Analysis of the Acid Deposition and Ozone Control Act (S. 172)

Prepared for:

The Senate Subcommittee on Clean Air, Wetlands, Private Property, and Nuclear Safety

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Office of Air and Radiation
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This analysis of Senate Bill 172 (S. 172) has been developed by the U.S. Environmental Protection Agency, Clean Air Markets Division in the Office of Atmospheric Programs. The analysis was requested by Senator James M. Inhofe, Chair of the Senate Subcommittee on Clean Air, Wetlands, Private Property, and Nuclear Safety. The report is an analysis of emissions and atmospheric impacts, costs, benefits and implications of S. 172 and does not represent an Agency endorsement or critique of the Bill itself. EPA personnel in the Office of Air and Radiation, and the Office of Research and Development contributed to the analysis. The analysis included technical components contributed by: ICF Consulting with Pechan Associates, Stratus Consulting, Inc., Dyntel, Inc., ASI, Inc., and Charles Driscoll of Syracuse University. This analysis utilizes approaches, methods, and tools that have received prior review and appear in the peer-reviewed literature or in EPA reports that received high-level Agency technical review.

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Executive Summary

This document, developed by the U.S. Environmental Protection Agency in response to a Congressional request, analyzes the environmental impacts, costs, and benefits of Senate Bill 172 (S. 172). The bill, entitled the Acid Deposition and Ozone Control Act, is designed to address multiple regional and national-scale health and environmental impacts associated with emissions from power generation.

S. 172 mandates year-round reductions in electric utility emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X). SO_2 emissions from utilities are to be cut in half, compared to the levels allowed by Title IV (Acid Deposition Control or "Acid Rain Program") of the Clean Air Act Amendments of 1990 (CAAA). Annual utility emissions of NO_X are to be reduced by about 60 percent below the levels projected to result from Title IV, with a somewhat greater reduction in the late spring and summer months when NO_X contributes to ozone formation. These reductions are to be achieved through the establishment of a nationwide NO_X cap-and-trade program. The bill also includes provisions relating to the monitoring of mercury levels, the possible reduction in mercury emissions, and the assessment of progress in meeting environmental goals; these provisions are not analyzed in detail in this report.

This report assesses the potential results of implementing S. 172 by comparing emission changes, corresponding changes in air quality and deposition levels, costs, and environmental benefits under a baseline scenario and a scenario representing S. 172. The analysis of costs and benefits employs methodologies with uncertainties that are summarized in Exhibit 27 of this report and described in detail in the Section 812 Prospective Study. Emission inventories (that is, profiles of emissions by pollutant, place, time, and source type) were developed for S. 172, as well as for scenarios with and without implementation of the current Clean Air Act (including Title IV). The impact of S. 172 on emission levels, power generation, and costs of achieving emission reductions were estimated using the Integrated Planning Model (IPM), a detailed linear programming model of the electric utility industry. These emission inventories were then used as inputs into two air quality models (the Regional Acid Deposition Model (RADM) and the Regulatory Modeling System for Aerosols and Acid Deposition (REMSAD)) to predict air concentration and deposition levels of several pollutants. Monetized human health benefits of S. 172 were estimated using existing tools and methods that were employed in two recent EPA studies, the Section 812 Prospective Study and the Regulatory Impact Analysis for the Tier 2 motor vehicle/gasoline sulfur rules (Tier 2 Rules). Specifically, to value reductions in premature mortality, the analysis of S. l72 uses the same approach, based on an estimated value of statistical life (VSL), but, in Exhibit 22, also presents an alternative approach to monetize reductions in premature mortality, based on an estimated value of a statistical life year (VSLY). (For details of the benefit estimation methods used in the analysis of S. l72, see Appendix 3.)

The analysis shows that implementation of S. 172 would substantially reduce emissions of SO_2 and NO_X nationwide, especially in the Ohio River Valley. These reductions would cut ambient air concentrations of fine particulate matter ($PM_{2.5}$) beyond levels that will be seen with the full implementation of Title IV. In turn, these reductions in air concentrations would result in:

- reduced impacts on human health, including a lower incidence of cardiopulmonary illness and death associated with $PM_{2.5}$,
- perceptible improvements in visibility, especially in scenic areas of the East, and
- substantially reduced deposition of sulfur and nitrogen and the associated environmental improvements.

The adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economic and public policy analysis community within and outside the Administration. In response to the sensitivity on this issue, this analysis provides estimates reflecting two alternative approaches. The primary benefits estimate uses a value of a statistical life (VSL) approach developed for the Clean Air Act Section 812 benefit-cost studies. An alternative, age-adjusted approach provides a benefits estimate based upon the value of a statistical life year (VSLY), which is derived directly from the VSL estimate. It differs only in incorporating an explicit assumption about the number of life years saved and an implicit assumption that the valuation of each life year is not affected by age. In addition, the independent outside economics experts of the Science Advisory Board Environmental Economics Advisory Committee recently conveyed new advice to EPA indicating support for EPA's continued reliance—pending the results of additional research—on the VSL approach for its primary analysis[1] and raising additional issues concerning the validity and reliability of the VSLY approach.[2] The primary estimate of S.172 benefits, using VSL to value reductions in premature mortality, results in total monetized health benefits of approximately $59.5 billion (1997$) in 2010. The alternative, age-adjusted approach to value reductions in premature mortality yields total monetized health benefits of $37.2 billion in 2010. In addition, there are an estimated $1.2 billion in visibility benefits in 2010. Total estimated annual benefits in 2010 (health plus visibility) of S. 172 monetized in this analysis are $60.7 billion using the primary benefits estimate and $38.4 billion using the alternative, age-adjusted approach.

