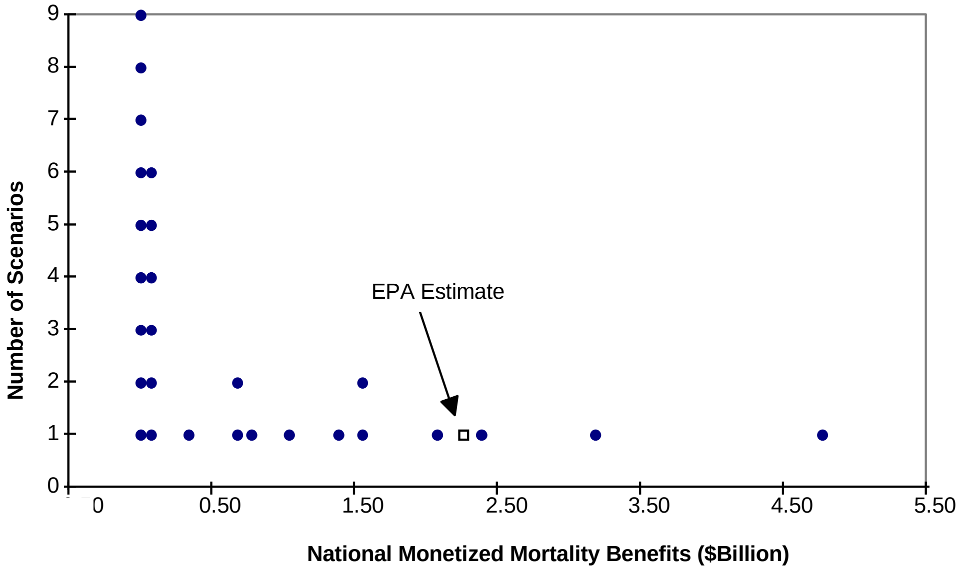


Figure 2-27. National Monetized Mortality Benefits Due to Full Attainment of Proposed Ozone Standard, Full Attribution of Mortality to Ozone



Some may choose not to accept the life-year valuation methodology which leads to the $2 million per "statistical life." Figure 2-28 illustrates the range of mortality benefits using the EPA's value of life ($4.8 million per "statistical life"). In this case, the range is widened, and 3 scenarios produce benefits above EPA's estimate. These are the scenarios with high relative risk, low threshold, and high attribution of mortality to ozone. However, most of the scenarios are still below EPA's estimate.[125] Twenty-one scenarios are below $1.5 billion.

Figure 2-28. National Monetized Mortality Benefits for Full Attainment of Proposed Ozone Standard, using EPA Valuation of Life



---

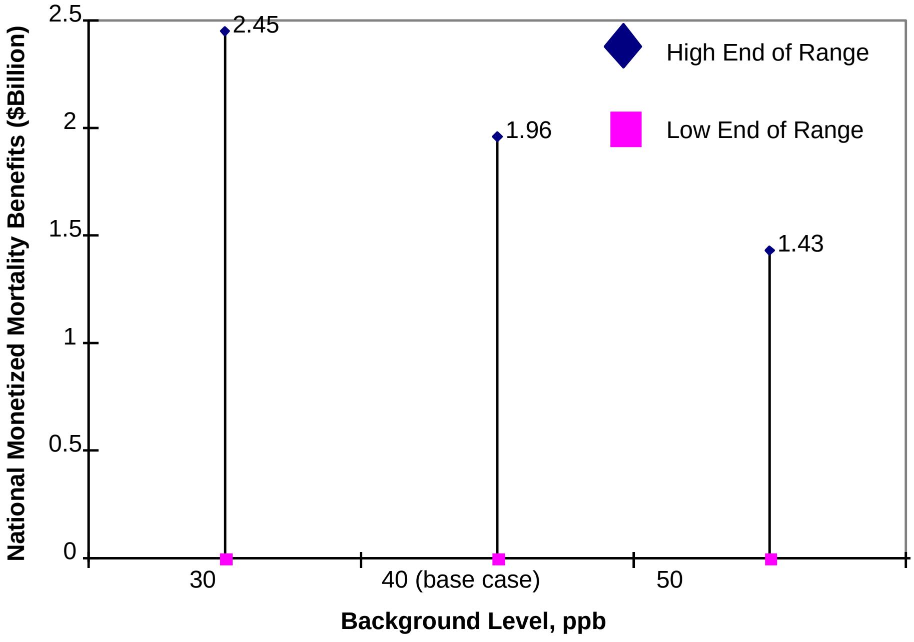
[125] It is important to note that this analysis is not assigning any probabilities to various scenarios, nor identifying a "most likely" scenario. All scenarios are considered plausible and realistic.

L. Additional Sensitivity Analysis: Effects of Background Ozone Level

Although not considered as a primary uncertainty in the development of the 27 scenarios, the effect of background ozone level could affect the incidence results. The EPA's *Staff Paper* states, "it is reasonable to estimate that the eight-hour daily maximum O_3 [concentration] during the summer is in the range of 0.03 to 0.05 ppm."[126] Based on this information, DFI used the middle of this range, 0.04 ppm (40 ppb) for its analysis. The EPA also used 0.04 ppm in its analysis. In the calculation of rollback, no rollback was necessary if the ozone concentration was already below background. If the ozone concentration was above background, rollback is calculated as a percentage of the difference between the current level and background, multiplied by the concentration.[127]

Use of different background levels changes the benefits by approximately 25 percent. Figure 2-29 illustrates the difference between using 30 ppb, 40 ppb, and 50 ppb. (These values are the low, middle, and high end of the range cited in the *Staff Paper*.)

Figure 2-29. Sensitivity of Range of Mortality Benefits to Background Ozone Level



M. Other Epidemiological Mortality Studies

This analysis has been based upon the 1996 Mexico City study by Loomis *et al.* The relative risk for ozone alone from this Mexico City study, using a 24-hour daily average measure of ozone, closely matches the relative risk from the 1995 Moolgavkar *et al.* study of Philadelphia used for the RIA high

---

[126] *OAQPS Staff Paper*, June, 1996, p. 21.

[127] EPA's rollback evidently is relative to zero, not background. Michelle McKeever, EPA, Personal communication, May 12, 1997.

estimate of mortality. The relative risk for ozone alone, using a one-hour maximum measure, closely matches the relative risk for ozone alone in the 1995 Kinney *et al*. study of Los Angeles. When particulate matter was included in addition to ozone, the significance of the association between mortality and ozone disappeared in both the Mexico City and in the 1995 Kinney *et al.* Los Angeles study. This result from the Kinney study is the basis of the RIA low estimate of zero mortality from ozone exposure.

This section briefly reviews other epidemiological studies that have explored the association between ozone and mortality (see Table 2-8 below). The RIA references two studies by Dockery *et al.* (1992). Dockery, Schwartz, and Spengler[128] investigated the association of mortality with ozone and other indices of air pollution in St. Louis and eastern Tennessee in a one-year period of 1985–1986. They found an association between several measures of particulate matter and mortality, but the association for ozone and for other gaseous pollutants (sulfur dioxide, nitrogen dioxide) was far from statistical significance. St. Louis had five violations of the current ozone standard during the one-year investigation period, while eastern Tennessee had none. There are several other studies of other areas (Detroit,[129] Steubenville, Ohio[130], Philadelphia[131]) published by Schwartz and Dockery, in which associations between mortality and particulate matter were found, but not associations with ozone. The reference to the second Dockery *et al.* (1995) study in the RIA is not clear.

Samet *et al.* (1997) have carried out further investigation of the Philadelphia data for 1974-1988 in their Phase I-B report to the Health Effects Institute.[132] This study used a 24-hour average as the index for ozone exposure, and the findings are similar to those of Moolgavkar *et al.* (1995) with a larger relative risk: 1.118 for ozone alone and 1.099 with other pollutants included. With other pollutants included in the model, the relative risk translates to approximately 1.072 for 8-hour maximum ozone concentrations.[133] This relative risk would imply an increase in avoided mortality of 12 percent to 20 percent compared to the high relative risk value of 1.063 used in this analysis.

Thurston recently submitted comments to EPA in which he claims that research he and colleagues at New York University are conducting shows a significant association of mortality with ozone for nine U.S. cities.[134] (Neither a published version nor an unpublished version with details of the procedures used was available for this analysis.) Thurston's results show much lower relative risk for cities with high ozone levels (Los Angeles, 1.03; Houston 1.02), compared to cities with moderate ozone levels (Atlanta, 1.08; Chicago, 1.07; Detroit, 1.10; New York, 1.08; St. Louis, 1.05), or low ozone levels in compliance with the current standard (Minneapolis, 1.07; San Francisco, 1.09). (All relative risks are per 100 ppb

---

[128] D.W. Dockery, J. Schwartz, and J.D. Spengler, "Air Pollution and Daily Mortality: Associations with Particulates and Acid Aerosols," *Environmental Research,* vol. 59, (1992), pp. 362–373.

[129] J. Schwartz, "Particulate Air Pollution and Daily Mortality in Detroit," *Environmental Research,* vol. 56, (1991), pp. 204–213.

[130] J. Schwartz, and D.W. Dockery, "Particulate Air Pollution and Daily Mortality in Steubenville, Ohio," *American Journal of Epidemiology*, vol. 135, (1992), pp. 12–19.

[131] J. Schwartz, and D.W. Dockery, "Increased Mortality in Philadelphia Associated with Daily Air Pollution Concentrations," *Am. Rev. Respir. Dis.*, vol. 145, (1992), pp. 600–604.

[132] Samet, J.; Zeger, S.; Kelsall, J.; Xu, J.; Kalkstein, L. *Particulate Air Pollution and Daily Mortality* (Cambridge, Mass.: Health Effects Institute, March, 1997).

[133] The HEI Mexico City study shows the relationship between relative risks for 24-hour ozone measurements and 8-hour ozone measurements. This relationship was used to translate the HEI Philadelphia study's relative risk.

[134] G. Thurston, Presentation to the Air & Waste Management Association's 90th Annual Meeting and Exhibition, (available in the Ozone Docket), p. 11.

increase, using a 1-hour daily maximum measure of ozone). This pattern of results of higher associations in the cities with lower ozone levels is counter-intuitive. One would expect a stronger association in locations where the pollutant concentrations are higher. The fact that Thurston finds almost exactly the opposite pattern is highly suggestive of one or more confounding factors correlated to variations in ozone level within each city. These factors could involve weather, the quality of indoor air,[135] or other air pollutants.

Several recent studies outside the United States cited by Thurston show the same pattern: that higher relative risks occur in cities with lower ozone levels. The Anderson *et al*. study of London,[136] a city whose maximum 8-hour ozone level of 74 ppb and maximum one-hour level meet both the current and proposed U.S. standards, calculated a relative risk of 1.11 for 100 ppb, 1-hour daily max. The Verhoeff *et al*. study of Amsterdam,[137] a city whose maximum 1-hour level of ozone at 153 ppb indicates nonattainment of the current U.S. standard similar to the moderate U.S. cities above, had a relative risk for current day ozone (1-hour maximum) of 1.04, and for ozone with a two-day lag, 1.10. A study of Belgium by Sartor *et al*.[138] during the 1994 summer heat wave, with 24-hour average concentrations of ozone reaching 53 ppb, very low in comparison with U.S. cities, found a 16 percent increase in daily mortality, equivalent to a 1.37 relative risk. This seasonal relative risk number for a 100 ppb increase in the 24-hour average ozone level cannot be compared directly with the other relative risk numbers for one-hour maximum ozone increases of 100 ppb, but it is clearly very high. In the Mexico City study, the relative risk was 1.058 for a 100 ppb increase in 24-hour averaged ozone.

The distinguished scientists on the review panel for the Health Effects Institute comment as follows in their review of the Samet *et al.* (1997) Phase I-B re-evaluation of the Philadelphia data set:

> *No single pollutant by itself accounts for the increase in daily mortality.... In reality, we do not know which variables have a causal function; indeed, one of the purposes of the analysis is to explore competing hypotheses in an attempt to infer which combination of variables is more likely to cause health effects.... Ultimately, it will require joint analysis of data sets from multiple cities with different copollutant correlations (such as planned for Phase II) to address further the role of multiple pollutants.... Statistical analyses of these complex, multivariable data cannot be expected to provide certainty concerning the causal role of particulate air pollution in daily mortality.*[139]

This conclusion seems appropriate for ozone as well as for particulate matter. There is much less evidence accumulated from epidemiological studies associating ozone with mortality than there is evidence implicating particulate matter. Further, the recent epidemiological studies have not undergone peer review within EPA's *Criteria Document* and *Staff Paper* process.

---

[135] D. Byrd, *Risk Policy Report*, April 18, 1997, pp. 42–43.

[136] H.R. Anderson, A. Ponce de Leon, J.M. Bland, J.S. Bower, and D.P. Strachan, "Air Pollution and Daily Mortality in London: 1987–92," *British Medical Journal*, vol. 312 (1996), pp. 665–669.

[137] A.P. Verhoeff, G. Hoek, J. Schwartz, J.H. Van Wijnen, "Air Pollution and Daily Mortality in Amsterdam," *Epidemiology*, vol. 7 (1995), pp. 225–230.

[138] F. Sartor, R. Snacken, C. Demuth, D. Walckiers, "Temperature, Ambient Ozone Levels, and Mortality During Summer 1994 in Belgium," *Environmental Research*, vol. 70, (1994), pp. 105–113.

[139] HEI (Samet), 1997, pp. 36–38.

Table 2-8. Summary of Other Studies of Ozone and Mortality (Full References Are in Appendix 3)

Study	Years of Study	Relative Risk[140]	95% Conf Interval for Relative Risk	Type of O_3 Concentration Measurement	Study Site
Schwartz (1991)	1973-82	1.00		avg of 1-hr max and 24-hr avg	Detroit
Dockery, Schwartz, & Spengler (1992)	1985-86	1.00		24-hour average	MO and TN
Sartor *et al.* (1995)	1994	1.37[141]		24-hour average	Belgium
Kinney & Ozkaynak (1991)	1970-79	1.02		1-hour maximum	Los Angeles
Kinney, Ito, & Thurston (1995)	1985-90	1.02	(1.00,1.05)	1-hour maximum	Los Angeles
HEI (1996)	1990-92	1.024	(1.015,1.044)	1-hour maximum	Mexico City
Ozkaynak (1995)	1972-90	1.04			Toronto
Thurston (1997)	1981-90	1.06	(1.02,1.10) (range, not CI)	1-hour maximum	9 cities
Moolgavkar *et al.* (1995)	1973-88	1.063	(1.018,1.108)	24-hour average	Philadelphia
Verhoeff *et al*. (1995)	1986-92	1.10		1-hour maximum	Amsterdam
Anderson *et al.* (1996)	1987-92	1.10[142]		8-hour maximum	London
HEI (1997)	1974-88	1.118		24-hour average	Philadelphia

N. Conclusions of the Ozone Benefit Analysis

This analysis has presented a set of calculations of the benefits for EPA's proposed new ozone standard of 80 ppb for the three-year average of the annual third-highest maximum eight-hour daily average. The analysis has focused only on mortality, since if mortality is not included, the benefits from the proposed new standard are, by EPA's calculations, well below $0.05 billion for health impacts avoided and up to an additional $0.5 billion for welfare impacts avoided, such as damage to crops and vegetation.

The mortality calculations are consistent with the methods, assumptions, and data used in the RIA. These calculations illustrate that EPA's point estimate of $2.3 billion in benefits can be obtained by making two sets of assumptions: (1) a high value should be assigned per "death avoided," and (2) the imposition of additional controls to meet the proposed ozone standard will actually reduce deaths.

This analysis has used a lower value per death avoided than the $4.8 million used by EPA. The observations from epidemiological studies strongly suggest that deaths associated with high air pollution are occurring primarily in elderly and sick individuals, and that the shortening of life involved is far less than in situations such as highway traffic accidents, where values such as $4.8 million per death avoided would be appropriate.

