

## APPENDICES

APPENDIX A | QUALITATIVE UNCERTAINTY ANALYSIS TABLES  
FROM THE FIRST PROSPECTIVE ANALYSIS

TABLE A-1. KEY UNCERTAINTIES ASSOCIATED WITH COST ESTIMATION

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE <sup>1</sup>
Costs are based on today’s technologies. Innovations in future emission control technology and competition among equipment suppliers tend to reduce costs over time.	Underestimate	Probably minor. Available evidence suggests that estimates of pollution control costs based on current engineering can substantially overestimate the ultimate cost incurred, resulting in understating net benefits. <sup>2</sup>
Uncertainty of final State strategies for meeting Reasonable Further Progress (RFP) requirements.	Underestimate	Probably minor. We apply a conservative estimate for costs of RFP measures. Available evidence for identified RFP measures suggests costs could be as much as 70 percent lower than this value. The bias most likely results in significantly understating net benefits.
Errors in emission projections that form the basis of selecting control strategies and costs in both the IPM and ERCAM models.	Unable to determine based on current information	Probably minor. In many cases, emissions reductions are specified in the regulations, suggesting that errors in the estimation of absolute levels of emissions under Pre- and Post-CAAA scenarios may have only a small impact on cost estimates. The effect on net benefits is unknown.
Exclusion of the impact of economic incentive provisions, including banking, trading, and emissions averaging provisions.	Underestimate	Probably minor. Economic incentive provisions can substantially reduce costs, but the major economic programs for trading of sulfur and nitrogen dioxide emissions are reflected in the analysis.
Incomplete characterization of certain indirect costs, including vehicle owner opportunity costs associated with Inspection and Maintenance Programs and performance degradation issues associated with the incorporation of emission control technology.	Overestimate	Probably minor. Preliminary evidence suggests that the opportunity costs of vehicle owners is most likely small relative to other cost inputs. <sup>3</sup> In addition, it will vary from State to State and is subject to a variety of influencing factors. The potential magnitude of indirect costs associated with performance degradation is more uncertain, because few data currently exist to quantify this effect.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE <sup>1</sup>
Choice to model direct costs rather than social costs.	Unable to determine based on current information	Probably minor. The relationship of social cost to direct cost estimates is influenced by multiple factors that operate in opposite directions, suggesting the magnitude of the net effect is reduced. Social cost estimates can reflect the net welfare changes across the full range of economic sectors in the U.S., and so may yield higher estimates of costs than a direct cost approach. In addition, social cost estimates can be constructed to reflect the potentially substantial cost magnifying effect of existing tax distortions. Direct cost estimates, however, are likely to overstate costs in the primary market because they do not reflect consumer and producer responses. The extent to which a direct cost estimate will overstate or understate a social cost estimate depends on the magnitude of the “ripple effects” in economic sectors not targeted by a regulation. In addition, assessment of the effect on net benefit estimates must also account for any economy-wide effects of direct benefits (e.g., the broader implications of improving health status, and improving environmental quality).
Use of costs for rules that are currently in draft form (i.e., not yet finalized).	Unable to determine based on current information	Probably minor. Rules that are most important to the overall cost estimate are largely finalized. For example, there is some uncertainty as to how the cap-and-trade program through the SIP process will lower NO <sub>x</sub> emissions in an efficient manner. The expected effect on net benefits is minimal.
Exclusion of costs of 7-year and 10-year MACT standards and the residential risk standards for the 2- and 4-year MACT standards.	Unable to determine based on current information	Probably minor. Costs for the 7- and 10-year MACT standards are likely to be less than for the 2- and 4-year standards included in the analysis and the need for, and potential scope and stringency of, future Title III residual risk standards remain highly uncertain. For consistency, benefits of the 7- and 10-year standards and the residual risk standards are also excluded.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE <sup>1</sup>
<p><sup>1</sup> The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of “potentially major” if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of “probably minor.”</p> <p><sup>2</sup> For more detail, see Harrington et al. (1999), referenced in Appendix B.</p> <p><sup>3</sup> Preliminary evidence based on Arizona’s Enhanced I/M program indicates that major components of the programs costs are associated with test and repair costs rather than the costs of waiting and travel for vehicle owners. (Harrington and McConnell, 1999). To date, Enhanced I/M programs have been implemented in only four States.</p>		