The annualized compliance cost of S. 172 is estimated to be $5 billion in 2010 (or $3.3 billion greater than the annualized cost in 2010 of implementing the regional NO_X reductions from electricity generating units (EGU) under the NO_X SIP call). Comparing this cost estimate with the primary estimate of the benefits indicates that the estimated net economic benefits to society are approximately $55.7 billion in 2010. Using the alternative, age-adjusted approach to valuing premature mortality, estimated net benefits are approximately $33.4 billion in 2010. Due to the uncertainties associated with this estimate of net benefits, it should be considered along with other components of this analysis, such as total cost, cost-effectiveness, and other considerations of benefits and costs that could not be monetized. (For a list of potential benefits, see Exhibit A3-2.) These unquantified benefits include improvements in coastal and surface waters and forested ecosystems, reduced damage to buildings and monuments, and the health and welfare benefits associated with ozone reductions.

[1] Science Advisory Board. 2000. *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reductions*, EPA-SAB-EEAC-00-013, U.S. EPA Science Advisory Board, Washington, D.C., July 27, 2000, page 1:. "Despite limitations of the VSL estimates, these seem to offer the best available basis at present for considering the value of fatal cancer risk reduction. We therefore recommend that the Agency continue to use a wage-risk-based VSL as its primary estimate, including appropriate sensitivity analyses to reflect the uncertainty of these estimates."

[2] SAB, ibid., page 7: "Inferring the value of a statistical life year ... requires assumptions about the discount rate and about the time path of expected utility of consumption. The Committee agrees with the judgement expressed [by EPA] ... that the theoretically appropriate method is to calculate [willingness to pay] for individuals whose ages correspond to those of the affected population, and that it is preferable to base these calculations on empirical estimates of WTP by age. The Committee urges that more research also be conducted on this topic."

1. Introduction: Continued Environmental and Human Health Concerns

1.1 Background

In the United States, the issue of acidic deposition emerged in the mid-1970s. At the time, little was known about the magnitude and distribution of acidic deposition, nor about its impacts on terrestrial and aquatic ecosystems. However, many believed that acidic deposition posed a potential threat to forests, aquatic organisms, crops, structures and cultural artifacts, and human health. Requiring further information regarding the formation and environmental effects of acidic deposition, Congress passed the Acid Precipitation Act of 1980 (PL 96-294, Title VII). The Act mandated creation of a federal Interagency Task Force and research effort referred to as the National Acid Precipitation Assessment Program (NAPAP). Beginning in 1980, NAPAP undertook a ten-year study to examine the relationships among fossil fuel combustion, acids, and other pollutants formed by emissions, and the effects of these pollutants on the environment, the economy, and human health.

The NAPAP 1990 Integrated Assessment Report documented a causal link between emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_X) and increases in the atmospheric concentration of acidic pollutants and "acid rain" (the common term used to describe deposition of acidic particles and acidic precipitation) (NAPAP 1991). Increases in wet and dry acidic deposition, and the emissions that produce them, were linked to acidification of surface water, decline of aquatic ecosystem health, depletion of forest soil nutrients and decline of health of some tree species, damage to structures and cultural materials, adverse impacts on human health, and increase of regional haze and reduced visibility.

In 1990, Congress took action intended to address the issues examined in a decade of research, passing Title IV of the Clean Air Act Amendments (CAAA) (42 U.S.C. 7651). The purpose of Title IV of the CAAA was to reduce the adverse effects of acidic deposition through phased reductions of annual emissions of its precursors, SO_2 and NO_X. As a means for achieving these reductions, Title IV authorized the creation of the Acid Deposition Control Program, commonly known as the "Acid Rain Program."

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Human health impacts of fine particulate matter ($PM_{2.5}$), including impacts of sulfates and nitrates – A substantial body of published scientific literature recognizes a correlation between elevated fine PM and increased incidence of illness and premature mortality. Much of this literature is summarized in the 1996 PM Criteria Document (U.S. EPA 1996a). Some scientific studies cited have attempted to correlate elevated fine PM levels and health effects while controlling for weather, individual health status and habits (such as smoking), and potentially confounding pollutants. Other research has shown the impact of outdoor fine PM on indoor fine PM levels. Though uncertainties remain, human health impacts are associated with both acute and chronic exposure to elevated PM, especially exposure to fine PM (i.e., $PM_{2.5}$ comprised of particles smaller than 2.5 micrometers in diameter) that can penetrate deep into the lungs. The health impacts include premature mortality, new cases of chronic bronchitis, hospitalizations due to cardio-respiratory symptoms, emergency room visits due to aggravated asthma symptoms, and acute respiratory symptoms (U.S. EPA 1995, U.S. EPA 1999b (the Section 812 Prospective Study) and U.S. EPA 1999c (Tier 2 RIA)).