A causal relationship between ozone exposure and mortality is not established at the present time. Neither EPA's carefully peer-reviewed *Criteria Document* nor its *Staff Paper* show significant scientific support for such a causal relationship. Much of the more recent epidemiological research has investigated whether ozone and other air pollutants might explain some of the association that has been observed between mortality and particulate matter. The review presented above notes that the highest predictions for an association between mortality and ozone have come from the cities with the lowest ozone levels. If ozone is actually linked with premature deaths, one would expect that the strongest evidence would instead come from studies of Los Angeles and Mexico City, where ozone levels remain far above current U.S. standards.

---

[140] Relative risks below are with respect to a 100 ppb change in ozone concentration.

[141] Confounding with temperature makes a conclusion with regard to ozone's role difficult.

[142] Relative risk was also calculated at 1.08 for one-hour maximum ozone.

This report has considered the uncertainty in ozone mortality benefits by examining 27 scenarios, representing three alternative assumptions for important uncertain factors: causality (the attribution of deaths avoided to reductions in ozone exposure), the magnitude of the relative risk relationship, and the potential that ozone causes mortality only when a threshold is exceeded, rather than at levels of ozone extending down to natural background. The results show that high benefits only occur if ozone is responsible for a large fraction of the deaths associated with air pollution, and that these deaths relate to ozone exposure at low levels.

The range of benefits calculated in this analysis is wide, ranging from near zero benefits to significantly higher than EPA's point estimate. This range stems from substantial uncertainties in key factors that drive the benefit estimates. The authors believe that each of the scenarios considered is plausible, and that the resulting range of national monetized benefits more accurately represents the state of knowledge than EPA's single point estimate. This range of benefits provides a more realistic context within which to evaluate the merits of the proposed standard.

Part 3

About the Authors

Dr. Anne E. Smith, a Vice President of Decision Focus Incorporated,[143] is an economist and risk analyst specializing in the integrated assessment of major policy issues. She has been analyzing and producing expert testimony on the benefits, costs, and economic impacts of ambient particulate matter controls over the past several years. Prior to her work on the NAAQS for PM, she performed the primary integrated and economic analyses for the Grand Canyon Visibility Transport Commission.

Dr. D. Warner North, a Sr. Vice President of Decision Focus Incorporated, is an international leader in the development of risk analysis techniques. Dr. North served with the Clean Air Scientific Advisory Committee (CASAC) in its most recent review of the scientific basis for the ozone NAAQS standard.

Dr. Kenneth Green is Environmental Studies Director and a Senior Policy Analyst at the Reason Foundation. Dr. Green has published three previous studies on the linkage between transportation and air quality: "Looking Beyond ECO," "Defending Automobility," and "Checking Up on Smog Check." He has also directed studies on electric vehicles and on roadway finance reform. Dr. Green serves on the California Department of Transportation Advisory Committee and also on the REACH Commission, a task force sponsored by the Federal Highway Administration and the Southern California Association of Governments to design pricing approaches for roadways in the South Coast Air Basin.

Acknowledgement

The authors would like to acknowledge the intensive research and technical support provided by Mr. **Charles J. Helman** on this project. We also commend him for his exceptional independent management of logistics and communications, which made possible the prompt completion of this rapid turnaround, wide-ranging sutdy.

---

[143] Decision Focus International is a management consulting firm that provides national leadership in multidisciplinary analysis of the important and complex policy issues that its clients face.

Appendix 1

Marginal Control Cost Estimates from EPA's Ozone RIA

Alternative 8H1AX-80: Marginal Emission Reductions and Costs by Nonattainment Area and Control Measure Under the RCS

Nonattainment Area	Source Category	Control Measure Control Measure	Reductions (tons/yr.) VOC	Reductions (tons/yr.) NO_x	Costs (1990$) VOC	Costs (1990$) NO_x	VOC+NO_x (tons)	VOC+NO_x ($)	$/ton
Atlanta, GA	Open Burning	Episodic Ban	2,436.90	462.1	0	0	2899	0	0
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	4,867.60	3,819.70	952,657	1,905,313	8687.3	2,857,970	329
	Industrial Boiler - Residual Oil	LNB	0	175.3	0	129,287	175.3	129,287	738
	Cement Manufacturing - Dry	LNB	0	141.1	0	118,154	141.1	118,154	837
	Industrial Boiler - Natural Gas	LNB	0	76.1	0	69,300	76.1	69,300	911
	Cement Manufacturing - Dry	SNCR - Urea based	0	141.1	0	181,642	141.1	181,642	1,287
	Industrial Boiler - Distillate Oil	LNB	0	16.2	0	22,570	16.2	22,570	1,393
	Industrial Boiler - PC	LNB	0	229.5	0	369,572	229.5	369,572	1,610
	Area Source Industrial NG Comb	RACT to small sources	0	40	0	68,692	40	68,692	1,717
	Glass Manufacturing - Container	LNB	0	339.2	0	814,003	339.2	814,003	2,400
	Glass Manufacturing - Container	SCR	0	296.8	0	1,141,514	296.8	1,141,514	3,846
	Nonroad gasoline	Reformulated gasoline	286.4	0	1,432,000	0	286.4	1,432,000	5,000
	Motor Vehicles	California Reform	-715	14,570.60	0	75,035,816	13855.6	75,035,816	5,416
	Industrial Boiler - Residual Oil	LNB + FGR	0	38.3	0	209,562	38.3	209,562	5,472
	Industrial Boiler - Natural Gas	LNB + FGR	0	38.1	0	237,338	38.1	237,338	6,229
	Motor Vehicles	Federal Reform	9,600.30	2,839.10	78,262,901	0	12439.4	78,262,901	6,292
	Industrial Boiler - Residual Oil	SCR	0	76.6	0	545,406	76.6	545,406	7,120
	Nonroad Diesels	CARB Stds for > 175 HP	0	326.6	0	2,664,317	326.6	2,664,317	8,158
	Industrial Boiler - Natural Gas	SCR	0	76.2	0	702,239	76.2	702,239	9,216
	Industrial Boiler - Distillate Oil	LNB + FGR	0	4.5	0	44,896	4.5	44,896	9,977
	Industrial Boiler - Distillate Oil	SCR	0	9.1	0	95,822	9.1	95,822	10,530
	Cement Manufacturing - Dry	SCR	0	169.3	0	1,980,056	169.3	1,980,056	11,696
	Industrial Boiler - PC	SNCR	0	45.9	0	569,962	45.9	569,962	12,417
	Industrial Boiler - PC	SCR	0	68.9	0	1,770,659	68.9	1,770,659	25,699
	Glass Manufacturing - Container	Oxy-Firing	0	84.8	0	2,819,334	84.8	2,819,334	33,247
	Motor Vehicles	Reform Diesel	0	520.4	0	27,274,484	520.4	27,274,484	52,411
	Utility Boiler - Oil-Gas/Tangential	SCR	0	3.4	0	2,423,615	3.4	2,423,615	712,828
		Total	16,476.20	24,608.90	80,647,558	121,193,553	41085.1	201,841,111	4,913
Atlantic City, NJ	Open Burning	Episodic Ban	243.5	46.2	0	0	289.7	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	321.6	0	8,040	0	321.6	8,040	25
	Wood product surface coating	Reformulationon	0.4	0	21	0	0.4	21	53
	Metal product surface coating	VOC content limits & improved	7.7	0	845	0	7.7	845	110
	Recreational vehicles	CARB standards	40.2	0	21,229	0	40.2	21,229	528
	Wood furniture surface coating	Reformulationon	8.6	0	10,454	0	8.6	10,454	1,216
	Point Sources	RE Improvements	139.4	0	278,860	0	139.4	278,860	2,000
	Aerosols	CARB Tier 2 Standards - Reform	42.3	0	105,864	0	42.3	105,864	2,503
	Automobile refinishing	CARB BARCT limits	18.8	0	69,071	0	18.8	69,071	3,674
	Motor Vehicles	California Reform	166.3	1,274.40	0	6,071,805	1440.7	6,071,805	4,214
	Nonroad gasoline	Reformulated gasoline	25.9	0	129,500	0	25.9	129,500	5,000
	Pesticide Application	Reformulationon - FIP rule	6.7	0	62,831	0	6.7	62,831	9,378
	Aerosols	SCAQMD Standards - Reformulation	42.3	0	423,456	0	42.3	423,456	10,011
	Automobile refinishing	FIP Rule (VOC Content & TE)	71.7	0	1,292,122	0	71.7	1,292,122	18,021
	marine surface coating	Add-on control levels	31.3	0	722,827	0	31.3	722,827	23,094
	Miscellaneous surface coating	Add-on control levels	3.8	0	221,789	0	3.8	221,789	58,366
		Total	1,170.50	1,320.60	3,346,909	6,071,805	2491.1	9,418,714	3,781
Bakersfiel	Aerosols	CARB Tier 2 Standards - Reform	0	0	0	0	0	0	0

d, CA									
	Aerosols	SCAQMD Standards - Reformulation	0	0	0	0	0	0	0
	Aircraft surface coating	Add-on control levels	0	0	0	0	0	0	0
	Automobile refinishing	CARB BARCT limits	0	0	0	0	0	0	0
	Automobile refinishing	FIP Rule (VOC Content & TE)	0	0	0	0	0	0	0
	Metal product surface coating	VOC content limits & improved	0	0	0	0	0	0	0
	Miscellaneous surface coating	Add-on control levels	0	0	0	0	0	0	0
	Miscellaneous surface coating	MACT level of control	0	0	0	0	0	0	0
	Nonroad gasoline	Reformulated gasoline	0	0	0	0	0	0	0
	Open Burning	Episodic Ban	0	0	0	0	0	0	0
	Pesticide Application	Reformulationon - FIP rule	0	0	0	0	0	0	0
	Point Sources	RE Improvements	0	0	0	0	0	0	0
	Recreational vehicles	CARB standards	0	0	0	0	0	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	0	0	0	0	0	0	0
	Wood furniture surface coating	Reformulationon	0	0	0	0	0	0	0
	Wood product surface coating	Reformulationon	0.7	0	16	0	0.7	16	23
		Total	0.7	0	16	0	0.7	16	23
Baltimore-D.C.	Adhesives - industrial	RACT	2.9	0	7,333	0	2.9	7,333	2,529
	Web Offset Lithography	New CTG (carbon adsorber)	0.4	0	-45	0	0.4	-45	-113
	Cutback Asphalt	Switch to emulsified asphalts	11.6	0	0	0	11.6	0	0
	Open Burning	Episodic Ban	829.7	158.1	0	0	987.8	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	824.2	0	0	0	824.2	0	0
	Point Source Wood Product Coating	FIP VOC Limits	7.3	0	183	0	7.3	183	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	2,761.00	0	80,261	0	2761	80,261	29
	Wood product surface coating	Reformulationon	18.6	0	602	0	18.6	602	32
	Metal product surface coating	VOC content limits & improved	600.4	0	26,412	0	600.4	26,412	44
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	4,219.60	4,304.60	1,004,762	2,009,525	8524.2	3,014,287	354
	Wood furniture surface coating	Reformulationon	1,033.90	0	395,887	0	1033.9	395,887	383
	Recreational vehicles	CARB standards	785.1	0	416,107	0	785.1	416,107	530
	Point Sources	RE Improvements	5,980.00	0	11,960,320	0	5980	11,960,320	2,000
	Miscellaneous surface coating	MACT level of control	131.2	0	327,585	0	131.2	327,585	2,497
	Aerosols	CARB Tier 2 Standards - Reform	838.8	0	2,096,568	0	838.8	2,096,568	2,499
	Automobile refinishing	CARB BARCT limits	441.1	0	1,622,379	0	441.1	1,622,379	3,678
	Nonroad gasoline	Reformulated gasoline	541.9	0	2,709,500	0	541.9	2,709,500	5,000
	Motor Vehicles	Federal Reform	449.5	131	3,989,469	0	580.5	3,989,469	6,872
	Pesticide Application	Reformulationon - FIP rule	272.8	0	2,535,796	0	272.8	2,535,796	9,295
	Aerosols	SCAQMD Standards - Reformulation	838.9	0	8,386,272	0	838.9	8,386,272	9,997
	marine surface coating	Add-on control levels	116.2	0	1,679,127	0	116.2	1,679,127	14,450
	Automobile refinishing	FIP Rule (VOC Content & TE)	1,683.90	0	30,350,042	0	1683.9	30,350,042	18,024
	Point Source Ind. Surface Coating	Add-on Control Levels	147.5	0	2,713,264	0	147.5	2,713,264	18,395
	Miscellaneous surface coating	Add-on control levels	260.3	0	5,369,000	0	260.3	5,369,000	20,626
	Aircraft surface coating	Add-on control levels	20.3	0	727,841	0	20.3	727,841	35,854
	Paper surface coating	Add-on control levels	40	0	2,915,609	0	40	2,915,609	72,890
		Total	22,857.10	4,593.70	79,314,274	2,009,525	27450.8	81,323,799	2,963
Baton Rouge, LA	Open burning	Seasonal/episodic ban	42.5	8.1	0	0	50.6	0	0
	Wood furniture surface coating	Reformulationon	0	0	0	0	0	0	0
	Wood product surface coating	Reformulationon	0	0	0	0	0	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	11.4	0	286	0	11.4	286	25
	Metal product surface coating	VOC content limits & improved	45.7	0	1,419	0	45.7	1,419	31
	Recreational vehicles	CARB standards	23.1	0	12,266	0	23.1	12,266	531
	Point Sources	RE Improvements	902.3	0	1,804,560	0	902.3	1,804,560	2,000
	Miscellaneous surface coating	MACT level of control	1.8	0	4,378	0	1.8	4,378	2,432
	Aerosols	CARB Tier 2 Standards - Reform	5.3	0	13,278	0	5.3	13,278	2,505
	Automobile refinishing	CARB BARCT limits	0.3	0	1,078	0	0.3	1,078	3,593
	Nonroad gasoline	Reformulated gasoline	5	0	25,000	0	5	25,000	5,000
	Motor Vehicles	Federal Reform	1,260.20	385.9	10,568,265	0	1646.1	10,568,265	6,420
	Pesticide Application	Reformulationon - FIP rule	36.9	0	343,654	0	36.9	343,654	9,313
	Aerosols	SCAQMD Standards - Reformulation	91.6	0	916,440	0	91.6	916,440	10,005
	marine surface coating	Add-on control levels	20.4	0	295,101	0	20.4	295,101	14,466
	Automobile refinishing	FIP Rule (VOC Content & TE)	84.7	0	1,526,835	0	84.7	1,526,835	18,026
	Miscellaneous surface coating	Add-on control levels	2.3	0	160,685	0	2.3	160,685	69,863
	Paper surface coating	Add-on control levels	4.5	0	467,671	0	4.5	467,671	103,927
		Total	2,538.00	394	16,140,916	0	2932	16,140,916	5,505
Beaumont, TX	Web Offset Lithography	New CTG (carbon adsorber)	2.6	0	-326	0	2.6	-326	-125
	Open Burning	Episodic Ban	313.4	59.3	0	0	372.7	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	22.6	0	0	0	22.6	0	0
	Cutback Asphalt	Switch to emulsified asphalts	27.3	0	0	0	27.3	0	0
	Open Burning	Episodic Ban	2,378.80	451.4	0	0	2830.2	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	6,953.00	0	0	0	6953	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	220	0	5,502	0	220	5,502	25
	Point Source Wood Product Coating	FIP VOC Limits	78.8	0	1,971	0	78.8	1,971	25
	Wood product surface coating	Reformulationon	25.3	0	650	0	25.3	650	26
	Wood product surface coating	Reformulationon	0.8	0	27	0	0.8	27	34