TABLE A-2. KEY UNCERTAINTIES ASSOCIATED WITH EMISSIONS ESTIMATION

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
PM <sub>2.5</sub> emissions are largely based on scaling of PM <sub>10</sub> emissions.	Overall, unable to determine based on current information, but current emission factors are likely to underestimate PM <sub>2.5</sub> emissions from combustion sources, implying a potential underestimation of benefits.	Potentially major. Source-specific scaling factors reflect the most careful estimation currently possible, using current emissions monitoring data. However, health benefit estimates related to changes in PM <sub>2.5</sub> constitute a large portion of overall CAAA-related benefits.
Primary PM <sub>2.5</sub> emissions estimates are based on unit emissions that may not accurately reflect composition and mobility of the particles. For example, the ratio of crustal to primary carbonaceous particulate material likely is high.	Underestimate. The effect of overestimating crustal emissions and underestimating carbonaceous when applied in later stages of the analysis, is to reduce the net impact of the CAAA on primary PM <sub>2.5</sub> emissions by underestimating PM <sub>2.5</sub> emissions reductions associated with mobile source tailpipe controls.	Potentially major. Mobile source primary carbonaceous particles are a significant contributor to public exposure to PM <sub>2.5</sub> . Overall, however, compared to secondary PM <sub>2.5</sub> precursor emissions, changes in primary PM <sub>2.5</sub> emissions have only a small impact on PM <sub>2.5</sub> related benefits.
The post-CAAA scenario includes implementation of a region-wide NO <sub>x</sub> emissions reduction strategy to control regional transport of ozone that may not reflect the NO <sub>x</sub> controls that are actually implemented in a regional ozone transport rule.	Unable to determine based on current information.	Probably minor. Overall, magnitude of estimated emissions reductions is comparable to that in expected future regional transport rule. In some areas of the 37-state region, emissions reductions are expected to be overestimated, but in other areas, NO <sub>x</sub> inhibition of ozone leads to underestimates of ozone benefits (e.g., some eastern urban centers).
VOC emissions are dependent on evaporation, and future patterns of temperature are difficult to predict.	Unable to determine based on current information.	Probably minor. We assume future temperature patterns are well characterized by historic patterns, but an acceleration of climate change (warming) could increase emissions.
Use of average temperatures (i.e., daily minimum and maximum) in estimating motor-vehicle emissions artificially reduces variability in VOC emissions.	Unable to determine based on current information.	Probably minor. Use of averages will overestimate emissions on some days and underestimate on other days. Effect is mitigated in Post-CAAA scenarios because of more stringent evaporative controls that are in place by 2000 and 2010.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
Economic growth factors used to project emissions are an indicator of future economic activity. They reflect uncertainty in economic forecasting as well as uncertainty in the link to emissions.	Unable to determine based on current information.	Probably minor. The same set of growth factors are used to project emissions under both the Pre-CAAA and Post-CAAA scenarios, mitigating to some extent the potential for significant errors in estimating differences in emissions.
Uncertainties in the stringency, scope, timing, and effectiveness of Post-CAAA controls included in projection scenarios.	Unable to determine based on current information.	Probably minor. Future controls could be more or less stringent, wide-reaching (e.g., NO <sub>x</sub> reductions in OTAG region - see above), or effective (e.g., uncertainty in realizing all Reasonable Further Progress requirements) than projected. Timing of emissions reductions may also be affected (e.g., sulfur emissions reductions from utility sources have occurred more rapidly than projected for this analysis).
<p>* The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of “potentially major” if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of “probably minor.”</p>		