$PM_{2.5}$ primarily consists of secondary particles formed by gaseous emissions including SO_2 and NO_X emissions from utilities. These gases interact in the atmosphere to form

Implemented by the Environmental Protection Agency, the program consists of two major components: SO_2 and NO_X emission reductions.

- The SO_2 emission reduction program employs a market-based mechanism to achieve reductions at low costs. The goal of this component is to reduce total annual SO_2 emissions by 10 million tons below 1980 levels by 2010 (roughly a 40 percent reduction), with Phase I initiated in January 1995 and Phase II in January 2000. When the SO_2 emission reduction component of the program is fully implemented, electric utility emissions will be capped at 8.95 million tons per year (representing approximately a 50 percent reduction for this sector). Non-utility industrial emissions of SO_2 were limited to 5.6 million tons per year, beginning in 1995.
- The NO_X emission reduction program aims to reduce annual NO_X emissions from coal-fired electric utility boilers by 2 million tons below what they would have been without Title IV. Phase I began in January 1996 and Phase II became effective in January 2000. There is no cap on NO_X emissions; with increased power generation, emissions may begin to rise gradually during Phase II.

1.2 Progress Using the Cap-and-Trade Mechanism

In creating Title IV, which established the Acid Rain Program, Congress chose a newer form of regulation as compared to more traditional command and control approaches. Results from Phase I of the Acid Rain Program clearly demonstrate the success of the innovative "cap-and-trade" approach to environmental management. In short, emissions of SO_2 have declined further, more rapidly, and at less cost than anticipated when Title IV was passed. More recently, implementation of a NO_X cap-and-trade program by eight northeastern states in the Ozone Transport Region has shown that the cap-and-trade approach can be applied successfully to additional pollutants.

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sulfates and nitrates. Sulfate aerosols comprise the majority of acidic aerosols in ambient air and a significant portion of atmospheric $PM_{2.5}$. In the eastern United States, sulfate aerosols represent 30 to 40 percent of the average ambient levels of $PM_{2.5}$; in the western United States, sulfates constitute 10 percent of $PM_{2.5}$, and nitrates constitute 15 to 20 percent (NAPAP 1998). While EPA's current programs under Title I and Title IV of the Clean Air Act Amendments of 1990 reduce PM pollution and thus reduce the associated health effects, additional reductions in SO_2 and NO_X emissions would further improve public health.

Visibility and regional haze impacts of particulate matter – Sulfates and nitrates that form in the atmosphere from SO_2 and NO_X emissions contribute to visibility impairment. Data from eleven IMPROVE visibility monitoring stations from 1991-1997 demonstrate a substantial difference in visibility between eastern and western monitoring stations (DOI 1999). Sulfates are a significant cause of visibility impairment in all areas of the United States, particularly in the East where high humidity increases the light extinction efficiency of sulfates and other particles. Data from 1991-1997 at four eastern IMPROVE network visibility monitoring sites (Acadia, Everglades, Great Smoky Mountains, and Shenandoah) demonstrate that sulfates contributed from 57 to 69 percent of the total light extinction (DOI 1999). Reduced SO_2 emissions under Title IV and EPA's Regional Haze Rule (40 CFR 51 July 18, 1997) are expected to decrease sulfate concentrations and their contribution to haze.

In the West, the contribution of nitrates to visibility impairment

The Acid Rain Program has been highly successful in achieving emission reduction targets established in the CAAA. In 1995, the first year of compliance under the Acid Rain Program, SO_2 emissions declined dramatically – by over three million tons – resulting in a nearly five million ton reduction of SO_2 from electric power generation from 1980 levels. Over the first four years of the program, emissions from Phase I units were about 30 percent below allowable levels and sulfur deposition decreased by as much as 25 percent. It is particularly important that the most significant emission reductions occurred in the highest-emitting states and regions of the country. Phase II requires further emission reductions to achieve the total ten million ton reduction in SO_2 emissions mandated by the CAAA.

In addition, implementation of SO_2 emission reductions has been achieved at a cost significantly lower than originally projected. In 1990, EPA projected that fully implementing the SO_2 emission reduction program, including allowance trading, would cost up to $5.9 billion per year (ICF 1990).[3] In 1994, the U.S. General Accounting Office projected that costs could be less than $2.5 billion per year (GAO 1994). According to a 1998 study published by Resources for the Future, the most recent estimate of annualized cost of compliance is approximately $1 billion per year (Burtraw et al. 1998).

Control of NO_X from coal-fired utility boilers under the Acid Rain Program began in 1996. For Phase I utility units, the average NO_X emission rate declined by 42 percent (from 0.69 lb/mmBtu to 0.40 lb/mmBtu). These same units exhibited about a 35 percent reduction in tons of NO_X emitted (approximately 400,000 tons below the 1990 level). However, NO_X emissions in 1997 and 1998 increased slightly from 1996 on both a national and a unit-by-unit basis, because of greater electricity production. In 2000, NO_X emissions from electric utility boilers will decline further for a total reduction of over two million tons per year. Without additional requirements to reduce emission rates,

[3] Note that all cost and benefit values have been developed in or converted to 1997 dollars.