	Metal product surface coating	VOC content limits & improved	3,362.50	0	119,678	0	3362.5	119,678	36
	Metal product surface coating	VOC content limits & improved	43.3	0	1,746	0	43.3	1,746	40
	Service stations - stage I-truck un	Vapor balance & P-V valves	3,158.00	0	139,715	0	3158	139,715	44
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	357.5	304.4	75,325	150,650	661.9	225,975	341
	Recreational vehicles	CARB standards	69.9	0	36,998	0	69.9	36,998	529
	Recreational vehicles	CARB standards	1,358.20	0	719,732	0	1358.2	719,732	530
	Wood furniture surface coating	Reformulationon	1,097.10	0	1,485,499	0	1097.1	1,485,499	1,354
	Wood furniture surface coating	Reformulationon	6.7	0	9,574	0	6.7	9,574	1,429
	Bulk Terminals	RACT	89	0	148,271	0	89	148,271	1,666
		Total	97,369.90	59.3	193,440,337	0	97429.2	193,440,337	1,985
Chicago, IL	Point Sources	RE Improvements	9,246.90	0	18,493,820	0	9246.9	18,493,820	2,000
	Point Sources	RE Improvements	96,693.20	0	193,386,490	2,009,525	96693.2	195,396,015	2,021
	Aerosols	CARB Tier 2 Standards - Reform	1,188.10	0	2,969,826	0	1188.1	2,969,826	2,500
	Miscellaneous surface coating	MACT level of control	1,271.30	0	3,177,986	0	1271.3	3,177,986	2,500
	Adhesives - industrial	RACT	17.5	0	43,823	0	17.5	43,823	2,504
	Automobile refinishing	CARB BARCT limits	662.6	0	2,436,920	0	662.6	2,436,920	3,678
	Motor Vehicles	California Reform	3,819.60	21,388.40	0	110,921,385	25208	110,921,385	4,400
	Nonroad gasoline	Reformulated gasoline	567.8	0	2,839,000	0	567.8	2,839,000	5,000
	Motor Vehicles	Federal Reform	70.8	24.8	679,832	0	95.6	679,832	7,111
	Pesticide Application	Reformulationon - FIP rule	314.4	0	2,923,605	0	314.4	2,923,605	9,299
	Aerosols	SCAQMD Standards - Reformulation	1,188.10	0	11,879,304	0	1188.1	11,879,304	9,999
	marine surface coating	Add-on control levels	99.5	0	1,440,735	0	99.5	1,440,735	14,480
	Automobile refinishing	FIP Rule (VOC Content & TE)	2,529.60	0	45,587,801	0	2529.6	45,587,801	18,022
	Point Source Ind. Surface Coating	Add-on Control Levels	3,315.70	0	61,008,144	0	3315.7	61,008,144	18,400
	Miscellaneous surface coating	Add-on control levels	1,416.80	0	36,920,959	0	1416.8	36,920,959	26,059
	Aircraft surface coating	Add-on control levels	8.5	0	288,264	0	8.5	288,264	33,913
	Paper surface coating	Add-on control levels	25.4	0	2,636,415	0	25.4	2,636,415	103,796
		Total	44,630.70	22,169.00	196,016,949	111072035	66799.7	307,088,984	4,597
Cincinnati, OH	Web Offset Lithography	New CTG (carbon adsorber)	8	0	-989	0	8	-989	-124
	Cutback Asphalt	Switch to emulsified asphalts	70	0	0	0	70	0	0
	Open Burning	Episodic Ban	1,973.10	375.1	0	0	2348.2	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	455.9	0	0	0	455.9	0	0
	Wood product surface coating	Reformulationon	8.7	0	228	0	8.7	228	26
	Metal product surface coating	VOC content limits & improved	233.8	0	6,817	0	233.8	6,817	29
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	18,368.90	13,119.30	675,395	1,350,789	31488.2	2,026,184	64
	Service stations - stage I-truck un	Vapor balance & P-V valves	852.4	0	119,526	0	852.4	119,526	140
	Wood furniture surface coating	Reformulationon	746.9	0	315,871	0	746.9	315,871	423
	Recreational vehicles	CARB standards	202.5	0	107,319	0	202.5	107,319	530
	Bulk Terminals	RACT	134.5	0	224,072	0	134.5	224,072	1,666
	Point Sources	RE Improvements	857.1	0	1,714,040	0	857.1	1,714,040	2,000
	Miscellaneous surface coating	MACT level of control	42.5	0	106,099	0	42.5	106,099	2,496
	Adhesives - industrial	RACT	79.4	0	198,526	0	79.4	198,526	2,500
	Aerosols	CARB Tier 2 Standards - Reform	270.2	0	675,798	0	270.2	675,798	2,501
	Automobile refinishing	CARB BARCT limits	100.6	0	370,237	0	100.6	370,237	3,680
	Motor Vehicles	California Reform	955.8	6,134.80	0	30,656,109	7090.6	30,656,109	4,323
	Nonroad gasoline	Reformulated gasoline	138.6	0	693,000	0	138.6	693,000	5,000
	Motor Vehicles	Federal Reform	3,876.30	938.1	26,812,203	0	4814.4	26,812,203	5,569
	Pesticide Application	Reformulationon - FIP rule	95.9	0	890,829	0	95.9	890,829	9,289
	Aerosols	SCAQMD Standards - Reformulation	270.2	0	2,703,192	0	270.2	2,703,192	10,004
	marine surface coating	Add-on control levels	9.9	0	143,004	0	9.9	143,004	14,445
	Automobile refinishing	FIP Rule (VOC Content & TE)	384.2	0	6,926,038	0	384.2	6,926,038	18,027
	Point Source Ind. Surface Coating	Add-on Control Levels	155.1	0	2,854,300	0	155.1	2,854,300	18,403
	Aircraft surface coating	Add-on control levels	51.8	0	1,873,198	0	51.8	1,873,198	36,162
	Miscellaneous surface coating	Add-on control levels	323.3	0	11,922,127	0	323.3	11,922,127	36,876
	Paper surface coating	Add-on control levels	43	0	3,019,753	0	43	3,019,753	70,227
		Total	30,708.60	20,567.30	62,350,583	32,006,898	51275.9	94,357,481	1,840
Dallas, TX	Petroleum refinery fugitives	RACT	167.1	0	-75,186	0	167.1	-75,186	-450
	Web Offset Lithography	New CTG (carbon adsorber)	30.3	0	-3,789	0	30.3	-3,789	-125
	Cutback Asphalt	Switch to emulsified asphalts	348.1	0	0	0	348.1	0	0
	Open Burning	Episodic Ban	2,152.80	408.2	0	0	2561	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	204	0	0	0	204	0	0
	Point Source Open Burning	Episodic Ban	9.1	0	0	0	9.1	0	0
	Point Source Wood Product Coating	FIP VOC Limits	208	0	5,202	0	208	5,202	25
	Metal product surface coating	VOC content limits & improved	1,160.40	0	41,375	0	1160.4	41,375	36
	Wood product surface coating	Reformulationon	15	0	857	0	15	857	57
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	32,776.90	29,743.00	2,029,995	4,059,989	62519.9	6,089,984	97
	SOCMI fugitives	RACT	1	0	141	0	1	141	141
	Service stations - stage I-truck un	Vapor balance & P-V valves	2,505.10	0	592,835	0	2505.1	592,835	237
	Pharmaceutical manufacture	RACT	1.3	0	417	0	1.3	417	321
	Oil and natural gas production fiel	RACT (equipment/maintenance)	34.9	0	13,809	0	34.9	13,809	396
	Recreational vehicles	CARB standards	761.1	0	403,346	0	761.1	403,346	530
	Wood furniture surface coating	Reformulationon	695	0	586,526	0	695	586,526	844
	Bulk Terminals	RACT	443.3	0	738,704	0	443.3	738,704	1,666
	Point Sources	RE Improvements	14,125.20	0	28,250,270	0	14125.2	28,250,270	2,000
	Adhesives - industrial	RACT	206.5	0	516,108	0	206.5	516,108	2,499

	Miscellaneous surface coating	MACT level of control	836.2	0	2,090,260	0	836.2	2,090,260	2,500
	Aerosols	CARB Tier 2 Standards - Reform	569.3	0	1,423,242	0	569.3	1,423,242	2,500
	Automobile refinishing	CARB BARCT limits	275.8	0	1,014,479	0	275.8	1,014,479	3,678
	SOCMI batch reactor processes	New CTG	1.7	0	7,007	0	1.7	7,007	4,122
	Motor Vehicles	Federal Reform	1,320.50	283.2	7,756,926	0	1603.7	7,756,926	4,837
	Nonroad gasoline	Reformulated gasoline	478.5	0	2,392,500	0	478.5	2,392,500	5,000
	Pesticide Application	Reformulationon - FIP rule	153.4	0	1,426,100	0	153.4	1,426,100	9,297
	Aerosols	SCAQMD Standards - Reformulation	569.2	0	5,692,968	0	569.2	5,692,968	10,002
	marine surface coating	Add-on control levels	15.1	0	218,518	0	15.1	218,518	14,471
	Automobile refinishing	FIP Rule (VOC Content & TE)	1,053.20	0	18,977,998	0	1053.2	18,977,998	18,019
	Point Source Ind. Surface Coating	Add-on Control Levels	4,042.70	0	74,386,416	0	4042.7	74,386,416	18,400
	Miscellaneous surface coating	Add-on control levels	738	0	17,418,524	0	738	17,418,524	23,602
	Aircraft surface coating	Add-on control levels	10.9	0	344,747	0	10.9	344,747	31,628
	Paper surface coating	Add-on control levels	69.3	0	6,065,109	0	69.3	6,065,109	87,520
		Total	65,978.90	30,434.40	172,315,404	4,059,989	96413.3	176,375,393	1,829
Eugene, OR	Web Offset Lithography	New CTG (carbon adsorber)	67.6	0	-8,447	0	67.6	-8,447	-125
	Cutback Asphalt	Switch to emulsified asphalts	351.5	0	0	0	351.5	0	0
	Open Burning	Episodic Ban	473.9	89.9	0	0	563.8	0	0
	Metal product surface coating	VOC content limits & improved	92.8	0	2,314	0	92.8	2,314	25
	Wood product surface coating	Reformulationon	58.6	0	1,464	0	58.6	1,464	25
	Wood furniture surface coating	Reformulationon	114.8	0	43,029	0	114.8	43,029	375
	Oil and natural gas production fiel	RACT (equipment/maintenance)	1.2	0	470	0	1.2	470	392
	Service stations - stage I-truck un	Vapor balance & P-V valves	358.9	0	186,182	0	358.9	186,182	519
	Recreational vehicles	CARB standards	75.8	0	40,095	0	75.8	40,095	529
	Motor Vehicles	Enhanced I/M	2,659.90	2,365.10	951,535	1,903,069	5025	2,854,604	568
	Bulk Terminals	RACT	173.6	0	289,200	0	173.6	289,200	1,666
	Miscellaneous surface coating	MACT level of control	49.2	0	122,853	0	49.2	122,853	2,497
	Adhesives - industrial	RACT	398.9	0	997,164	0	398.9	997,164	2,500
	Aerosols	CARB Tier 2 Standards - Reform	67.3	0	168,276	0	67.3	168,276	2,500
	Automobile refinishing	CARB BARCT limits	27.4	0	100,653	0	27.4	100,653	3,673
	Nonroad gasoline	Reformulated gasoline	34.8	0	174,000	0	34.8	174,000	5,000
		Total	5,006.20	2,455.00	3,068,788	1,903,069	7461.2	4,971,857	666
Fairfield, CT	Service stations - stage I-truck un	Vapor balance & P-V valves	349.8	0	8,745	0	349.8	8,745	25
	Wood product surface coating	Reformulationon	3.1	0	80	0	3.1	80	26
	Metal product surface coating	VOC content limits & improved	82.5	0	11,089	0	82.5	11,089	134
	Recreational vehicles	CARB standards	218	0	115,514	0	218	115,514	530
	Wood furniture surface coating	Reformulationon	23.6	0	37,782	0	23.6	37,782	1,601
	Aerosols	CARB Tier 2 Standards - Reform	104.9	0	262,200	0	104.9	262,200	2,500
	Motor Vehicles	California Reform	414.2	2,580.70	0	14,343,658	2994.9	14,343,658	4,789
	Nonroad gasoline	Reformulated gasoline	71.6	0	358,000	0	71.6	358,000	5,000
	Pesticide Application	Reformulationon - FIP rule	1	0	8,816	0	1	8,816	8,816
	Aerosols	SCAQMD Standards - Reformulation	104.9	0	1,048,800	0	104.9	1,048,800	9,998
	Point Source Ind. Surface Coating	Add-on Control Levels	39.4	0	725,328	0	39.4	725,328	18,409
	Automobile refinishing	FIP Rule (VOC Content & TE)	173.8	0	5,062,064	0	173.8	5,062,064	29,126
	Miscellaneous surface coating	Add-on control levels	45	0	2,937,767	0	45	2,937,767	65,284
	Paper surface coating	Add-on control levels	3.1	0	313,572	0	3.1	313,572	101,152
		Total	1,634.90	2,580.70	10,889,757	14,343,658	4215.6	25,233,415	5,986
Fresno, CA	Web Offset Lithography	New CTG (carbon adsorber)	4.1	0	-508	0	4.1	-508	-124
	Cutback Asphalt	Switch to emulsified asphalts	57	0	0	0	57	0	0
	Open Burning	Episodic Ban	276.4	52.4	0	0	328.8	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	52.6	0	0	0	52.6	0	0
	Wood product surface coating	Reformulationon	6.2	0	154	0	6.2	154	25
	Metal product surface coating	VOC content limits & improved	77.5	0	1,931	0	77.5	1,931	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	454.2	0	103,431	0	454.2	103,431	228
	Wood furniture surface coating	Reformulationon	102.1	0	38,279	0	102.1	38,279	375
	Motor Vehicles	Enhanced I/M	750.9	1,264.00	298,651	597,301	2014.9	895,952	445
	Recreational vehicles	CARB standards	60.8	0	32,225	0	60.8	32,225	530
	Bulk Terminals	RACT	57.2	0	95,380	0	57.2	95,380	1,667
	Point Sources	RE Improvements	3,519.30	0	7,038,660	0	3519.3	7,038,660	2,000
	Miscellaneous surface coating	MACT level of control	27.8	0	69,321	0	27.8	69,321	2,494
	Adhesives - industrial	RACT	14.2	0	35,444	0	14.2	35,444	2,496
	Aerosols	CARB Tier 2 Standards - Reform	119.6	0	298,638	0	119.6	298,638	2,497
	Automobile refinishing	CARB BARCT limits	58.9	0	217,170	0	58.9	217,170	3,687
	Nonroad gasoline	Reformulated gasoline	63	0	315,000	0	63	315,000	5,000
	Pesticide Application	Reformulationon - FIP rule	742.3	0	6,903,465	0	742.3	6,903,465	9,300
	Aerosols	SCAQMD Standards - Reformulation	119.6	0	1,194,552	0	119.6	1,194,552	9,988
	marine surface coating	Add-on control levels	11.1	0	160,048	0	11.1	160,048	14,419
	Miscellaneous surface coating	Add-on control levels	93.6	0	1,460,681	0	93.6	1,460,681	15,606
	Automobile refinishing	FIP Rule (VOC Content & TE)	225.5	0	4,062,635	0	225.5	4,062,635	18,016
	Paper surface coating	Add-on control levels	4.5	0	298,193	0	4.5	298,193	66,265
		Total	6,898.40	1,316.40	22,623,350	597,301	8214.8	23,220,651	2,827
Grand Rapids, MI	Web Offset Lithography	New CTG (carbon adsorber)	8.5	0	-1,067	0	8.5	-1,067	-126