TABLE A-3. KEY UNCERTAINTIES ASSOCIATED WITH AIR QUALITY MODELING

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE*
PM <sub>10</sub> and PM <sub>2.5</sub> concentrations in the East (RADM domain) are based exclusively on changes in the concentrations of sulfate and nitrate particles, omitting the effect of anticipated reductions in organic or primary particulate fractions.	Underestimate	Potentially major. Nitrates and sulfates constitute major components of PM, especially PM <sub>2.5</sub> , in most of the RADM domain and changes in nitrates and sulfates may serve as a reasonable approximation of changes in total PM <sub>10</sub> and total PM <sub>2.5</sub> . Of the other components, primary crustal particulate emissions are not expected to change between scenarios; primary organic carbon particulate emissions are expected to change, but an important unknown fraction of the organic PM is from biogenic emissions, and biogenic emissions are not expected to change between scenarios. If the underestimation is major, it is likely the result of not capturing reductions in motor vehicle primary elemental carbon and organic carbon particulate emissions.
The number of PM <sub>2.5</sub> ambient concentration monitors throughout the U.S. is limited. As a result, cross estimation of PM <sub>2.5</sub> concentrations from PM <sub>10</sub> (or TSP) data was necessary in order to complete the “monitor-level” observational dataset used in the calculation of air quality profiles.	Unable to determine based on the current information.	Potentially major. PM <sub>2.5</sub> exposure is linked to mortality, and avoided mortality constitutes a large portion of overall CAAA benefits. Cross estimation of PM <sub>2.5</sub> , however, is based on studies that account for seasonal and geographic variability in size and species composition of particulate matter. Also, results are aggregated to the annual level, improving the accuracy of cross estimation.
Use of separate air quality models for individual pollutants and for different geographic regions does not allow for a fully integrated analysis of pollutants and their interactions.	Unable to determine based on current information	Potentially major. There are uncertainties introduced by different air quality models operating at different scales for different pollutants. Interaction is expected to be most significant for PM estimates. However, important oxidant interactions are represented in all PM models and the models are being used as designed. The greatest likelihood of error in this case is for the summer period in areas with NO <sub>x</sub> inhibition of ambient ozone (e.g., Los Angeles).



POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE*
Future-year adjustment factors for seasonal or annual monitoring data are based on model results for a limited number of simulation days.	Overall, unable to determine based on current information	Probably minor. RADM/RPM and REMSAD PM modeling simulation periods represent all four seasons and characterize the full seasonal distribution. Potential overestimation of ozone, due to reliance on summertime episodes characterized by high ozone levels and applied to the May-September ozone season, is mitigated by longer simulation periods, which contain both high and low ozone days. Also, underestimation of UAM-V western and UAM-IV Los Angeles ozone concentrations (see below) may help offset the potential bias associated with this uncertainty.
Comparison of modeled and observed concentrations indicates that ozone concentrations in the western states were somewhat underpredicted by the UAM-V model, and ozone concentrations in the Los Angeles area were underestimated by the UAM-IV model.	Unable to determine based on current information	Probably minor. Because model results are used in a relative sense (i.e., to develop adjustment factors for monitor data) the tendency for UAM-V or UAM to underestimate absolute ozone concentrations would be unlikely to affect overall results. To the extent that the model is not accurately estimating the relative changes in ozone concentrations across regulatory scenarios, the effect could be greater.
Ozone modeling in the eastern U.S. relies on a relatively coarse 12 km grid, suggesting NO <sub>x</sub> inhibition of ambient ozone levels may be underrepresented in some eastern urban areas. Coarse grid may affect both model performance and response to emissions changes.	Unable to determine based on current information	Probably minor. Though potentially major for eastern ozone results in those cities with known NO <sub>x</sub> inhibition, ozone benefits contribute only minimally to net benefit projections in this study. Grid size affects chemistry, transport, and diffusion processes which in turn determine the response to changes in emissions, and may also affect the relative benefits of low-elevation versus high-stack controls. However, the approach is consistent with current state-of-the-art for regional-scale ozone modeling.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE*
UAM-V modeling of ozone in the western U.S. uses a coarser grid than the eastern UAM-V (OTAG) or UAM-IV models, limiting the resolution of ozone predictions in the West.	Unable to determine based on current information	Probably minor. Also, probably minor for ozone results. Grid cell-specific adjustment factors for monitors are less precise for the west and may not capture local fluctuations. However, exposure tends to be lower in the predominantly non-urban west, and models with finer grids have been applied to three key population centers with significant ozone concentrations. May result in underestimation of benefits in the large urban areas not specifically modeled (e.g., Denver, Seattle) with finer grid.
Emissions estimated at the county level (e.g., area source and motor vehicle NO <sub>x</sub> and VOC emissions) are spatially and temporally allocated based on land use, population, and other surrogate indicators of emissions activity. Uncertainty and error are introduced to the extent that area source emissions are not perfectly spatially or temporally correlated with these indicators.	Unable to determine based on current information	Probably minor. Potentially major for estimation of ozone, which depends largely on VOC and NO <sub>x</sub> emissions; however, ozone benefits contribute only minimally to net benefit projections in this study.
The REMSAD model underpredicted western PM concentrations during fall and winter simulation periods.	Unable to determine based on current information	Probably minor. Because model results are used in a relative sense (i.e., to develop adjustment factors for monitor data) REMSAD's underestimation of absolute PM concentrations would be unlikely to significantly affect overall results. To the extent that the model is not accurately estimating the relative changes in PM concentrations across regulatory scenarios, or the individual PM components (e.g., sulfates, primary emissions) do not vary uniformly across seasons, the affect could be greater.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE*
Lack of model coverage for acid deposition in Western states.	Underestimate	Probably minor. Because acid deposition tends to be a more significant problem in the eastern U.S. and acid deposition reduction contributes only minimally to net monetized benefits, the monetized benefits of reduced acid deposition in the western states would be unlikely to significantly alter the total estimate of monetized benefits.
Uncertainties in biogenic emissions inputs increase uncertainty in the AQM estimates.	Unable to determine based on current information	Probably minor. Potentially major impacts for ozone outputs, but ozone benefits contribute only minimally to net benefit projects in this study. Uncertainties in biogenics may be as large as a factor of 2 to 3. These biogenic inputs affect the emissions-based VOC/NO <sub>x</sub> ratio and, therefore, potentially affect the response of the modeling system to emissions changes.
<p>* The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of “potentially major” if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of “probably minor.”</p>		