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typically exceeds that of sulfates. For example, nitrates dominate visibility problems in mountainous areas outside Los Angeles. Western visibility impairment is often a localized problem dominated by NO_X emissions from cars and trucks. Even so, because changes in PM concentrations are more visibly noticeable in relatively cleaner air, reducing western emissions of NO_X from power generation (and, in some places, SO_2) may contribute to significant and perceptible improvements in western visibility (U.S. EPA 1996b;U.S. EPA 1997a).

Human health and ecological impacts of ozone – The emission of NO_X is a key contributor to the formation of ground-level ozone. While naturally occurring stratospheric ozone provides an important shield from dangerous solar radiation, ground-level ozone is the primary ingredient in smog. By 1970, research had identified ozone as an intensely irritant gas and had observed a wide variation in individual reactions to ozone exposure. Short-term (1-3 hours) and prolonged (6-8 hours) exposures to ground-level ozone have been linked to a number of deleterious health effects. Increases in U.S. and Canadian hospital admissions for acute respiratory disease have been associated with high levels of ambient ozone during the summer. Emergency room visits by asthmatics are known to increase during ozone episodes. Prolonged exposure to ozone can cause repeated inflammation of the lungs, which could lead to premature aging of the lungs and/or chronic respiratory illnesses, such as emphysema, chronic bronchitis and chronic asthma. Children are most at risk from ozone exposure because typically they are active outdoors however, NO_X emissions are expected to rise gradually with increased utilization of coal-fired boilers for the generation of electricity.

1.3 Increasing Concerns for Multiple Effects of Emissions from Power Generation

On the basis of new research results on the effects of sulfur and nitrogen deposition, questions have been raised as to whether the health and environmental goals of Title IV can be achieved with the emission reduction targets provided under Title IV. Some of these results, as well as basic discussions of the complex effects of emissions from power generation, are highlighted in the boxes accompanying these pages. Given that Title IV is not yet fully implemented, it is premature to draw final conclusions regarding the ecological response to the full range of Title IV provisions. However, concerns identified by modeling results and recent analyses of ecological response to Phase I reductions raise the possibility that Title IV is moving us in the right direction, but not far enough. In other words, while the innovative and flexible approach implemented under Title IV has been extremely successful in achieving cost-effective emission reductions, the anticipated levels of environmental, human health, and other benefits may not be realized without emission reductions beyond those mandated under Phase II of the Acid Rain Program.

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during the summer when ozone levels are highest. Evidence also exists of a possible relationship between daily increases in ozone levels and increases in daily mortality levels. (U.S. EPA 1999c). Because a number of recent studies have identified key health effects caused when people are exposed to levels of ozone found in many areas of the country, ozone reduction is a pressing public health issue.

Ozone also affects ecosystems and vegetation, causing decreased agricultural and commercial forest yields, increased mortality and reduced growth of tree seedlings, and increased plant susceptibility to disease, pests, and environmental stresses (e.g., harsh weather) (U.S. EPA 1998a). Since NO_X emissions result in formation of ground-level ozone, reducing NO_X emissions will reduce ozone levels and thus reduce ozone's deleterious effects on human health and on ecosystems.

Slow recovery of surface waters in the eastern United States – Overall indicators of recovery of lakes and streams, such as acid neutralizing capacity (ANC) and pH, show little consistent change in the eastern United States in response to reduced SO_2 emissions (Likens et al. 1996). In some regions, lakes and streams have exhibited substantial decreases in sulfate concentrations in response to reduced levels of atmospheric sulfur deposition (Stoddard et al. 1999). In areas such as New England, lakes and streams demonstrate evidence of recovery from acidification (Stoddard et al. 1998; NAPAP 1998). In areas such as the Adirondacks, however, the majority of lakes have remained fairly constant in terms of acidification levels, while the most sensitive Adirondack lakes continue to acidify (Driscoll et al. 1998; NAPAP 1998; Stoddard et al. 1998). Acid deposition can cause long-term adverse effects on fish populations and other aquatic organisms in lakes and streams that are chronically acidic. As surface waters acidify, pH levels decrease, with increasingly significant impacts on aquatic organisms and overall aquatic biodiversity. While many fish species are acid-sensitive, the primary lethal agent is increased concentrations of dissolved aluminum in stream water that occur with falling pH levels (Bulger et al. 1998; Van Sickle et al. 1996). Recent research on small streams also demonstrates that episodic acidification can have long-term adverse effects on fish communities (Baker et al. 1996).

Ecological impacts of episodic acidification – Episodic acidification involves short-term (hours to weeks) decreases of ANC which often occur during high stream flow associated with hydrologic events that have a strong seasonal correlation, such as rainstorms or snow melt. Recent research demonstrates that surface waters affected by acidic deposition have episodes of greater magnitude

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(lower pH and ANC and higher aluminum concentrations) and longer duration than would occur as a result of natural processes alone (Wigington et al. 1996a). Moreover, recent findings also suggest that nitrogen is quantitatively as important or, in some areas, possibly more important than sulfur as a cause of episodic acidification (NAPAP 1998; Wigington et al. 1996b). Year-round reductions of NO_X, particularly during winter, are critical for addressing these concerns.