	Cutback Asphalt	Switch to emulsified asphalts	85.3	0	0	0	85.3	0	0
	Open Burning	Episodic Ban	648.1	122.9	0	0	771	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	292.2	0	7,305	0	292.2	7,305	25
	Metal product surface coating	VOC content limits & improved	199.1	0	4,981	0	199.1	4,981	25
	Wood product surface coating	Reformulationon	6.5	0	298	0	6.5	298	46
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	8,035.80	5,841.00	409,302	818,603	13876.8	1,227,905	88
	Pharmaceutical manufacture	RACT	138.2	0	46,285	0	138.2	46,285	335
	Wood furniture surface coating	Reformulationon	4,967.90	0	1,862,987	0	4967.9	1,862,987	375
	Oil and natural gas production fiel	RACT (equipment/maintenance)	37.2	0	14,770	0	37.2	14,770	397
	Recreational vehicles	CARB standards	548.1	0	290,468	0	548.1	290,468	530
	Point Sources	RE Improvements	6,025.10	0	12,050,110	0	6025.1	12,050,110	2,000
	Aerosols	CARB Tier 2 Standards - Reform	102.6	0	256,368	0	102.6	256,368	2,499
	Adhesives - industrial	RACT	130.6	0	326,390	0	130.6	326,390	2,499
	Automobile refinishing	CARB BARCT limits	62.2	0	228,904	0	62.2	228,904	3,680
	Motor Vehicles	California Reform	364.6	2,984.10	0	13,408,026	3348.7	13,408,026	4,004
	Nonroad gasoline	Reformulated gasoline	101.6	0	508,000	0	101.6	508,000	5,000
	Motor Vehicles	Federal Reform	1,844.40	488.6	13,996,171	0	2333	13,996,171	5,999
	Pesticide Application	Reformulationon - FIP rule	72.5	0	673,506	0	72.5	673,506	9,290
	Aerosols	SCAQMD Standards - Reformulation	102.6	0	1,025,472	0	102.6	1,025,472	9,995
	marine surface coating	Add-on control levels	68.1	0	985,510	0	68.1	985,510	14,472
	Automobile refinishing	FIP Rule (VOC Content & TE)	237.6	0	4,282,146	0	237.6	4,282,146	18,023
	Miscellaneous surface coating	Add-on control levels	1,366.50	0	31,117,326	0	1366.5	31,117,326	22,772
	Aircraft surface coating	Add-on control levels	3.7	0	132,865	0	3.7	132,865	35,909
	Paper surface coating	Add-on control levels	22.2	0	1,402,309	0	22.2	1,402,309	63,167
		Total	25,471.20	9,436.60	69,620,406	14,226,629	34907.8	83,847,035	2,402
Hartford, CT	Open Burning	Episodic Ban	890.4	168.9	0	0	1059.3	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	102.9	0	0	0	102.9	0	0
	Wood product surface coating	Reformulationon	5.5	0	136	0	5.5	136	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	508.9	0	12,723	0	508.9	12,723	25
	Metal product surface coating	VOC content limits & improved	103.8	0	13,957	0	103.8	13,957	134
	Recreational vehicles	CARB standards	342	0	181,179	0	342	181,179	530
	Wood furniture surface coating	Reformulationon	92	0	146,938	0	92	146,938	1,597
	Aerosols	CARB Tier 2 Standards - Reform	159	0	397,518	0	159	397,518	2,500
	Motor Vehicles	California Reform	708	4,400.20	0	22,365,569	5108.2	22,365,569	4,378
	Nonroad gasoline	Reformulated gasoline	112.5	0	562,500	0	112.5	562,500	5,000
	Pesticide Application	Reformulationon - FIP rule	15.3	0	141,676	0	15.3	141,676	9,260
	Aerosols	SCAQMD Standards - Reformulation	159.1	0	1,590,072	0	159.1	1,590,072	9,994
	Point Source Ind. Surface Coating	Add-on Control Levels	5.8	0	107,456	0	5.8	107,456	18,527
	Automobile refinishing	FIP Rule (VOC Content & TE)	298.6	0	8,697,450	0	298.6	8,697,450	29,127
	Aircraft surface coating	Add-on control levels	116.4	0	6,094,635	0	116.4	6,094,635	52,359
	Miscellaneous surface coating	Add-on control levels	88.4	0	6,479,450	0	88.4	6,479,450	73,297
	Paper surface coating	Add-on control levels	22.7	0	2,278,121	0	22.7	2,278,121	100,358
		Total	3,731.30	4,569.10	26,703,811	22,365,569	8300.4	49,069,380	5,912
Houston, TX	Web Offset Lithography	New CTG (carbon adsorber)	10.5	0	-1,319	0	10.5	-1,319	-126
	Cutback Asphalt	Switch to emulsified asphalts	112.6	0	0	0	112.6	0	0
	Open burning	Seasonal/episodic ban	73.7	13.8	0	0	87.5	0	0
	marine surface coating	Add-on control levels	0	0	0	0	0	0	0
	Paper surface coating	Add-on control levels	0	0	0	0	0	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	0	0	0	0	0	0	0
	Point Sources	RE Improvements	0	0	0	0	0	0	0
	Point Source Wood Product Coating	FIP VOC Limits	62.8	0	1,570	0	62.8	1,570	25
	Metal product surface coating	VOC content limits & improved	5.1	0	129	0	5.1	129	25
	Wood product surface coating	Reformulationon	1.5	0	38	0	1.5	38	25
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	1,635.50	1,168.20	291,551	583,101	2803.7	874,652	312
	Wood furniture surface coating	Reformulationon	12.1	0	4,536	0	12.1	4,536	375
	Oil and natural gas production fiel	RACT (equipment/maintenance)	11.8	0	4,674	0	11.8	4,674	396
	Recreational vehicles	CARB standards	21.5	0	11,363	0	21.5	11,363	529
	Service stations - stage I-truck un	Vapor balance & P-V valves	260.9	0	195,467	0	260.9	195,467	749
	Bulk Terminals	RACT	203.7	0	339,507	0	203.7	339,507	1,667
	Miscellaneous surface coating	MACT level of control	2.2	0	5,479	0	2.2	5,479	2,490
	Aerosols	CARB Tier 2 Standards - Reform	17.9	0	44,754	0	17.9	44,754	2,500
	Adhesives - industrial	RACT	27.2	0	68,115	0	27.2	68,115	2,504
	Automobile refinishing	CARB BARCT limits	2.7	0	10,196	0	2.7	10,196	3,776
	Motor Vehicles	Federal Reform	456.6	99	2,622,337	0	555.6	2,622,337	4,720
	Nonroad gasoline	Reformulated gasoline	13.7	0	68,500	0	13.7	68,500	5,000
	Pesticide Application	Reformulationon - FIP rule	105.6	0	981,616	0	105.6	981,616	9,296
	Aerosols	SCAQMD Standards - Reformulation	17.8	0	179,016	0	17.8	179,016	10,057
	Automobile refinishing	FIP Rule (VOC Content & TE)	10.6	0	190,748	0	10.6	190,748	17,995
	Miscellaneous surface coating	Add-on control levels	2.6	0	46,902	0	2.6	46,902	18,039
	Point Source Ind. Surface Coating	Add-on Control Levels	85	0	1,564,828	0	85	1,564,828	18,410
		Total	3,153.60	1,281.00	6,630,007	583,101	4434.6	7,213,108	1,627
Huntington, WV	Web Offset Lithography	New CTG (carbon adsorber)	8.7	0	-1,087	0	8.7	-1,087	-125
	Cutback Asphalt	Switch to emulsified asphalts	77.5	0	0	0	77.5	0	0

	Open Burning	Episodic Ban	443	83.6	0	0	526.6	0	0
	Metal product surface coating	VOC content limits & improved	43.3	0	1,721	0	43.3	1,721	40
	SOCMI fugitives	RACT	61.3	0	8,345	0	61.3	8,345	136
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	3,256.80	2,435.50	263,196	526,392	5692.3	789,588	139
	Oil and natural gas production fiel	RACT (equipment/maintenance)	0.5	0	188	0	0.5	188	376
	Service stations - stage I-truck un	Vapor balance & P-V valves	241.6	0	93,577	0	241.6	93,577	387
	Wood furniture surface coating	Reformulationon	26.8	0	10,523	0	26.8	10,523	393
	Recreational vehicles	CARB standards	34	0	18,019	0	34	18,019	530
	Bulk Terminals	RACT	36.6	0	60,913	0	36.6	60,913	1,664
	Point Sources	RE Improvements	6,281.00	0	12,561,840	0	6281	12,561,840	2,000
	Aerosols	CARB Tier 2 Standards - Reform	51.1	0	127,602	0	51.1	127,602	2,497
	Miscellaneous surface coating	MACT level of control	13.7	0	34,223	0	13.7	34,223	2,498
	Adhesives - industrial	RACT	23.8	0	59,522	0	23.8	59,522	2,501
	Automobile refinishing	CARB BARCT limits	12.6	0	46,575	0	12.6	46,575	3,696
	Motor Vehicles	California Reform	145.1	1,267.40	0	5,466,889	1412.5	5,466,889	3,870
	SOCMI batch reactor processes	New CTG	105.1	0	426,152	0	105.1	426,152	4,055
	Nonroad gasoline	Reformulated gasoline	23.7	0	118,500	0	23.7	118,500	5,000
	Motor Vehicles	Federal Reform	729.3	205.3	5,708,990	0	934.6	5,708,990	6,108
	Pesticide Application	Reformulationon - FIP rule	4.3	0	39,618	0	4.3	39,618	9,213
	Aerosols	SCAQMD Standards - Reformulation	51.1	0	510,408	0	51.1	510,408	9,988
	marine surface coating	Add-on control levels	5.7	0	82,393	0	5.7	82,393	14,455
	Miscellaneous surface coating	Add-on control levels	10	0	164,121	0	10	164,121	16,412
	Automobile refinishing	FIP Rule (VOC Content & TE)	48.4	0	871,265	0	48.4	871,265	18,001
	Point Source Ind. Surface Coating	Add-on Control Levels	12.4	0	228,344	0	12.4	228,344	18,415
	Paper surface coating	Add-on control levels	0.5	0	38,060	0	0.5	38,060	76,120
		Total	11,747.90	3,991.80	21,473,008	5,993,281	15739.7	27,466,289	1,745
Knoxville, TN	Web Offset Lithography	New CTG (carbon adsorber)	79.9	0	-9,997	0	79.9	-9,997	-125
	Cutback Asphalt	Switch to emulsified asphalts	280.6	0	0	0	280.6	0	0
	Open Burning	Episodic Ban	938.2	177.9	0	0	1116.1	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	358.2	0	8,956	0	358.2	8,956	25
	Metal product surface coating	VOC content limits & improved	167.1	0	8,216	0	167.1	8,216	49
	Wood product surface coating	Reformulationon	2.1	0	135	0	2.1	135	64
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	8,942.20	6,407.40	1,648,631	3,297,263	15349.6	4,945,894	322
	Wood furniture surface coating	Reformulationon	284.6	0	106,743	0	284.6	106,743	375
	Recreational vehicles	CARB standards	42.8	0	22,703	0	42.8	22,703	530
	Process Heaters - Natural Gas	ULNB	0	62.7	0	40,020	62.7	40,020	638
	Industrial Boiler - Residual Oil	LNB	0	16.2	0	12,168	16.2	12,168	751
	Cement Manufacturing - Dry	LNB	0	262.9	0	210,670	262.9	210,670	801
	Industrial Boiler - Natural Gas	LNB	0	31.2	0	28,823	31.2	28,823	924
	Cement Manufacturing - Dry	SNCR - Urea based	0	262.9	0	323,865	262.9	323,865	1,232
	Industrial Boiler - Distillate Oil	LNB	0	2.2	0	3,080	2.2	3,080	1,400
	Industrial Boiler - PC	LNB	0	884.5	0	1,421,744	884.5	1,421,744	1,607
	Industrial Boiler - Stoker	SNCR	0	113.6	0	244,779	113.6	244,779	2,155
	Area Source Industrial Oil Comb	RACT to small sources	0	0.8	0	1,758	0.8	1,758	2,198
	Miscellaneous surface coating	MACT level of control	32.9	0	82,138	0	32.9	82,138	2,497
	Adhesives - industrial	RACT	329.4	0	823,688	0	329.4	823,688	2,501
	Aerosols	CARB Tier 2 Standards - Reform	108.5	0	271,524	0	108.5	271,524	2,503
	Automobile refinishing	CARB BARCT limits	33.1	0	121,990	0	33.1	121,990	3,685
	Area Source Industrial Coal Comb	RACT to small sources	0	22.7	0	88,259	22.7	88,259	3,888
	Motor Vehicles	California Reform	-113.2	3,111.80	0	14,082,175	2998.6	14,082,175	4,696
	Nonroad gasoline	Reformulated gasoline	58.7	0	293,500	0	58.7	293,500	5,000
	Industrial Boiler - Residual Oil	LNB + FGR	0	6.2	0	34,572	6.2	34,572	5,576
	Motor Vehicles	Federal Reform	1,943.40	541.8	14,703,239	0	2485.2	14,703,239	5,916
	Industrial Boiler - Natural Gas	LNB + FGR	0	6.2	0	38,107	6.2	38,107	6,146
	Industrial Boiler - Residual Oil	SCR	0	12.6	0	89,980	12.6	89,980	7,141
	Nonroad Diesels	CARB Stds for > 175 HP	0	67.8	0	553,880	67.8	553,880	8,169
	Industrial Boiler - Distillate Oil	LNB + FGR	0	0.5	0	4,283	0.5	4,283	8,566
	Industrial Boiler - Natural Gas	SCR	0	12.6	0	112,742	12.6	112,742	8,948
	Pesticide Application	Reformulationon - FIP rule	9.3	0	86,601	0	9.3	86,601	9,312
	Industrial Boiler - Stoker	SCR	0	90.9	0	905,202	90.9	905,202	9,958
	Commercial Marine Vessels	Emission Fees	0	33.2	0	331,535	33.2	331,535	9,986
	Aerosols	SCAQMD Standards - Reformulation	108.5	0	1,086,096	0	108.5	1,086,096	10,010
	Industrial Boiler - Distillate Oil	SCR	0	0.9	0	9,136	0.9	9,136	10,151
	Cement Manufacturing - Dry	SCR	0	315.5	0	3,530,444	315.5	3,530,444	11,190
	Industrial Boiler - PC	SNCR	0	176.9	0	2,192,644	176.9	2,192,644	12,395
	marine surface coating	Add-on control levels	122.4	0	1,771,300	0	122.4	1,771,300	14,471
	Automobile refinishing	FIP Rule (VOC Content & TE)	126.6	0	2,282,141	0	126.6	2,282,141	18,026
	Point Source Ind. Surface Coating	Add-on Control Levels	864	0	15,896,772	0	864	15,896,772	18,399
	Paper surface coating	Add-on control levels	13.5	0	308,857	0	13.5	308,857	22,878
	Industrial Boiler - PC	SCR	0	265.4	0	6,811,724	265.4	6,811,724	25,666
	Process Heaters - Natural Gas	LNB + SCR	0	10.9	0	304,598	10.9	304,598	27,945
	Aircraft surface coating	Add-on control levels	4	0	125,719	0	4	125,719	31,430
	Miscellaneous surface coating	Add-on control levels	179.3	0	8,570,343	0	179.3	8,570,343	47,799
	Motor Vehicles	Reform Diesel	0	131	0	6,648,656	131	6,648,656	50,753
		Total	14,916.10	13,029.20	48,209,295	41,322,107	27945.3	89,531,402	3,204
Los Angeles, CA	Aerosols	CARB Tier 2 Standards - Reform	0	0	0	0	0	0	0
	Aerosols	SCAQMD Standards - Reformulation	0	0	0	0	0	0	0