TABLE A-4. KEY UNCERTAINTIES ASSOCIATED WITH HUMAN HEALTH EFFECTS MODELING

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
Application of C-R relationships only to those subpopulations matching the original study population.	Underestimate	Potentially major. The C-R functions for several health endpoints (including PM-related premature mortality) were applied only to subgroups of the U.S. underestimate the whole population benefits of reductions in pollutant exposures. In addition, the demographics of the study population in the Pope et al. study (largely white and middle class) may result in an underestimate of PM-related mortality, because the effects of PM tend to be significantly greater among groups of lower socioeconomic status.
No quantification of health effects associated with exposure to air toxics.	Underestimate	Potential major. According to EPA criteria, over 100 air toxics are known or suspected carcinogens and many air toxics are also associated with adverse health effects such as neurotoxicity, reproductive toxicity, and developmental toxicity. Unfortunately, current data and methods are insufficient to develop (and value) quantitative estimates of the health effects of these pollutants.
Use of long-term global warming estimates in Title VI analysis that show more severe warming than is now generally anticipated.	Overestimate (for Title VI estimate only)	Potentially major. Global warming can accelerate the pace of stratospheric ozone recovery; if warming is less severe than anticipated at the time the Title VI analyses were conducted, the modeled pace of ozone recovery may be overestimated, suggesting benefits of the program could be delayed, perhaps by many years. The magnitude of estimated Title VI benefits suggests that the impact of delaying benefits could be major.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
<p>The quantitative analysis of Title VI (see next section) does not account for potential increases in averting behavior (i.e., people’s efforts to protect themselves from UV-b radiation).</p>	<p>Unable to determine based on current information</p>	<p>Potentially major. Murdoch and Thayer (1990) estimate that the cost-of-illness estimates for nonmelanoma skin cancer cases between 2000 and 2050 may be almost twice the estimated cost of averting behavior (application of sunscreen). Our Title VI analysis relies on epidemiological studies, which incorporate averting behavior as currently practiced. Omission of future increases in averting behavior, however, may overstate the benefits of reduced emissions of ozone-depleting chemicals. Benefits could be understated if individuals alter their behaviors in ways that could increase exposure or risk (e.g., sunbathing more frequently). A recent European study by Autier et al. (1999) found that the use of high sun protection factor (SPF) sun screen is associated with increased frequency and duration of sun exposure.</p>
<p>Analysis assumes a causal relationship between PM exposure and premature mortality based on strong epidemiological evidence of a PM/mortality association. However, epidemiological evidence alone cannot establish this causal link.</p>	<p>Unable to determine based on current information</p>	<p>Potentially major. A basic underpinning of this analysis, this assumption is critical to the estimation of health benefits. However, the assumption of causality is suggested by the epidemiologic evidence and is consistent with current practice in the development of a best estimate of air pollution-related health benefits. At this time, we can identify no basis to support a conclusion that such an assumption results in a known or suspected overestimation bias.</p>