Nitrogen deposition impacts on high elevation western lakes – Recent research shows high nitrate concentrations in surface waters of high-elevation tundra and spruce-fir forest watersheds in the Colorado Front Range (Williams and Tonnessen, in press; Williams et al. 1996). Nitrogen deposition stimulates changes in alpine tundra biotic communities that exacerbate nitrogen losses to alpine streams and help to account for increased surface water nitrate concentrations (Bowman and Steltzer 1998).

Atmospheric nitrogen deposition impacts on coastal water quality – Atmospheric deposition is a rapidly growing anthropogenic source of biologically available nitrogen in marine and coastal systems. Depending upon the location, from 10 percent to more than 40 percent of new nitrogen inputs to coastal waters along the east coast of the United States are of atmospheric origin (Valigura et al. 1996). Increased inputs of nitrogen to estuarine and coastal waters can have significant ecological impacts, including massive die-offs of estuarine and marine plants and animals, loss of biological diversity, and degradation of essential coastal ecosystem habitat (e.g., seagrass beds). Recent studies also link atmospheric nitrogen deposition, coastal eutrophication, and harmful algal blooms with human health impacts (Paerl and Whitall 1999; Epstein et al. 1998; Burkholder and Glasgow 1997; Paerl 1997).

Air pollution impacts on forests and forest soils – Air pollution can affect forest ecosystems by directly damaging plant tissue (Taylor et al. 1994). One of the best examples of direct damage involves leaching of foliar calcium from the needles of red spruce, which reduces the cold tolerance of individual trees and has contributed to the decline of montane red spruce forests throughout eastern North America (DeHayes et al. 1999). In other cases, multiple air pollutants such as ozone, SO_2, and NO_X can combine to weaken trees and make them vulnerable to other threats, such as pests, which cause mortality (Fenn and Bytnerowicz 1993; Bytnerowicz and Fenn 1996). Air pollution also can impact forest ecosystems by causing physiological changes that either reduce the productivity of an individual tree species or otherwise alter a species' competitive advantage. Impacts of sulfur and nitrogen deposition on forest soils include: (1) leaching of plant nutrients from soils, particularly base cations like calcium, magnesium, and potassium (Lawrence et al. 1995; Lawrence et al. 1997); (2) elevated levels of aluminum and calcium/aluminum ratios in soil water that affect the ability of trees to use soil nutrients (Minocha et al. 1997); and (3) elevated levels of aluminum that can be directly toxic to plant roots (Minocha et al. 1996).

Terrestrial and aquatic impacts of nitrogen saturation – Human activity has greatly altered the terrestrial and atmospheric nitrogen cycle, doubling the annual amount of nitrogen available in forms that are useful to living organisms (Vitousek et al. 1997). While nitrogen is an essential nutrient, its availability is naturally limited, making it an important factor in regulating the structure and functioning of both terrestrial (Wedin and Tilman 1996) and aquatic ecological systems (Carpenter et al. 1998). In areas affected by air pollution, nitrogen deposition may be many times higher than background levels. One of the most significant results of elevated nitrogen deposition levels is nitrogen saturation, which involves increased availability of mineral nitrogen in excess of demand by plants (Aber et al. 1989; Aber et al. 1998), accompanied by a decrease in the capacity of ecological systems to retain nitrogen (Magill et al. 1996). In the United States, evidence of nitrogen saturated forest watersheds is most apparent in the northeastern and central regions (e.g., New York, Virginia, West Virginia, Tennessee, North Carolina), southern California (e.g., San Gabriel Mountains, San Bernardino Mountains), southwestern Sierra Nevada mountains in central California, and the Front Range in northern Colorado (Fenn et al. 1998). Nitrogen saturation of watersheds has contributed to environmental problems such as reduced drinking water quality, nitrate-induced toxic effects on freshwater organisms, eutrophication of estuaries and coastal waters, increased soil acidification and aluminum mobility, increased emissions from soil of nitrogenous greenhouse trace gases, reduction of methane consumption in soil, and forest decline and reduced productivity (Fenn et al. 1998).

Acid deposition damage to materials and cultural resources – Approximately 900,000 properties of aesthetic and historical value in the United States are potentially at risk for damage from air pollution, including sulfates, other PM, and ozone. Acid deposition (in both wet and dry form) damages materials and cultural resources, although pollution compromises the general utility of cultural resources (e.g., statues) more rapidly than it diminishes the utility of a bridge or other purely operational assets.

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Structures made of limestone and marble are particularly sensitive to acid deposition. The soiling effects and the loss of structural integrity of the stone associated with the salts produced on stone surfaces as a result of acid deposition are now considered to be potentially more damaging than are the dissolution effects of the actual acid delivered to the stone (NAPAP 1998).