	Aircraft surface coating	Add-on control levels	0	0	0	0	0	0	0
	Automobile refinishing	CARB BARCT limits	0	0	0	0	0	0	0
	Automobile refinishing	FIP Rule (VOC Content & TE)	0	0	0	0	0	0	0
	marine surface coating	Add-on control levels	0	0	0	0	0	0	0
	Metal product surface coating	VOC content limits & improved	0	0	0	0	0	0	0
	Miscellaneous surface coating	Add-on control levels	0	0	0	0	0	0	0
	Miscellaneous surface coating	MACT level of control	0	0	0	0	0	0	0
	Nonroad gasoline	Reformulated gasoline	0	0	0	0	0	0	0
	Open Burning	Episodic Ban	0	0	0	0	0	0	0
	Paper surface coating	Add-on control levels	0	0	0	0	0	0	0
	Pesticide Application	Reformulationon - FIP rule	0	0	0	0	0	0	0
	Point Source Ind. Surface Coating	Add-on Control Levels	0	0	0	0	0	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	0	0	0	0	0	0	0
	Point Source Wood Product Coating	FIP VOC Limits	0	0	0	0	0	0	0
	Point Sources	RE Improvements	0	0	0	0	0	0	0
	Recreational vehicles	CARB standards	0	0	0	0	0	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	0	0	0	0	0	0	0
	Wood furniture surface coating	Reformulationon	0	0	0	0	0	0	0
	Wood product surface coating	Reformulationon	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0
Manitowoc, WI	Web Offset Lithography	New CTG (carbon adsorber)	2.5	0	-312	0	2.5	-312	-125
	Open Burning	Episodic Ban	163.5	30.9	0	0	194.4	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	16.4	0	0	0	16.4	0	0
	Metal product surface coating	VOC content limits & improved	34.7	0	865	0	34.7	865	25
	Point Source Wood Product Coating	FIP VOC Limits	17.9	0	447	0	17.9	447	25
	Wood product surface coating	Reformulationon	2	0	50	0	2	50	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	48.6	0	1,220	0	48.6	1,220	25
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	1,274.40	1,030.20	91,780	183,560	2304.6	275,340	119
	Wood furniture surface coating	Reformulationon	116.4	0	43,659	0	116.4	43,659	375
	Recreational vehicles	CARB standards	40.7	0	21,584	0	40.7	21,584	530
	Aerosols	CARB Tier 2 Standards - Reform	19.9	0	49,596	0	19.9	49,596	2,492
	Miscellaneous surface coating	MACT level of control	56.8	0	142,041	0	56.8	142,041	2,501
	Motor Vehicles	California Reform	56.6	580.5	0	2,299,274	637.1	2,299,274	3,609
	Automobile refinishing	CARB BARCT limits	8.1	0	29,881	0	8.1	29,881	3,689
	Nonroad gasoline	Reformulated gasoline	15.4	0	77,000	0	15.4	77,000	5,000
	Motor Vehicles	Federal Reform	304.4	88.5	2,403,498	0	392.9	2,403,498	6,117
	Pesticide Application	Reformulationon - FIP rule	34.9	0	324,459	0	34.9	324,459	9,297
	Aerosols	SCAQMD Standards - Reformulation	19.9	0	198,384	0	19.9	198,384	9,969
	marine surface coating	Add-on control levels	96.5	0	1,395,871	0	96.5	1,395,871	14,465
	Miscellaneous surface coating	Add-on control levels	31.5	0	547,300	0	31.5	547,300	17,375
	Automobile refinishing	FIP Rule (VOC Content & TE)	31	0	558,983	0	31	558,983	18,032
	Point Source Ind. Surface Coating	Add-on Control Levels	104.4	0	1,920,776	0	104.4	1,920,776	18,398
	Paper surface coating	Add-on control levels	1.1	0	75,421	0	1.1	75,421	68,565
		Total	2,497.60	1,730.10	7,882,503	2,482,834	4227.7	10,365,337	2,452
Modesto, CA	Open Burning	Episodic Ban	97.6	18.5	0	0	116.1	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	61	0	0	0	61	0	0
	Metal product surface coating	VOC content limits & improved	352.8	0	8,725	0	352.8	8,725	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	131.9	0	3,297	0	131.9	3,297	25
	Wood product surface coating	Reformulationon	2.5	0	63	0	2.5	63	25
	Wood furniture surface coating	Reformulationon	78.4	0	29,408	0	78.4	29,408	375
	Recreational vehicles	CARB standards	24.4	0	12,907	0	24.4	12,907	529
	Aerosols	CARB Tier 2 Standards - Reform	46.7	0	116,760	0	46.7	116,760	2,500
	Miscellaneous surface coating	MACT level of control	17.1	0	42,760	0	17.1	42,760	2,501
	Automobile refinishing	CARB BARCT limits	30	0	110,381	0	30	110,381	3,679
	Nonroad gasoline	Reformulated gasoline	25.1	0	125,500	0	25.1	125,500	5,000
	Pesticide Application	Reformulationon - FIP rule	108.9	0	1,012,621	0	108.9	1,012,621	9,299
	Aerosols	SCAQMD Standards - Reformulation	46.7	0	467,040	0	46.7	467,040	10,001
	Miscellaneous surface coating	Add-on control levels	64.2	0	1,006,908	0	64.2	1,006,908	15,684
	Automobile refinishing	FIP Rule (VOC Content & TE)	114.6	0	2,064,926	0	114.6	2,064,926	18,019
	Point Source Ind. Surface Coating	Add-on Control Levels	74.1	0	1,363,348	0	74.1	1,363,348	18,399
	Paper surface coating	Add-on control levels	9.4	0	632,619	0	9.4	632,619	67,300
		Total	1,285.40	18.5	6,997,263	0	1303.9	6,997,263	5,366
Muskegon, MI	Open Burning	Episodic Ban	190.1	35.9	0	0	226	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	63.7	0	1,594	0	63.7	1,594	25
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	1,589.50	1,175.30	47,591	95,182	2764.8	142,773	52
	Wood furniture surface coating	Reformulationon	406.8	0	152,532	0	406.8	152,532	375
	Recreational vehicles	CARB standards	111.9	0	59,310	0	111.9	59,310	530
	Aerosols	CARB Tier 2 Standards - Reform	22.1	0	55,344	0	22.1	55,344	2,504
	Automobile refinishing	CARB BARCT limits	11.9	0	43,723	0	11.9	43,723	3,674
	Motor Vehicles	California Reform	60.2	608.9	0	2,717,140	669.1	2,717,140	4,061
	Nonroad gasoline	Reformulated gasoline	20.9	0	104,500	0	20.9	104,500	5,000
	Motor Vehicles	Federal Reform	350.5	99.1	2,836,015	0	449.6	2,836,015	6,308
	Pesticide Application	Reformulationon - FIP rule	8.6	0	79,850	0	8.6	79,850	9,285

	Aerosols	SCAQMD Standards - Reformulation	22.1	0	221,376	0	22.1	221,376	10,017
	Automobile refinishing	FIP Rule (VOC Content & TE)	45.4	0	817,916	0	45.4	817,916	18,016
	Miscellaneous surface coating	Add-on control levels	98.5	0	3,018,808	0	98.5	3,018,808	30,648
	Aircraft surface coating	Add-on control levels	1.9	0	67,602	0	1.9	67,602	35,580
	Paper surface coating	Add-on control levels	6.2	0	414,248	0	6.2	414,248	66,814
		Total	3,010.30	1,919.20	7,920,409	2,812,322	4929.5	10,732,731	2,177
Nashville, TN	Open Burning	Episodic Ban	746.4	141.4	0	0	887.8	0	0
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	11,604.10	8,719.20	567,807	1,135,614	20323.3	1,703,421	84
	Process Heaters - Natural Gas	ULNB	0	5.9	0	3,734	5.9	3,734	633
	Industrial Boiler - Natural Gas	LNB	0	6.8	0	6,100	6.8	6,100	897
	Area Source Industrial Oil Comb	RACT to small sources	0	0.5	0	1,073	0.5	1,073	2,146
	IC Engines - Natural Gas	NSCR	0	491.3	0	1,241,469	491.3	1,241,469	2,527
	Municipal Waste Combustors	SNCR	0	131.6	0	439,269	131.6	439,269	3,338
	Area Source Industrial Coal Comb	RACT to small sources	0	27.7	0	107,750	27.7	107,750	3,890
	Nonroad gasoline	Reformulated gasoline	91.6	0	458,000	0	91.6	458,000	5,000
	Motor Vehicles	California Reform	-162.8	4,007.30	0	20,150,267	3844.5	20,150,267	5,241
	Industrial Boiler - Residual Oil	LNB + FGR	0	1.7	0	9,893	1.7	9,893	5,819
	Motor Vehicles	Federal Reform	2,630.30	768.2	21,020,978	0	3398.5	21,020,978	6,185
	Industrial Boiler - Natural Gas	LNB + FGR	0	69	0	438,362	69	438,362	6,353
	Industrial Boiler - Residual Oil	SCR	0	3.5	0	25,747	3.5	25,747	7,356
	Nonroad Diesels	CARB Stds for > 175 HP	0	104.6	0	852,643	104.6	852,643	8,151
	Industrial Boiler - Natural Gas	SCR	0	138	0	1,297,032	138	1,297,032	9,399
	Commercial Marine Vessels	Emission Fees	0	27.6	0	274,516	27.6	274,516	9,946
	Industrial Boiler - Distillate Oil	LNB + FGR	0	6.3	0	64,698	6.3	64,698	10,270
	Industrial Boiler - Stoker	SCR	0	39.7	0	413,030	39.7	413,030	10,404
	Industrial Boiler - Distillate Oil	SCR	0	12.6	0	138,075	12.6	138,075	10,958
	Industrial Boiler - PC	SNCR	0	44.4	0	577,548	44.4	577,548	13,008
	Gas Turbines - Natural Gas	SCR + STEAM INJECTION	0	37.3	0	801,585	37.3	801,585	21,490
	Gas Turbines - Oil	SCR + WATER INJECTION	0	246.5	0	5,652,452	246.5	5,652,452	22,931
	Industrial Boiler - PC	SCR	0	66.6	0	1,794,222	66.6	1,794,222	26,940
	Process Heaters - Natural Gas	LNB + SCR	0	5.4	0	170,509	5.4	170,509	31,576
	Motor Vehicles	Reform Diesel	0	152.3	0	7,739,306	152.3	7,739,306	50,816
	Process Heaters - Distillate Oil	LNB + SCR	0	0	0	1,637	0	1,637	#DIV/0!
		Total	14,909.60	15,255.40	22,046,785	43,336,531	30165	65,383,316	2,168
New London, CT	Open Burning	Episodic Ban	849.4	161.1	0	0	1010.5	0	0
	Wood product surface coating	Reformulationon	5.3	0	130	0	5.3	130	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	460.7	0	11,517	0	460.7	11,517	25
	Metal product surface coating	VOC content limits & improved	283.2	0	16,501	0	283.2	16,501	58
	Recreational vehicles	CARB standards	604.1	0	320,133	0	604.1	320,133	530
	Wood furniture surface coating	Reformulationon	77.4	0	122,710	0	77.4	122,710	1,585
	Point Sources	RE Improvements	1,007.70	0	2,015,530	0	1007.7	2,015,530	2,000
	Miscellaneous surface coating	MACT level of control	19.7	0	49,140	0	19.7	49,140	2,494
	Aerosols	CARB Tier 2 Standards - Reform	158.8	0	396,912	0	158.8	396,912	2,499
	Automobile refinishing	CARB BARCT limits	6.5	0	24,006	0	6.5	24,006	3,693
	Motor Vehicles	California Reform	630.1	3,961.20	0	20,401,080	4591.3	20,401,080	4,443
	Nonroad gasoline	Reformulated gasoline	164.1	0	820,500	0	164.1	820,500	5,000
	Pesticide Application	Reformulationon - FIP rule	10.1	0	93,725	0	10.1	93,725	9,280
	Aerosols	SCAQMD Standards - Reformulation	158.8	0	1,587,648	0	158.8	1,587,648	9,998
	marine surface coating	Add-on control levels	2.9	0	41,886	0	2.9	41,886	14,443
	Point Source Ind. Surface Coating	Add-on Control Levels	97.8	0	1,799,888	0	97.8	1,799,888	18,404
	Automobile refinishing	FIP Rule (VOC Content & TE)	238.2	0	6,660,863	0	238.2	6,660,863	27,963
	Aircraft surface coating	Add-on control levels	13.4	0	704,628	0	13.4	704,628	52,584
	Miscellaneous surface coating	Add-on control levels	71.7	0	6,276,407	0	71.7	6,276,407	87,537
	Paper surface coating	Add-on control levels	24.2	0	2,346,314	0	24.2	2,346,314	96,955
		Total	4,884.10	4,122.30	23,288,438	20,401,080	9006.4	43,689,518	4,851
New Orleans, LA	Web Offset Lithography	New CTG (carbon adsorber)	115.6	0	-14,447	0	115.6	-14,447	-125
	Cutback Asphalt	Switch to emulsified asphalts	1,068.40	0	0	0	1068.4	0	0
	Open Burning	Episodic Ban	1,167.10	221.5	0	0	1388.6	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	20.4	0	0	0	20.4	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	598.5	0	14,963	0	598.5	14,963	25
	Metal product surface coating	VOC content limits & improved	277.9	0	9,701	0	277.9	9,701	35
	Wood product surface coating	Reformulationon	1.4	0	89	0	1.4	89	64
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	11,508.40	6,549.10	1,773,573	3,547,145	18057.5	5,320,718	295
	Pharmaceutical manufacture	RACT	5.7	0	1,878	0	5.7	1,878	329
	Oil and natural gas production fiel	RACT (equipment/maintenance)	268.9	0	106,656	0	268.9	106,656	397
		Total	15,032.30	6,770.60	1,892,413	3,547,145	21802.9	5,439,558	249
New York, NY	Aerosols	CARB Tier 2 Standards - Reform	0	0	0	0	0	0	0
	Aerosols	SCAQMD Standards-Reformulation	0	0	0	0	0	0	0
	Aircraft surface coating	Add-on control levels	0	0	0	0	0	0	0
	Automobile refinishing	CARB BARCT limits	0	0	0	0	0	0	0
	Automobile refinishing	FIP Rule (VOC Content & TE)	0	0	0	0	0	0	0
	marine surface coating	Add-on control levels	0	0	0	0	0	0	0