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
Across-study variance/application of regionally derived C-R estimates to entire U.S.	Unable to determine based on current information	Potentially major. The differences in the expected changes in health effects calculated using different underlying studies can be large. If differences reflect real regional variation in the PM/mortality relationship, applying individual C-R functions throughout the U.S. could result in considerable uncertainty in health effect estimates.
Estimate of non-melanoma skin cancer mortality resulting from reductions in stratospheric ozone is calculated indirectly, by assuming the mortality rate is a fixed percentage of non-melanoma incidence.	Unable to determine based on current information	Potentially major. New data on the death rate for non-melanoma skin cancer may significantly influence the Title VI mortality estimate. Some preliminary estimates suggest that this estimate may need to be adjusted downward.
The baseline incidence estimate of chronic bronchitis based on Abbey et al. (1995) excluded 47 percent of the cases reported in that study because those reported “cases” experienced a reversal of symptoms during the study period. These “reversals” may constitute acute bronchitis cases that are not included in the acute bronchitis analysis (based on Dockery et al. 1996).	Underestimate	Probably minor. The relative contribution of acute bronchitis cases to the overall benefits estimate is small compared to other health benefits such as avoided mortality and avoided chronic bronchitis.
CAAA fugitive dust controls implemented in PM non-attainment areas would reduce lead exposures by reducing the re-entrainment of lead particles emitted prior to 1990. This analysis does not estimate these benefits.	Underestimate	Probably minor. While the health and economic benefits of reducing lead exposure can be substantial (e.g., see section 812 Retrospective Study Report to Congress), most additional fugitive dust controls implemented under the Post-CAAA scenario (e.g., unpaved road dust suppression, agricultural tilling controls, etc.) tend to be applied in relatively low population areas.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
Exclusion of C-R functions from short-term exposure studies in PM mortality calculations.	Underestimate	Probably minor. Long-term PM exposure studies may be able to capture some of the impact of short-term peak exposure on mortality; however, the extent of overlap between the two study types is unclear.
Age-specific C-R functions for PM related premature mortality not reported by Pope et al. (1995). Estimation of the degree of life-shortening associated with PM-related mortality used a single C-R function for all applicable age groups.	Unable to determine based on current information	Unknown, possibly major when using a value of life year's approach. Varying the estimate of degree of prematurity has no effect on the aggregate benefit estimate when a value of statistical life approach is used, since all incidences of premature mortality are valued equally. Under the alternative approach based on valuing individual life-years, the influence of alternative values for number of average life years lost may be significant.
Assumption that PM-related mortality occurs over a period of five-years following the critical PM exposure. Analysis assumes that 25 percent of deaths occur in year one, 25 percent in year two, and 16.7 percent in each of the remaining three years.	Unable to determine based on current information	Probably minor. If the analysis underestimates the lag period, benefits will be overestimated, and vice-versa. However, available epidemiological studies do not provide evidence of the existence or potential magnitude of a lag between exposure and incidence. Thus, an underestimate of the lag seems unlikely. If the assumed lag structure is an overestimate, even if benefits are fully discounted from the future year of death, application of reasonable discount rates over this period would not significantly alter the monetized benefit estimate.

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS ESTIMATE	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES IN NET BENEFIT ESTIMATE*
Extrapolation of criteria pollutant concentrations to populations distant from monitors.	Unable to determine based on current information	Probably minor. Extrapolation method is most accurate in areas where monitor density is high. Monitor density tends to be highest in areas with high criteria pollutant exposures; thus most of this uncertainty affects low exposure areas where benefits are likely to be low. In addition, an enhanced extrapolation method incorporation modeling results is used for areas far (> 50 km) from a monitor.
Exposure analysis in areas beyond 50 km is based on a new technique that relies on the direct use of air quality modeling results in combination with adjusted monitor data.	Unable to determine based on current information	Probably minor. The new technique is used for less than 10 percent of the country for PM exposure, and less than 15 percent for ozone. The approach we use should be more accurate than the alternative approach of linear interpolation over long distances. The new method nonetheless requires further testing against monitor data to access its accuracy.
Pope et al. (1995) study did not include pollutants other than PM.	Unable to determine based on current information	Probably minor. If ozone and other criteria pollutants correlated with PM contribute to mortality, that effect may be captured in the PM estimate. Thus, PM is essentially used as a surrogate for a mix of pollutants. This uncertainty does make it difficult to disaggregate avoided mortality benefits by pollutant; however other studies (besides Pope) suggest that PM is the dominant factor in premature mortality.
* The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of "potentially major" if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of "probably minor."		