Human health and environmental impacts of mercury emissions – Of the human activities causing mercury to enter the environment, coal-burning electric utilities emit more mercury to the air than any other source category. According to a 1997 EPA report, these utilities contribute about 52 tons annually or one-third of total U.S. anthropogenic emissions. Mercury is transported through the air and deposited to the water and land where humans and wildlife are exposed. Once mercury enters waters, either through air deposition or as it runs off the land, it can bioaccumulate in fish and animal tissue in a highly toxic form, methylmercury. Human exposures are most likely to occur through fish consumption, which can cause a variety of adverse effects depending on the dose and time of exposure. Generally, the most subtle indicator of methylmercury toxicity is neurological impairment. Methylmercury-induced neurotoxicity is of greatest concern when the exposure occurs to the developing fetus and in early childhood. Mercury is the most frequent basis for fish advisories in the United States. Forty-one states have fish advisories warning people about eating fish from over 60 percent of all U.S. water bodies. (For further information, see U.S. EPA 1997b.) In a recent report to Congress, the National Research Council of the National Academies of Science and Engineering reiterated concerns about methylmercury, concluding that each year about 60,000 children may be born in the United States with neurological problems as a result of their mothers' consumption of large amounts of fish and seafood during pregnancy (NRC 2000).

2. The Proposed Legislation

2.1 Brief History

On October 6, 1998, the Subcommittee on Clean Air, Wetlands, Private Property, and Nuclear Safety of the Senate Committee on Environment and Public Works held a hearing on S. 1097, the Acid Deposition Control Act. After the hearing, Senators Daniel Patrick Moynihan and Charles E. Schumer (NY) reintroduced S. 1097 as S. 172, entitled the Acid Deposition and Ozone Control Act. Introduced on January 19, 1999, S. 172 is currently cosponsored by Senators Barbara Boxer (CA), Christopher J. Dodd (CT), Dianne Feinstein (CA), James M. Jeffords (VT), Edward M. Kennedy (MA), John F. Kerry (MA), Frank R. Lautenberg (NJ), Joseph I. Leiberman (CT), Jack Reed (RI), and Ron Wyden (OR). The reintroduced Senate bill has two companion bills in the House: H.R. 25, also entitled the Acid Deposition and Ozone Control Act, which was introduced by Congressman Sherwood L. Boehlert (NY) on January 6, 1999; and H.R. 657, entitled the Acid Deposition Control Act, introduced by Congressman John E. Sweeney (NY) on February 9, 1999.

2.2 Provisions of the Acid Deposition and Ozone Control Act (S. 172)

The bill states that its purpose is to recognize the current scientific understanding that emissions of NO_X and SO_2, and the acid deposition resulting from those emissions, present a substantial human health and environmental risk, and to require reductions in NO_X and SO_2 emissions. In addition, the legislation is intended to support the goals of the Ozone Transport Assessment Group to reduce regional ozone pollution.

The main thrust of the legislation is to mandate reductions in electric utility emissions of SO_2 and NO_X. SO_2 emissions from utilities are to be cut in half, compared to the levels allowed by Title IV. The implementation of these emission reductions is compatible with the existing Title IV SO_2 program: the same cap-and-trade allowance mechanism is to be used, but each allowance will be redefined so as to allow the emission of only half of a ton of SO_2, rather than a full ton, beginning with the allowances issued for the year 2005. This step will result in an effective halving of the SO_2 cap. Annual utility emissions of NO_X are to be reduced by about 60 percent below the levels projected to result from Title IV, with a somewhat greater reduction in the months in which NO_X

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Nitrogen Oxide Allowance Program – Not later than 18 months after enactment of S. 172, EPA must establish a NO_X allowance program. Facilities affected by the program are those with one or more combustion units serving at least one electricity generator with capacity equal to or greater than 25 megawatts.

NO_X Allowance Allocation (emissions caps)

– During calendar years 2002 through 2004, EPA shall distribute 5.4 million NO_X allowances.

– From 2005 onward, EPA shall distribute 3.0 million NO_X allowances.

– Allowances are retired to achieve greater NO_X reductions during the ozone season. Each NO_X allowance authorizes an affected facility to emit one ton of NO_X during the months of October through April, or one-half ton of NO_X during May, June, July, August, and September.

NO_X Allowance Distribution

– Allowances are to be allocated in 2002 and each year thereafter to the 48 contiguous states and the District of Columbia in proportion to each state's share of total electric power generated by all of the states. Each state has discretion over distribution of allowances to individual facilities.

– If a state fails to allocate allowances by September 30, EPA must distribute the NO_X allowances by November 30 to each affected facility in proportion to the affected facility's share of the total electric power generated in the state.

contributes to ozone formation. These reductions are to be achieved through the establishment of a nationwide cap-and-trade program, similar to several recent programs: Title IV's SO_2 program, the cap-and-trade program being used to reduce NO_X in the states of the Ozone Transport Region, and the cap-and-trade program proposed by EPA to reduce ozone transport through revisions to State Implementation Plans (SIPs) for 22 eastern states (i.e., the SIP call). To give utilities the incentive to concentrate their emission reductions in the late spring and summer months (when NO_X emissions contribute strongly to region-wide ozone problems), the allowance mechanism would require the surrender of two allowances for every ton of NO_X emitted in the ozone season, compared to only one allowance per ton in the rest of the year.