	Metal product surface coating	VOC content limits & improved	0	0	0	0	0	0	0
	Miscellaneous surface coating	Add-on control levels	0	0	0	0	0	0	0
	Miscellaneous surface coating	MACT level of control	0	0	0	0	0	0	0
	Motor Vehicles	California Reform	0	0	0	0	0	0	0
	Nonroad gasoline	Reformulated gasoline	0	0	0	0	0	0	0
	Open Burning	Episodic Ban	0	0	0	0	0	0	0
	Paper surface coating	Add-on control levels	0	0	0	0	0	0	0
	Pesticide Application	Reformulationon - FIP rule	0	0	0	0	0	0	0
	Point Source Ind. Surface Coating	Add-on Control Levels	0	0	0	0	0	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	0	0	0	0	0	0	0
	Point Source Wood Product Coating	FIP VOC Limits	0	0	0	0	0	0	0
	Point Sources	RE Improvements	0	0	0	0	0	0	0
	Recreational vehicles	CARB standards	0	0	0	0	0	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	0	0	0	0	0	0	0
	Wood furniture surface coating	Reformulationon	0	0	0	0	0	0	0
	Wood product surface coating	Reformulationon	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0
Philadelphia, PA	Open Burning	Episodic Ban	2,582.60	489.7	0	0	3072.3	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	366.2	0	0	0	366.2	0	0
	Point Source Wood Product Coating	FIP VOC Limits	97.1	0	2,427	0	97.1	2,427	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	2,028.70	0	50,721	0	2028.7	50,721	25
	Metal product surface coating	VOC content limits & improved	661.9	0	23,283	0	661.9	23,283	35
	Wood product surface coating	Reformulationon	13.2	0	477	0	13.2	477	36
	Recreational vehicles	CARB standards	799.6	0	423,651	0	799.6	423,651	530
	Wood furniture surface coating	Reformulationon	841.2	0	884,447	0	841.2	884,447	1,051
	Point Sources	RE Improvements	30,474.20	0	60,948,430	0	30474.2	60,948,430	2,000
	Miscellaneous surface coating	MACT level of control	49	0	122,400	0	49	122,400	2,498
	Aerosols	CARB Tier 2 Standards - Reform	849.5	0	2,124,030	0	849.5	2,124,030	2,500
	Automobile refinishing	CARB BARCT limits	550.3	0	2,023,964	0	550.3	2,023,964	3,678
	Motor Vehicles	California Reform	2,768.40	16,305.20	0	83,136,982	19073.6	83,136,982	4,359
	Nonroad gasoline	Reformulated gasoline	516.8	0	2,584,000	0	516.8	2,584,000	5,000
	Pesticide Application	Reformulationon - FIP rule	122.7	0	1,140,144	0	122.7	1,140,144	9,292
	Aerosols	SCAQMD Standards - Reformulation	849.6	0	8,496,120	0	849.6	8,496,120	10,000
	marine surface coating	Add-on control levels	138.1	0	2,413,661	0	138.1	2,413,661	17,478
	Automobile refinishing	FIP Rule (VOC Content & TE)	2,101.00	0	37,862,493	0	2101	37,862,493	18,021
	Point Source Ind. Surface Coating	Add-on Control Levels	5,061.80	0	93,137,488	0	5061.8	93,137,488	18,400
	Aircraft surface coating	Add-on control levels	28	0	1,012,040	0	28	1,012,040	36,144
	Miscellaneous surface coating	Add-on control levels	369.8	0	19,157,461	0	369.8	19,157,461	51,805
	Paper surface coating	Add-on control levels	68.2	0	5,050,766	0	68.2	5,050,766	74,058
		Total	51,337.90	16,794.90	237,458,003	83,136,982	68132.8	320,594,985	4,705
Phoenix, AZ	Web Offset Lithography	New CTG (carbon adsorber)	6.4	0	-795	0	6.4	-795	-124
	Cutback Asphalt	Switch to emulsified asphalts	109.7	0	0	0	109.7	0	0
	Open Burning	Episodic Ban	1,589.90	303.4	0	0	1893.3	0	0
	Metal product surface coating	VOC content limits & improved	521.6	0	12,986	0	521.6	12,986	25
	Wood product surface coating	Reformulationon	23.1	0	576	0	23.1	576	25
	Motor Vehicles	Enhanced I/M	21,094.90	12,639.60	1,199,840	2,399,679	33734.5	3,599,519	107
	Service stations - stage I-truck un	Vapor balance & P-V valves	1,131.70	0	212,983	0	1131.7	212,983	188
	Wood furniture surface coating	Reformulationon	891	0	334,128	0	891	334,128	375
	Recreational vehicles	CARB standards	318.6	0	168,875	0	318.6	168,875	530
	Motor Vehicles	Federal Reform	36,455.70	3,002.30	47,793,100	0	39458	47,793,100	1,211
	Bulk Terminals	RACT	115.1	0	191,712	0	115.1	191,712	1,666
	Aerosols	CARB Tier 2 Standards - Reform	402	0	1,004,856	0	402	1,004,856	2,500
	Miscellaneous surface coating	MACT level of control	417.7	0	1,044,188	0	417.7	1,044,188	2,500
	Adhesives - industrial	RACT	39.2	0	98,028	0	39.2	98,028	2,501
	Automobile refinishing	CARB BARCT limits	182.6	0	671,796	0	182.6	671,796	3,679
	Nonroad gasoline	Reformulated gasoline	306.9	0	1,534,500	0	306.9	1,534,500	5,000
		Total	63,606.10	15,945.30	54,266,773	2,399,679	79551.4	56,666,452	712
Portland, ME	Open Burning	Episodic Ban	801.7	152.3	0	0	954	0	0
	Area Source Industrial NG Comb	RACT to small sources	0	1.6	0	2,349	1.6	2,349	1,468
	Residential NG Consumption	LNB Space heaters	0	12.5	0	20,258	12.5	20,258	1,621
	Area Source Industrial Oil Comb	RACT to small sources	0	3.7	0	7,486	3.7	7,486	2,023
	Area Source Industrial Coal Comb	RACT to small sources	0	0.1	0	235	0.1	235	2,350
	Motor Vehicles	California Reform	208.9	1,844.30	0	7,957,384	2053.2	7,957,384	3,876
	Nonroad gasoline	Reformulated gasoline	23.3	0	117,000	0	23.3	117,000	5,021
	Industrial Boiler - Residual Oil	LNB + FGR	0	66.3	0	379,442	66.3	379,442	5,723
	Industrial Boiler - Natural Gas	LNB + FGR	0	0.9	0	5,706	0.9	5,706	6,340
	Industrial Boiler - Residual Oil	SCR	0	132.5	0	987,553	132.5	987,553	7,453
	Nonroad Diesels	CARB Stds for > 175 HP	0	4	0	33,035	4	33,035	8,259
	Industrial Boiler - Natural Gas	SCR	0	1.8	0	16,880	1.8	16,880	9,378
	Commercial Marine Vessels	Emission Fees	0	90.8	0	907,683	90.8	907,683	9,997
	Industrial Boiler - Distillate Oil	LNB + FGR	0	2.9	0	29,602	2.9	29,602	10,208
	Industrial Boiler - Distillate Oil	SCR	0	5.8	0	63,175	5.8	63,175	10,892
	Utility Boiler - Oil-Gas/Tangential	SCR	0	181.7	0	2,235,995	181.7	2,235,995	12,306
	Utility Boiler - Oil-Gas/Tangential	LNB + FGR + OFA	0	58.2	0	977,858	58.2	977,858	16,802
	Motor Vehicles	Reform Diesel	0	81.5	0	4,121,838	81.5	4,121,838	50,575
		Total	1,033.90	2,640.90	117,000	17,746,479	3674.8	17,863,479	4,861

Portland, OR	Web Offset Lithography	New CTG (carbon adsorber)	259.3	0	-32,399	0	259.3	-32,399	-125
	Cutback Asphalt	Switch to emulsified asphalts	320.2	0	0	0	320.2	0	0
	Open Burning	Episodic Ban	2,265.50	429.5	0	0	2695	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	139.8	0	0	0	139.8	0	0
	Metal product surface coating	VOC content limits & improved	406.7	0	10,136	0	406.7	10,136	25
	Point Source Wood Product Coating	FIP VOC Limits	217.2	0	5,429	0	217.2	5,429	25
	Wood product surface coating	Reformulationon	43.4	0	1,779	0	43.4	1,779	41
	SOCMI fugitives	RACT	12.7	0	1,729	0	12.7	1,729	136
	Motor Vehicles	Enhanced I/M	11,068.20	10,483.50	1,747,796	3,495,591	21551.7	5,243,387	243
	Pharmaceutical manufacture	RACT	4.2	0	1,408	0	4.2	1,408	335
	Wood furniture surface coating	Reformulationon	487.7	0	182,937	0	487.7	182,937	375
	Service stations - stage I-truck un	Vapor balance & P-V valves	1,432.70	0	562,989	0	1432.7	562,989	393
	Recreational vehicles	CARB standards	403.8	0	214,057	0	403.8	214,057	530
	Bulk Terminals	RACT	364.1	0	606,885	0	364.1	606,885	1,667
	Point Sources	RE Improvements	19,187.00	0	38,373,910	0	19187	38,373,910	2,000
		Total	36,612.50	10,913.00	41,676,656	3,495,591	47525.5	45,172,247	950
Providence, RI	Open Burning	Episodic Ban	510.9	97.1	0	0	608	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	129.6	0	0	0	129.6	0	0
	Metal product surface coating	VOC content limits & improved	285.3	0	7,100	0	285.3	7,100	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	313	0	7,823	0	313	7,823	25
	Wood product surface coating	Reformulationon	5.1	0	130	0	5.1	130	25
	Wood furniture surface coating	Reformulationon	402.2	0	150,805	0	402.2	150,805	375
	Recreational vehicles	CARB standards	545.9	0	289,257	0	545.9	289,257	530
	Point Sources	RE Improvements	2,381.30	0	4,762,520	0	2381.3	4,762,520	2,000
	Aerosols	CARB Tier 2 Standards - Reform	133.1	0	332,580	0	133.1	332,580	2,499
	Miscellaneous surface coating	MACT level of control	129.2	0	323,006	0	129.2	323,006	2,500
	Automobile refinishing	CARB BARCT limits	83.6	0	307,511	0	83.6	307,511	3,678
	Motor Vehicles	California Reform	410.5	2,548.70	0	13,834,606	2959.2	13,834,606	4,675
	Nonroad gasoline	Reformulated gasoline	101.8	0	509,000	0	101.8	509,000	5,000
	Pesticide Application	Reformulationon - FIP rule	1.6	0	15,196	0	1.6	15,196	9,498
	Aerosols	SCAQMD Standards - Reformulation	133.1	0	1,330,320	0	133.1	1,330,320	9,995
	marine surface coating	Add-on control levels	131.6	0	1,905,058	0	131.6	1,905,058	14,476
	Miscellaneous surface coating	Add-on control levels	193.3	0	3,130,460	0	193.3	3,130,460	16,195
	Automobile refinishing	FIP Rule (VOC Content & TE)	319.2	0	5,752,666	0	319.2	5,752,666	18,022
	Point Source Ind. Surface Coating	Add-on Control Levels	177.8	0	3,270,692	0	177.8	3,270,692	18,395
	Aircraft surface coating	Add-on control levels	0.2	0	4,764	0	0.2	4,764	23,820
	Paper surface coating	Add-on control levels	0.8	0	50,406	0	0.8	50,406	63,008
		Total	6,389.10	2,645.80	22,149,294	13,834,606	9034.9	35,983,900	3,983
Redding, CA	Web Offset Lithography	New CTG (carbon adsorber)	14.3	0	-1,791	0	14.3	-1,791	-125
	Cutback Asphalt	Switch to emulsified asphalts	180.7	0	0	0	180.7	0	0
	Open Burning	Episodic Ban	15.6	3	0	0	18.6	0	0
	Metal product surface coating	VOC content limits & improved	18.8	0	468	0	18.8	468	25
	Wood product surface coating	Reformulationon	8.3	0	208	0	8.3	208	25
	Wood furniture surface coating	Reformulationon	7.4	0	2,761	0	7.4	2,761	373
	Motor Vehicles	Enhanced I/M	2,316.30	3,420.10	841,481	1,682,962	5736.4	2,524,443	440
	Recreational vehicles	CARB standards	12.8	0	6,824	0	12.8	6,824	533
	Service stations - stage I-truck un	Vapor balance & P-V valves	731	0	547,670	0	731	547,670	749
	Bulk Terminals	RACT	303.5	0	505,794	0	303.5	505,794	1,667
	Miscellaneous surface coating	MACT level of control	3.7	0	9,223	0	3.7	9,223	2,493
	Aerosols	CARB Tier 2 Standards - Reform	26.1	0	65,190	0	26.1	65,190	2,498
	Adhesives - industrial	RACT	97	0	242,361	0	97	242,361	2,499
	Automobile refinishing	CARB BARCT limits	12.7	0	46,813	0	12.7	46,813	3,686
	Nonroad gasoline	Reformulated gasoline	13.7	0	68,500	0	13.7	68,500	5,000
	Pesticide Application	Reformulationon - FIP rule	24.2	0	225,693	0	24.2	225,693	9,326
	Aerosols	SCAQMD Standards - Reformulation	26.1	0	260,760	0	26.1	260,760	9,991
	Paper surface coating	Add-on control levels	64.3	0	774,483	0	64.3	774,483	12,045
	marine surface coating	Add-on control levels	6.4	0	93,094	0	6.4	93,094	14,546
	Miscellaneous surface coating	Add-on control levels	8.6	0	133,220	0	8.6	133,220	15,491
	Automobile refinishing	FIP Rule (VOC Content & TE)	48.6	0	875,746	0	48.6	875,746	18,019
		Total	3,940.10	3,423.10	4,698,498	1,682,962	7363.2	6,381,460	867
Reno, NV	Web Offset Lithography	New CTG (carbon adsorber)	97	0	-12,130	0	97	-12,130	-125
	Open Burning	Episodic Ban	82.3	15.6	0	0	97.9	0	0
	Metal product surface coating	VOC content limits & improved	37.5	0	934	0	37.5	934	25
	Wood product surface coating	Reformulationon	2	0	50	0	2	50	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	153.1	0	3,845	0	153.1	3,845	25
	Motor Vehicles	Enhanced I/M	1,537.10	1,483.50	94,145	188,291	3020.6	282,436	94
	Wood furniture surface coating	Reformulationon	68.8	0	25,794	0	68.8	25,794	375
	Recreational vehicles	CARB standards	118.5	0	62,805	0	118.5	62,805	530
	Motor Vehicles	Federal Reform	1,919.70	357.6	5,606,016	0	2277.3	5,606,016	2,462
	Aerosols	CARB Tier 2 Standards - Reform	44.1	0	110,244	0	44.1	110,244	2,500
	Miscellaneous surface coating	MACT level of control	30.7	0	76,867	0	30.7	76,867	2,504
	Automobile refinishing	CARB BARCT limits	30.8	0	113,240	0	30.8	113,240	3,677
	Nonroad gasoline	Reformulated gasoline	39.8	0	199,000	0	39.8	199,000	5,000
		Total	4,161.40	1,856.70	6,280,810	188,291	6018.1	6,469,101	1,075
Sacramento	Web Offset Lithography	New CTG (carbon adsorber)	6.6	0	-825	0	6.6	-825	-125