TABLE A-5. KEY UNCERTAINTIES ASSOCIATED WITH ECOLOGICAL EFFECTS ESTIMATION

POTENTIAL SOURCE OF ERROR	DIRECTION OF POTENTIAL BIAS FOR NET BENEFITS	LIKELY SIGNIFICANCE RELATIVE TO KEY UNCERTAINTIES ON NET BENEFITS ESTIMATE*
Incomplete coverage of ecological effects identified in existing literature, including the inability to adequately discern the role of air pollution in multiple stressor effects on ecosystems.	Underestimate	Potentially major. The extent of unquantified and unmonetized benefits is largely unknown, but the available evidence suggests the impact of air pollutants on ecological systems may be widespread and significant. At the same time, it is possible that a complete quantification of effects might yield economic valuation results that remain small in comparison to the total magnitude of health benefits.
Omission of the effects of nitrogen deposition as a nutrient with beneficial effects.	Overestimate	Probably minor. Although nitrogen does have beneficial effects as a nutrient in a wide range of ecological systems, nitrogen in excess also has significant and in some cases persistent detrimental effects that are also not adequately reflected in the analysis.
Incomplete assessment of long-term bioaccumulative and persistent effects of air pollutants.	Underestimate	Potentially major. Little is currently known about the longer-term effects associated with the accumulation of toxins in ecosystems. But what is known suggests the potential for major impacts. Future research into the potential for threshold effects is necessary to establish the ultimate significance of this factor.
The PnET II modeling of the effects of ozone on timber yields relies on a simplified mechanism of response (i.e., changes in net primary productivity).	Overestimate	Probably minor. Existing evidence suggests that the growth changes PnET II projects are relatively large, however none of the currently available points of comparison fully address such issues as the impact of stand-level competition, and the net primary productivity results are within the range of results of other studies of environmental and anthropogenic stressors.
* The classification of each potential source of error reflects the best judgment of the section 812 Project Team. The Project Team assigns a classification of “potentially major” if a plausible alternative assumption or approach could influence the overall monetary benefit estimate by approximately five percent or more; if an alternative assumption or approach is likely to change the total benefit estimate by less than five percent, the Project Team assigns a classification of “probably minor.”		

TABLE A-6. SUMMARY OF KEY SOURCES OF UNCERTAINTY AND THEIR IMPACT ON COSTS AND BENEFITS

SOURCE OF UNCERTAINTY	DESCRIPTION OF ALTERNATIVE PARAMETER INPUTS	IMPACT ON ANNUAL ESTIMATES IN 2010	
		COSTS	BENEFITS
Measurement error and uncertainty in the physical effects and economic valuation steps.	Use a range of input assumptions to reflect statistical measurement uncertainty in concentration-response functions, modeling of physical effects, and estimation of economic values. Most important input parameters are value of statistical life and estimated relationship between particulate matter and premature mortality (see Chapters 5, 6, and 7).	None	For Titles I through V, effect of the use of alternative input assumptions ranges from \$84 billion decrease (5 <sup>th</sup> percentile) to a \$160 billion increase (95 <sup>th</sup> percentile).
Measurement error and uncertainty in direct cost inputs	Use alternative assumptions for key input parameters for six of the highest cost provisions. Conduct sensitivity tests for each provision separately (see Chapter 3, pages 30 to 32). As discussed in Chapter 3 and in this chapter, aggregation of provision-specific results would be inappropriate.	High estimates for some provisions are \$1 billion higher than primary estimate. Low estimates are as much as \$2 billion below primary estimates.	None
Value of statistical life-based estimates do not reflect age at death.	Use estimates of the incremental number of life-years lost from exposure to ambient PM and a value of statistical life-year as opposed to measuring number of lives lost and a value of statistical life (see Chapters 5 and 6).	None	Decrease by \$47 billion
Basis of estimate of avoided mortality from PM exposure	The Dockery et al. study provides an alternative estimate of the long-term relationship between chronic PM exposure and mortality (see Chapter 5).	None	Increase by \$100 to \$150 billion
Uncertainties in title VI health benefits analysis	Major uncertainties include: estimating fatal cancer cases resulting from UV-b exposure; not accounting for future averting behavior; and not accounting for future improvements in the early detection and treatment of melanoma (see Table 5–6).	None	Not quantified, but net effect is probably that benefits estimates are too low.

SOURCE OF UNCERTAINTY	DESCRIPTION OF ALTERNATIVE PARAMETER INPUTS	IMPACT ON ANNUAL ESTIMATES IN 2010	
		COSTS	BENEFITS
Omission of potentially important benefits categories from primary estimates.	Non-quantified categories of impacts summarized in Chapters 5 and 7. Quantified but omitted categories include household soiling, nitrogen deposition, and residential viability (see Chapter 7).	None	Increase by at least \$8 billion, (does not reflect unquantified categories).