The bill also includes provisions relating to the monitoring of mercury levels, but does not directly mandate specific reductions in those levels; future mercury control decisions are left to the EPA Administrator.

The bill's specific provisions to require the SO_2 and NO_X reductions, and its provisions relating to emissions monitoring, assessment and research, and regulation of mercury emissions are presented in the boxes accompanying this section.

2.3 Summary of the Findings

Implementation of S. 172 would substantially reduce emissions of SO_2 and NO_X nationwide, especially in the Ohio River Valley. These reductions would cut ambient air concentrations of $PM_{2.5}$ compared to levels that will be seen with the implementation of Title IV alone. In turn, S. 172's reductions in $PM_{2.5}$ concentrations would lead to a lower incidence of cardio-respiratory illness and death associated with $PM_{2.5}$ pollution, and to perceptible improvements in visibility, especially in scenic areas of the East. S. 172's reductions in the deposition of sulfur and nitrogen also would reduce damage to the ecosystem and to buildings and monuments. By 2010, annual monetized benefits to human health of $59.5 billion (1997$) are projected to result from S. 172 using EPA's primary benefits methodology (value of a statistical life or VSL approach). The VSL approach, favored by some within the economic and public policy community within and outside the Administration, was developed for the Clean Air Act Section 812 benefit-cost studies. Using an alternative, age-adjusted approach to evaluating health benefits (value of a statistical life year (VSLY)) that is preferred by others within the economic and policy analysis community, leads to an to an estimate of annual monetized benefits of $37.2 billion in 2010. This alternative approach leads to an estimate of the

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NO_X Allowance Transfer System

– Within 18 months of enactment, EPA must promulgate regulations for issuing, recording, transferring, and tracking the use and transfer of NO_X allowances.

– The regulations must stipulate that allowances may not be used prior to the calendar year for which they are allocated.

– Unused allowances can be carried forward (banked) and added to future year allocations.

– NO_X allowance allocation or transfer shall be a part of each affected facility's operating permit requirements.

New Source Reserve

– The Administrator will place 10 percent of each state's annual NO_X allowances in a New Source Reserve to be distributed according to criteria outlined in the bill. This provision ensures that new facilities are allocated necessary allowances.

– For the calendar years 2000 through 2005, the Administrator shall conduct auctions for the purpose of allocating undistributed NO_X allowances remaining in the New Source Reserve.

value of a statistical life year (VSLY), which is derived directly from the VSL estimate. It differs only in incorporating an explicit assumption about the number of life years saved and an implicit assumption that the valuation of each life year is not affected by age. In addition, there are an estimated \$1.2 billion in visibility benefits in 2010.

The annualized compliance cost of S. 172 is estimated to be \$5 billion in 2010 (or \$3.3 billion greater than the annualized cost in 2010 of implementing the NO_X SIP call). Comparing this cost estimate with EPA's primary benefits estimate of the economic benefits to society indicates that the estimated net economic benefits to society are approximately \$55.7 billion in 2010. Using the alternative, age-adjusted approach to valuing premature mortality, estimated net benefits are approximately \$33.4 billion in 2010. (This analysis uses methodologies to project emission changes, estimate air quality changes and deposition impact, and value cost of controls as well as benefits related to projected emissions changes. The uncertainties associated with these methodologies used in this analysis to project emission changes are well documented in U.S. EPA 1999b. Also, the benefits monetized here do not reflect the impact of reduced ozone nor do they reflect the benefits of reduced nitrogen and sulfur deposition for lakes, streams, coastal waters, and forests and for buildings and monuments. For a list of potential benefits, see Exhibit A3.2.)

SUMMARY OF S. 172'S PROVISIONS

SO_2 Allowance Program Revisions

– Amends Section 402(3) of the CAA: For allowances allocated for the calendar year 2005 and each year thereafter, each allowance authorizes a facility to emit one half ton of SO_2.

Industrial Source Monitoring

– Requires any industrial facility with a capacity of 100 mmBtus per hour or more to monitor emissions consistent with Title IV.

Mercury Emissions Study and Controls

– Within two years of enactment of S. 172, EPA must report to Congress on the practicality of monitoring mercury emissions from all combustion units with a capacity of at least 250 mmBtus per hour.

– Within one year of submitting the report, EPA must promulgate a regulation requiring reporting of mercury emissions from combustion units with a capacity of at least 250 mmBtus.

– Within one year of commencing monitoring activities, EPA must promulgate a regulation controlling electric utility and industrial source emissions of mercury taking into account technological feasibility, cost, and the projected reduction in levels of mercury emissions that will result from implementation of this bill.

Assessment, Research, and Reporting Requirements

– By December 31, 2002, EPA must submit a report to Congress identifying "objectives for scientifically credible environmental indicators" for sensitive ecosystems as noted in the bill.

– In the 2002 report, the acid neutralizing capacity of water bodies in sensitive receptor areas must be one of the indicators of progress.