, CA									
	Cutback Asphalt	Switch to emulsified asphalts	72.2	0	0	0	72.2	0	0
	Open Burning	Episodic Ban	444	84	0	0	528	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	313.9	0	0	0	313.9	0	0
	Metal product surface coating	VOC content limits & improved	236.7	0	5,867	0	236.7	5,867	25
	Wood product surface coating	Reformulationon	16	0	399	0	16	399	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	799	0	130,285	0	799	130,285	163
	Wood furniture surface coating	Reformulationon	252.5	0	94,698	0	252.5	94,698	375
	Motor Vehicles	Enhanced I/M	828.8	1,377.30	326,808	653,615	2206.1	980,423	444
	Recreational vehicles	CARB standards	102.4	0	54,329	0	102.4	54,329	531
	Bulk Terminals	RACT	12.8	0	21,347	0	12.8	21,347	1,668
	Point Sources	RE Improvements	40.5	0	81,030	0	40.5	81,030	2,001
	Aerosols	CARB Tier 2 Standards - Reform	201.3	0	503,034	0	201.3	503,034	2,499
	Miscellaneous surface coating	MACT level of control	105.2	0	262,951	0	105.2	262,951	2,500
	Adhesives - industrial	RACT	34.5	0	86,360	0	34.5	86,360	2,503
	Automobile refinishing	CARB BARCT limits	127.1	0	467,563	0	127.1	467,563	3,679
	Nonroad gasoline	Reformulated gasoline	106.5	0	532,500	0	106.5	532,500	5,000
	Pesticide Application	Reformulationon - FIP rule	114.2	0	1,062,488	0	114.2	1,062,488	9,304
	Aerosols	SCAQMD Standards - Reformulation	201.2	0	2,012,136	0	201.2	2,012,136	10,001
	marine surface coating	Add-on control levels	4.2	0	60,687	0	4.2	60,687	14,449
	Miscellaneous surface coating	Add-on control levels	119.5	0	1,938,485	0	119.5	1,938,485	16,222
	Automobile refinishing	FIP Rule (VOC Content & TE)	485.3	0	8,746,744	0	485.3	8,746,744	18,023
	Point Source Ind. Surface Coating	Add-on Control Levels	361.7	0	6,655,556	0	361.7	6,655,556	18,401
	Paper surface coating	Add-on control levels	3.1	0	206,239	0	3.1	206,239	66,529
		Total	4,989.20	1,461.30	23,248,681	653,615	6450.5	23,902,296	3,705
San Diego, CA	Aerosols	CARB Tier 2 Standards - Reform	0	0	0	0	0	0	0
	Aerosols	SCAQMD Standards - Reformulationon	0	0	0	0	0	0	0
	Automobile refinishing	CARB BARCT limits	0	0	0	0	0	0	0
	Automobile refinishing	FIP Rule (VOC Content & TE)	0	0	0	0	0	0	0
	Metal product surface coating	VOC content limits & improved	0	0	0	0	0	0	0
	Miscellaneous surface coating	Add-on control levels	0	0	0	0	0	0	0
	Miscellaneous surface coating	MACT level of control	0	0	0	0	0	0	0
	Nonroad gasoline	Reformulated gasoline	0	0	0	0	0	0	0
	Open Burning	Episodic Ban	0	0	0	0	0	0	0
	Paper surface coating	Add-on control levels	0	0	0	0	0	0	0
	Pesticide Application	Reformulationon - FIP rule	0	0	0	0	0	0	0
	Point Source Ind. Surface Coating	Add-on Control Levels	0	0	0	0	0	0	0
	Point Sources	RE Improvements	0	0	0	0	0	0	0
	Recreational vehicles	CARB standards	0	0	0	0	0	0	0
	Service stations - stage I-truck un	Vapor balance & P-V valves	0	0	0	0	0	0	0
	Wood furniture surface coating	Reformulationon	0	0	0	0	0	0	0
	Wood product surface coating	Reformulationon	0	0	0	0	0	0	0
		Total	0	0	0	0	0	0	0
Santa Barbara, CA	Open Burning	Episodic Ban	134.4	25.5	0	0	159.9	0	0
	Metal product surface coating	VOC content limits & improved	44	0	1,098	0	44	1,098	25
	Wood product surface coating	Reformulationon	1.6	0	40	0	1.6	40	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	196	0	4,901	0	196	4,901	25
	Motor Vehicles	Enhanced I/M	1,827.60	2,680.20	106,112	212,224	4507.8	318,336	71
	Wood furniture surface coating	Reformulationon	52.3	0	19,616	0	52.3	19,616	375
	Recreational vehicles	CARB standards	5.8	0	3,072	0	5.8	3,072	530
	Point Sources	RE Improvements	91.6	0	183,230	0	91.6	183,230	2,000
	Miscellaneous surface coating	MACT level of control	45.7	0	114,149	0	45.7	114,149	2,498
	Aerosols	CARB Tier 2 Standards - Reform	50.1	0	125,256	0	50.1	125,256	2,500
	Automobile refinishing	CARB BARCT limits	25.1	0	92,413	0	25.1	92,413	3,682
	Nonroad gasoline	Reformulated gasoline	26	0	130,000	0	26	130,000	5,000
	Pesticide Application	Reformulationon - FIP rule	34.8	0	323,156	0	34.8	323,156	9,286
	Aerosols	SCAQMD Standards - Reformulationon	50.1	0	501,024	0	50.1	501,024	10,000
	Miscellaneous surface coating	Add-on control levels	18.2	0	303,110	0	18.2	303,110	16,654
	Automobile refinishing	FIP Rule (VOC Content & TE)	95.9	0	1,728,785	0	95.9	1,728,785	18,027
	Aircraft surface coating	Add-on control levels	10.5	0	330,223	0	10.5	330,223	31,450
	Paper surface coating	Add-on control levels	1.3	0	84,224	0	1.3	84,224	64,788
		Total	2,711.00	2,705.70	4,050,409	212,224	5416.7	4,262,633	787
Seattle, WA	Web Offset Lithography	New CTG (carbon adsorber)	532.5	0	-66,548	0	532.5	-66,548	-125
	Cutback Asphalt	Switch to emulsified asphalts	454.5	0	0	0	454.5	0	0
	Open Burning	Episodic Ban	1,232.70	233.9	0	0	1466.6	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	8.8	0	0	0	8.8	0	0
	Metal product surface coating	VOC content limits & improved	578.7	0	14,445	0	578.7	14,445	25
	Point Source Wood Product Coating	FIP VOC Limits	93.1	0	2,327	0	93.1	2,327	25
	Wood product surface coating	Reformulationon	22.6	0	1,182	0	22.6	1,182	52
	Service stations - stage I-truck un	Vapor balance & P-V valves	2,104.60	0	699,089	0	2104.6	699,089	332
	Wood furniture surface coating	Reformulationon	989.4	0	371,013	0	989.4	371,013	375
	Motor Vehicles	Enhanced I/M	4,292.70	3,491.00	1,372,151	2,744,303	7783.7	4,116,454	529
	Recreational vehicles	CARB standards	628.9	0	333,244	0	628.9	333,244	530

	Motor Vehicles	California LEV	8,992.70	15,879.00	12,434,797	12,434,797	24871.7	24,869,594	1,000
	Bulk Terminals	RACT	248.4	0	413,881	0	248.4	413,881	1,666
	Adhesives - industrial	RACT	105.8	0	264,172	0	105.8	264,172	2,497
	Aerosols	CARB Tier 2 Standards - Reform	467.2	0	1,167,756	0	467.2	1,167,756	2,499
	Miscellaneous surface coating	MACT level of control	240.4	0	601,215	0	240.4	601,215	2,501
	Automobile refinishing	CARB BARCT limits	250.9	0	922,119	0	250.9	922,119	3,675
	Motor Vehicles	Federal Reform	11,865.00	3,331.60	67,981,645	0	15196.6	67,981,645	4,473
	Nonroad gasoline	Reformulated gasoline	292.5	0	1,462,500	0	292.5	1,462,500	5,000
	Pesticide Application	Reformulationon - FIP rule	71.3	0	662,233	0	71.3	662,233	9,288
	Aerosols	SCAQMD Standards - Reformulation	467	0	4,671,024	0	467	4,671,024	10,002
	Motor Vehicles	California Reform	1,615.10	4,241.60	0	65,175,421	5856.7	65,175,421	11,128
		Total	35,554.80	27,177.10	93,308,245	80,354,520	62731.9	173,662,765	2,768
St. Louis, MO	Web Offset Lithography	New CTG (carbon adsorber)	2.2	0	-281	0	2.2	-281	-128
	Cutback Asphalt	Switch to emulsified asphalts	48.5	0	0	0	48.5	0	0
	Open Burning	Episodic Ban	1,607.90	304.9	0	0	1912.8	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	874.2	0	0	0	874.2	0	0
	Wood product surface coating	Reformulationon	6.8	0	168	0	6.8	168	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	1,235.80	0	30,896	0	1235.8	30,896	25
	Metal product surface coating	VOC content limits & improved	836.5	0	35,843	0	836.5	35,843	43
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	26,691.50	19,604.60	948,486	1,896,971	46296.1	2,845,457	61
	Oil and natural gas production fiel	RACT (equipment/maintenance)	4.2	0	1,690	0	4.2	1,690	402
	Recreational vehicles	CARB standards	253	0	133,902	0	253	133,902	529
	Wood furniture surface coating	Reformulationon	335.3	0	482,482	0	335.3	482,482	1,439
	Point Sources	RE Improvements	3,298.80	0	6,597,740	0	3298.8	6,597,740	2,000
	Adhesives - industrial	RACT	18.4	0	45,877	0	18.4	45,877	2,493
	Aerosols	CARB Tier 2 Standards - Reform	364.1	0	910,368	0	364.1	910,368	2,500
	Miscellaneous surface coating	MACT level of control	176	0	440,252	0	176	440,252	2,501
	Automobile refinishing	CARB BARCT limits	183.9	0	676,359	0	183.9	676,359	3,678
	Nonroad gasoline	Reformulated gasoline	151.4	0	757,000	0	151.4	757,000	5,000
	Motor Vehicles	California Reform	24.8	8,761.50	0	45,829,827	8786.3	45,829,827	5,216
	Motor Vehicles	Federal Reform	6,064.00	1,717.00	47,795,117	0	7781	47,795,117	6,143
	Pesticide Application	Reformulationon - FIP rule	217.1	0	2,019,308	0	217.1	2,019,308	9,301
	Aerosols	SCAQMD Standards - Reformulation	364.1	0	3,641,472	0	364.1	3,641,472	10,001
	marine surface coating	Add-on control levels	17.2	0	249,014	0	17.2	249,014	14,478
	Automobile refinishing	FIP Rule (VOC Content & TE)	702.2	0	12,652,662	0	702.2	12,652,662	18,019
	Point Source Ind. Surface Coating	Add-on Control Levels	7,192.00	0	132,332,064	0	7192	132,332,064	18,400
	Aircraft surface coating	Add-on control levels	120.4	0	3,790,114	0	120.4	3,790,114	31,479
	Miscellaneous surface coating	Add-on control levels	241.9	0	15,971,880	0	241.9	15,971,880	66,027
	Paper surface coating	Add-on control levels	23.6	0	2,442,361	0	23.6	2,442,361	103,490
		Total	51,055.80	30,388.00	231,954,774	47,726,798	81443.8	279,681,572	3,434
Stockton, CA	Open Burning	Episodic Ban	146.1	27.8	0	0	173.9	0	0
	Metal product surface coating	VOC content limits & improved	315.6	0	7,806	0	315.6	7,806	25
	Point Source Wood Product Coating	FIP VOC Limits	138	0	3,449	0	138	3,449	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	184.4	0	4,610	0	184.4	4,610	25
	Wood furniture surface coating	Reformulationon	214	0	80,240	0	214	80,240	375
	Recreational vehicles	CARB standards	31.5	0	16,720	0	31.5	16,720	531
	Miscellaneous surface coating	MACT level of control	38	0	94,975	0	38	94,975	2,499
	Aerosols	CARB Tier 2 Standards - Reform	63.9	0	159,828	0	63.9	159,828	2,501
	Automobile refinishing	CARB BARCT limits	30.9	0	113,829	0	30.9	113,829	3,684
	Nonroad gasoline	Reformulated gasoline	32.9	0	164,500	0	32.9	164,500	5,000
	Pesticide Application	Reformulationon - FIP rule	162.5	0	1,510,952	0	162.5	1,510,952	9,298
	Aerosols	SCAQMD Standards - Reformulation	63.9	0	639,312	0	63.9	639,312	10,005
	marine surface coating	Add-on control levels	2.6	0	37,680	0	2.6	37,680	14,492
	Miscellaneous surface coating	Add-on control levels	86.9	0	1,429,779	0	86.9	1,429,779	16,453
	Automobile refinishing	FIP Rule (VOC Content & TE)	118.2	0	2,129,416	0	118.2	2,129,416	18,015
	Paper surface coating	Add-on control levels	5.3	0	358,421	0	5.3	358,421	67,627
		Total	1,634.70	27.8	6,751,517	0	1662.5	6,751,517	4,061
Tell City (IN-KY)	Petroleum refinery fugitives	RACT	52.5	0	-23,622	0	52.5	-23,622	-450
	Web Offset Lithography	New CTG (carbon adsorber)	14.8	0	-1,846	0	14.8	-1,846	-125
	Cutback Asphalt	Switch to emulsified asphalts	40.9	0	0	0	40.9	0	0
	Open Burning	Episodic Ban	73.8	13.9	0	0	87.7	0	0
	Point Source Metal Surface Coating	FIP VOC Limits	220.4	0	0	0	220.4	0	0
	Metal product surface coating	VOC content limits & improved	9.8	0	323	0	9.8	323	33
	Motor Vehicles	Enhanced I/M (w/49 State LEV)	626.6	531	130,727	261,453	1157.6	392,180	339
	Wood furniture surface coating	Reformulationon	118.8	0	44,537	0	118.8	44,537	375
	Oil and natural gas production fiel	RACT (equipment/maintenance)	2.2	0	840	0	2.2	840	382
		Total	1,159.80	544.9	150,959	261,453	1704.7	412,412	242
Visalia, CA	Open Burning	Episodic Ban	93.7	17.7	0	0	111.4	0	0
	Metal product surface coating	VOC content limits & improved	49.9	0	1,238	0	49.9	1,238	25
	Wood product surface coating	Reformulationon	2.7	0	67	0	2.7	67	25
	Service stations - stage I-truck un	Vapor balance & P-V valves	110.8	0	2,770	0	110.8	2,770	25
	Wood furniture surface coating	Reformulationon	8.2	0	3,088	0	8.2	3,088	377

	Recreational vehicles	CARB standards	22.4	0	11,867	0	22.4	11,867	530
	Aerosols	CARB Tier 2 Standards - Reform	42.6	0	106,380	0	42.6	106,380	2,497
	Miscellaneous surface coating	MACT level of control	19.7	0	49,270	0	19.7	49,270	2,501
	Automobile refinishing	CARB BARCT limits	11.2	0	41,327	0	11.2	41,327	3,690
	Nonroad gasoline	Reformulated gasoline	23.1	0	115,500	0	23.1	115,500	5,000
	Pesticide Application	Reformulationon - FIP rule	250.4	0	2,329,073	0	250.4	2,329,073	9,301
	Aerosols	SCAQMD Standards - Reformulation	42.6	0	425,520	0	42.6	425,520	9,989
	Miscellaneous surface coating	Add-on control levels	22	0	333,737	0	22	333,737	15,170
	Automobile refinishing	FIP Rule (VOC Content & TE)	42.9	0	773,106	0	42.9	773,106	18,021
		Total	742.2	17.7	4,192,943	0	759.9	4,192,943	5,518

Source: Ozone RIA, Table B-4. Alternative 8H1AX-80: Marginal Emission Reductions and Costs by Nonattainment Area and Control Measure Under the RCS.

Appendix 2

Potential State-Level Disaggregations

I. Potential State-Level Cost Allocation

The economic analysis is performed with an eight-region version of the model. For a pro forma economic assessment of a control program of the sort that the $90 billion annual cost reflects, it does not make sense to suggest that costs could be attributed to regions with great accuracy. Further, the exceptional resource requirements of developing and applying a 50 region model, and the time constraints of this project made it simply infeasible to consider an economic analysis at the state level of detail. However, many may be interested in understanding the potential relative costs at the level of the individual state. This appendix provides a possible set of such inputs for the reader's interest, but it is emphasized that these state-level data were not used as inputs to any REMI model run. They should be thought of as the comparable regional breakdown of costs that might have been used if the analysis were being performed with a 50-state model.

As the main text of this report indicates, regional cost inputs were developed from information about relative contributions to ozone and $PM_{2.5}$ precursors of each of 53 sectors of the economy, rather than from specific engineering-based cost estimates that could be linked to specific facilities in specific regions. This same attribution method was applied to the regional costs that were the actual REMI model inputs for the illustrative $90 billion per year cost scenario. In this case, the percent contribution of each state to its region's total weighted relevant emissions were used to attribute costs back to the individual states. The results of this attribution are presented in Table A2-1. Again, the reader should note that the data in this table were not used as actual model inputs.

Table A2-1. Potential State-Level Control Costs Consistent with a $90 billion per year Cost Estimate (Note: These are not model input assumptions)

State	Cost by State ($b)	Rank
Alabama	1.8	18
Alaska	0.0	50
Arizona	1.0	30
Arkansas	1.0	31
California	9.1	1
Colorado	0.5	37
Connecticut	0.6	35
Delaware	0.4	42
District of Columbia	0.1	49

Florida	2.6	11
Georgia	1.9	16
Hawaii	0.0	50
Idaho	0.6	34
Illinois	3.9	6
Indiana	4.1	5
Iowa	1.3	26
Kansas	0.7	33
Kentucky	2.6	9
Louisiana	2.5	13
Maine	0.4	41
Maryland	1.5	21
Massachusetts	1.3	27
Michigan	2.6	10
Minnesota	1.4	24
Mississippi	1.1	29
Missouri	2.5	12
Montana	0.4	39
Nebraska	0.4	43
Nevada	0.3	45
New Hampshire	0.3	44
New Jersey	1.5	23
New Mexico	1.4	25
New York	3.3	7
North Carolina	1.8	19
North Dakota	0.5	38
Ohio	4.9	3
Oklahoma	2.1	15
Oregon	0.9	32
Pennsylvania	4.9	4
Rhode Island	0.1	48
South Carolina	1.1	28
South Dakota	0.2	46
Tennessee	1.9	17
Texas	9.0	2
Utah	0.5	36
Vermont	0.1	47
Virginia	2.3	14
Washington	1.5	22
West Virginia	2.6	8
Wisconsin	1.6	20
Wyoming	0.4	40
National	90.0	

A. Potential State-Level Employment Impact Allocation

For the same reason that the REMI model used in this analysis does not use state-level cost inputs, the model also does not provide estimates of impacts at the state-level. The only way to estimate specific state-level impacts is to make a range of rough judgments about how impacts would be spread among states. Such judgments should be consistent with the way that model inputs were developed, but even that consistency does not ensure accuracy in estimating what individual states may experience. Although this appendix provides the results of one way of making such attributions, readers should be aware that these estimates are quite speculative.

It is also important to point out that there is no linkage between the potential state-level costs of Table A2-1 above and the state-level employment estimates provided below. The model was run on an eight-region level with only regional-scale cost inputs, and the results are reported only at the eight region level. The state-level employment impacts are estimated using assumptions that are consistent with the model results for the $90 billion per year cost scenario, and using an understanding of the root economic causes in the model of the potential net job losses. However, it is emphasized that the state-level estimates are not themselves results of the economic model.

There are several possible ways to allocate the potential 200,000 net national job losses that are found in later, post-implementation years of the model results for the $90 billion per year scenario. One could simply allocate them back to states according to their relative population sizes. Or, one could allocate them back to states proportionately to the sources of relevant emissions that need to be controlled. Each method generates quite different results. However, one can make use of the sectoral detail behind these employment impacts, and an understanding of the causes for each type of impact. Specifically, behind a net national impact of 200,000 jobs is an approximate loss of 385,000 jobs in retail and service sectors. These losses stem primarily from the loss of real disposable income among consumers, and as such, the majority of such job losses would tend to be located near consumers, or roughly proportional to population. In turn, there are net job increases of about 185,000 in the manufacturing sectors. Even though these sectors are where the pollution control costs are applied, as a group they also benefit relatively more from the increased demand associated with pollution control measures. Thus, one would expect jobs in these sectors to be more closely aligned with where the control measures are being applied, or roughly proportional to the location of the relevant emissions.

Table A2-2 shows the net job losses by region for sectors that are categorized as “population-oriented” and those that are categorized as “emissions-oriented.” As can be seen, the relative proportions differ by region. Net state-level impacts involved attributing these two types of job impacts by each state’s proportion of its regional population and weighted emissions, respectively. Table A2-3 summarizes the net job impact categories by state that the procedure generates.

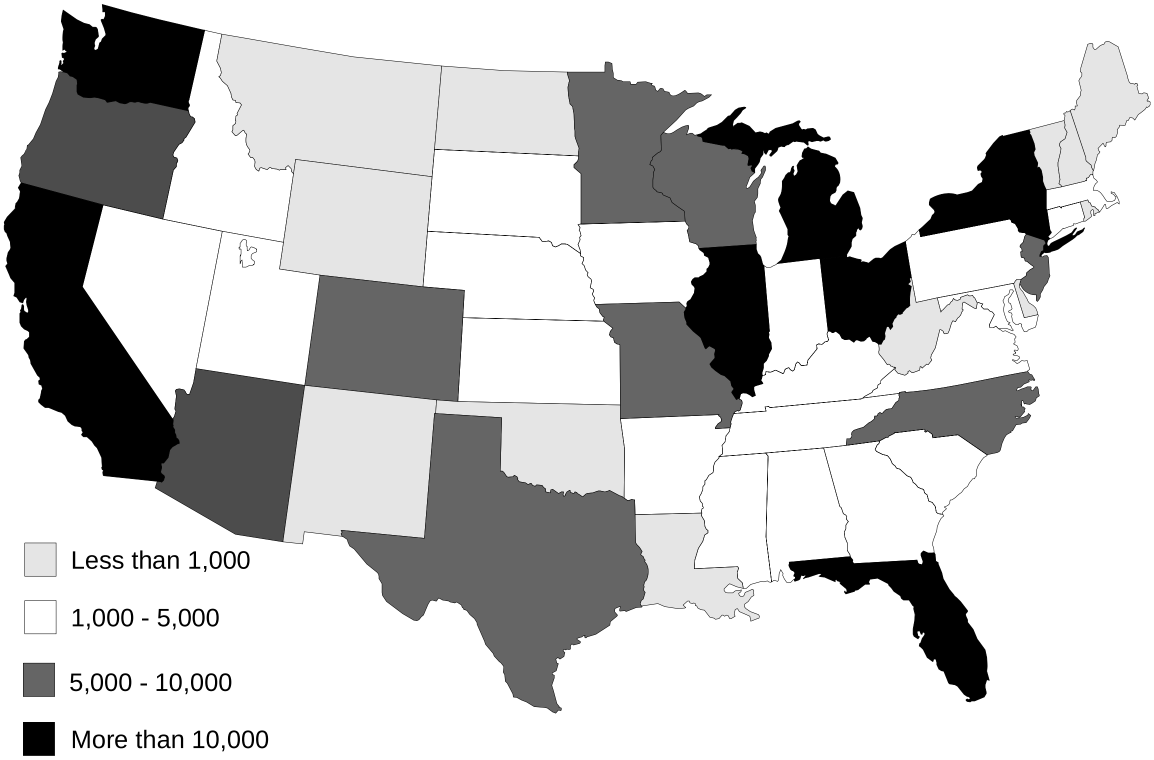
Table A2-2. Regional Job Category Impacts (Thousands of Jobs)

Region	Net Impact	Job Impacts in Population-Oriented Sectors	Job Impacts in Emissions-Oriented Sectors
1. NE/MidAtl	-29	-77	48
2. Southeast	-30	-64	34
3. North Central	-63	-100	36
4. South Central	-7	-35	28
5. NW Central	-14	-21	7
6. West	-11	-15	4
7. Far West	-29	-51	23
8. Northwest	-18	-19	2
National	**-201**	**-383**	**182**

Table A2-3: Rough Estimates of Potential State-Level Job Impacts Consistent with 200,000 Net Job Loss at the National Scale

(Note: These are <u>not</u> model outputs. They are approximated, based on analyst judgments using model results at the eight-region level:

States That Might Experience Job Losses Less than 1,000	States That Might Experience Job Losses Between 1,000 and 5,000	States That Might Experience Job Losses Between 5,000 and 10,000	States That Might Experience Job Losses Greater than 10,000
1 Delaware	1 Alabama	1 Arizona	1 California
2 District of Columbia	2 Arkansas	2 Colorado	2 Florida
3 Louisiana	3 Connecticut	3 Minnesota	3 Illinois
4 Maine	4 Georgia	4 Missouri	4 Michigan
5 Montana	5 Idaho	5 New Jersey	5 New York
6 New Hampshire	6 Indiana	6 North Carolina	6 Ohio
7 New Mexico	7 Iowa	7 Oregon	7 Washington
8 North Dakota	8 Kansas	8 Texas	
9 Oklahoma	9 Kentucky	9 Wisconsin	
10 Rhode Island	10 Maryland		
11 Vermont	11 Massachusetts		
12 West Virginia	12 Mississippi		
13 Wyoming	13 Nebraska		
	14 Nevada		
	15 Pennsylvania		
	16 South Carolina		
	17 South Dakota		
	18 Tennessee		
	19 Utah		
	20 Virginia		



(Note: These are <u>not</u> model outputs. They are approximated, based on analyst judgments using model results at the eight-region level)

Appendix 3

Reference List of PM and Ozone Mortality Studies

Reference List of PM and Ozone Mortality Studies

A. Short-term PM Mortality Studies

[1] Schwartz, J., Dockery, D.W., Neas, L.M. Is daily mortality associated specifically with fine particles? *J. Air Waste Manage. Assoc*., 46:927-939, 1996.

[2] Dockery, D.W. *Particle/Mortality Associations in St. Louis and Eastern Tennessee; Elaboration of Published Results*. Prepared for: EPA critical evaluation workshop on particulate matter-mortality epidemiology studies; November, 1994; Raleigh, NC. Harvard School of Public Health, Boston, MA, 1995.

[3] Pope, C.A., III, Schwartz, J., Ransom, M.R. Daily mortality and PM_{10} pollution in Utah valley. *Arch. Environ. Health*, 47:211-217, 1992.

[4] Pope, C.A., III, Kalkstein, L.S. Synoptic weather modeling and estimates of the exposure-response relationship between daily mortality and particulate air pollution. *Environ. Health Perspect*., 104, 1996.

[5] Schwartz, J. Air pollution and daily mortality in Birmingham, Alabama. *Am. J. Epidemiol*. 137:1136-1147, 1993.

[6] Dockery, D.W., Schwartz, J., Spengler, J.D. Air pollution and daily mortality: associations with particulates and acid aerosols. *Environ. Res*., 59:362-373, 1992.

[7] Ozkaynak, H., Xue, J., Severance, P., Burnett, R., Raizenne, M. *Associations between daily mortality, ozone, and particulate air pollution in Toronto, Canada*. University of California, Irvine, Air Pollution Health Effects Laboratory, report no. 94-02, 1994.

[8] Kinney, P.L., Ito, K., Thurston, G.D. A sensitivity analysis of mortality/PM_{10} associations in Los Angeles. *Inhalation Toxicol*., 7:59-69, 1995.

[9] Ito, K., Kinney, P., Thurston, G.D. Variations in PM_{10} concentrations within two metropolitan areas and their implications for health effects analyses. *Inhalation Toxicol*., 7:735-745, 1995.

[10] Styer, P., McMillan, N., Gao, F., Davis, J., Sacks, J. The effect of airborne particulate matter on daily death counts. *Environ. Health Perspect*., 13: 490-497, 1995.

[11] Ito, K., Thurston, G.D. Daily PM_{10}/mortality associations: an investigation of at-risk sub-populations. *J. Exposure Anal. Environ. Epidemiol*., 1996.

[12] Ostro, B., Sanchez, J.M., Aranda, C., Eskeland, G.S. Air pollution and mortality: results from a study of Santiago, Chile. *J. Exposure Anal. Environ. Epidemiol*., 1996.

[13] Ostro, B. The association of air pollution and mortality: examining the case for inference. *Arch. Environ. Health*, 48:336-342, 1993.

[14] Dockery, D.W., Pope, C.A., III. Acute respiratory effects of particulate air pollution. *Annu. Rev. Public Health*, 15:107-132, 1994.

[15] Moolgavkar, S.H., Luebeck, E.G., Hall, T.A., Anderson, E.L. Particulate air pollution, sulfur dioxide, and daily mortality: a reanalysis of the Steubenville data. *Inhalation Toxicol*., 7:35-44, 1995.

B. Long-term PM Mortality Studies

[16] Dockery, D.W., Pope, C.A., III, Xu, X., Spengler, J.D., Ware, J.H., Fay, M.E., Ferris, B.G., Jr., Speizer, F.E. An association between air pollution and mortality in six U.S. cities. *N. Engl. J. Med*., 329:1753-1759, 1993.

[17] Pope, C.A., III, Thun, M.J., Namboodiri, M.M., Dockery, D.W., Evans, J.S., Speizer, F.E., Heath, C.W., Jr. Particulate air pollution as a predictor of mortality in a prospective study of U.S. adults. *A. J. Respir. Crit. Care Med*., 151: 669-674, 1995.

[18] Lipfert, F.W. *Community Air Pollution and Mortality: Analysis of 1980 Data from U.S. Metropolitan Areas. I. Particulate Air Pollution.* U.S. Dept. of Energy, Brookhaven National Laboratory, Report No. BNL 48446-R.

[19] Ozkaynak, H., Thurston, G.D. Associations between 1980 U.S. mortality rates and alternative mesaures of airborne particle concentration. *Risk Anal*., 7:449-461, 1987.

C. Chronic Bronchitis Studies

[1] Schwartz, J. Particulate air pollution and chronic respiratory disease. *Environ. Res*., 62:7-13, 1993.

[2] Abbey, D. E.; Peterson, F.; Mills, P.K.; Beeson, W.L. Long-term ambient concentration of total suspended particles, ozone and sulfur dioxide and respiratory sysmptoms in a nonsmoking population. *Arch. Environ. Health.*, 48:Jan./Feb(1) 33-46., 1993.

D. Ozone Mortality Studies

[1] Anderson, H.R.; Ponce de Leon, A; Bland, J. M.; Bower, J.S.; Strachan, D.P. Air pollution and daily mortality in London: 1987-92. *British Medical Journal*, 312:665-669, 1996.

[2] Dockery, D.W.; Schwartz, J.; Spengler, J.D. Air pollution and daily mortality: associations with particulates and acid aerosols. *Environmental Research*, 59:362-373, 1992.

[3] Loomis, D.; Borja-Aburto, V.; Bangdiwala, S.; Shy, C. *Ozone Exposure and Daily Mortality in Mexico City: A Time-Series Analysis*. Health Effects Institute. Cambridge, MA. Research Report No. 75, October 1996.

[4] Samet, J.; Zeger, S; Kelsall, J.; Xu, J.; Kalkstein, L. *Particulate Air Pollution and Daily Mortality: Analyses of the Effects of Weather and Multiple Air Pollutants*, The Phase I.B Report of the Particle Epidemiology Evaluation Project. Health Effects Institute, Cambridge, MA. March 1997.

[5] Kinney, P.L.; Ito, K.; Thurston, G.D. A sensitivity analysis of mortality/PM_{10} associations in Los Angeles. *Inhalation Toxicol.*, 7:59-69, 1995.

[6] Kinney, P.L.; Ozkaynak, H. Associations of Daily Mortality and Air Pollution in Los Angeles County. *Environmental Res.*, 54:99-120, 1991.

[7] Moolgavkar, S.H.; Luebeck, E.G.; Hall, T.A.; Anderson, E. L. Air pollution and daily mortality in Philadelphia. *Epidemiology*, September 1995, pp. 476-484.

[8] Sartor, F.; Snacken, R.; Demuth, C.; Walckiers, D. Temperature, ambient ozone levels, and mortality during summer, 1994, in Belgium. *Environmental Res.*, 70:105-113, 1994.

[9] Schwartz, J. Particulate air pollution and daily mortality in Detroit. *Environmental Res.*, 56:204-213, 1991.

[10] Thurston, G. *Ozone Air Pollution and Human Mortality*. Presentation to the Air & Waste Management Association's 90th Annual Meeting and Exhibition, June 8-13, 1997, Toronto, Ontario, Canada (and submitted to the Ozone docket).

[11] Verhoeff, A.P.; Hoek, G.; Schwartz, J.; Van Wijnen, J.H. Air pollution and daily mortality in Amsterstdam. *Epidemiology*, 7:225-230, 1995.

Table of Contents