– By December 31, 2008, EPA must determine whether the emission reductions required under S. 172 are sufficient to achieve the objectives stated in the 2002 report on environmental indicators for regional ecosystems. If the Administrator determines that emission reductions required under S. 172 are insufficient to achieve the objectives stated in the 2002 report, then EPA must, within two years, promulgate regulations that are necessary to protect the ecosystems described in the 2002 report. Such regulations may include modification of the NO_X and SO_2 caps.

– EPA must establish a competitive grants program funding research on the effects of nitrogen deposition on sensitive watersheds and coastal estuaries in the eastern United States. The bill authorizes appropriation of \$1 million per year for fiscal years 2000 through 2005.

– By September 30, 2001, EPA must report to Congress on the health and chemistry of lakes and streams in the Adirondacks that were subjects of the reports required under Section 404 of the CAAA. Within 2 years, EPA must update the 2001 report. The bill authorizes \$1 million per year for the fiscal years 2000, 2001, 2007, and 2008 to comply with these reporting requirements.

3. Analysis of the Emissions and Costs of S. 172

This report presents the potential results of implementing S. 172 by comparing emission changes, costs, and environmental benefits across emission scenarios. Comparing the costs and environmental impacts of various emission scenarios with the costs and impacts of a scenario representing S. 172 provides estimates of the incremental effects of S. 172.

Emission inventories (that is, profiles of emissions by pollutant, place, time, and source type) were developed for S. 172 as well as for scenarios with and without implementation of the current Clean Air Act (including Title IV). The emission analysis uses emission inventories recently developed for other purposes, where appropriate, and develops several new emission scenarios specific to S. 172.

In particular, the analysis adapted inventories developed for a prospective study required by Section 812 of the Clean Air Act. Using the Section 812 Prospective Study to establish a baseline emission inventory, the utility portion of the inventory was varied (using the Integrated Planning Model (IPM), described in Appendix 1) in order to analyze the impact of S. 172 on emission levels, power generation, and costs of achieving emission reductions. Emission inventories were then used as inputs into two air quality models in order to estimate changes in the air concentration and deposition levels of relevant chemical species. The modeling results of implementing S. 172 were compared to implementation of the current Clean Air Act to examine the consequences of S. 172 implementation on human health and the environment.

3.1 Scenarios Analyzed

S. 172 focuses on emissions from electric power generation because they account for about two-thirds of the total SO_2 emissions and one-third of the NO_X emissions in the United States (U.S. EPA 1998c). Available control options and the costs associated with particular control scenarios are well understood (U.S. EPA 1998d and U.S. EPA 1999b).

For this analysis EPA analyzed emission inventories for the following seven scenarios. In addition to the historical and baseline scenarios, EPA analyzed the full S. 172, its SO_2 provisions alone, and its NO_X provisions alone. Finally, EPA analyzed a scenario representing the effects of the NO_X SIP call, making it possible to assess the effects of S. 172's nationwide, year-round approach relative to the more narrowly focused SIP call.

- **1990 Actual Emission (90 Actual)** – This emission profile is the same as the 1990 emissions used in the Section 812 Prospective Study. The profile consists of actual emissions for all emission sources in the United States for the year 1990. More detail on how this inventory was compiled is available in Appendix 2 of this document and in the Section 812 Prospective Study itself.
- **2010 With No Title IV (No Title IV)** – This profile was developed using runs from the Section 812 Prospective Study under the counterfactual assumption that Title IV's Acid Rain Program was not implemented.
- **Baseline: Existing Clean Air Act (Title IV)** – The baseline scenario for electric utility emissions was

developed using IPM (U.S. EPA 1998d) but without the effect of the NO_X SIP call. To project all non-utility emissions for the year 2010, this scenario employs the Section 812 Prospective Study, assuming full implementation of the existing Clean Air Act.

- **Full Bill: Existing Clean Air Act with additional SO_2 and NO_X controls specified in S. 172 (S. 172)** – This scenario is the same as the Clean Air Act Baseline (including Title IV) plus the reductions called for in S. 172. For this scenario, the relevant provisions of S.172 include a 50 percent reduction in the SO_2 emissions cap beginning in 2005; a national annual NO_X allowance cap for electric generation units set at 5.4 million tons beginning in the year 2002; and reduction of the annual NO_X allowance allocation to 3 million allowances (equal to 2.2 million tons) beginning in the year 2005. The emissions are lower than available allowances because during the ozone season, NO_X emissions count against the NO_X allowance cap on a 2-for-1 basis (i.e., two allowances are required for each ton of emissions) while emissions during the rest of the year count against this cap on a 1-for-1 basis.

- **SO_2 reductions only (SO_2 Only)** – This scenario is the same as the Full Bill scenario except that it does not include additional NO_X controls on electric utility units beyond Title IV.

- **National NO_X reductions only (NO_X Only)** – This scenario is the same as the Full Bill scenario except that it does not include additional SO_2 controls on electric utility units beyond Title IV.

- **State Implementation Plan for Ozone Control (NO_X SIP Call)** – This is the scenario develped for the final regulatory action issued in September 1998. Under this scenario, NO_X emissions from power plants in 22 eastern states and the District of Columbia are held to 549,000 tons for the months of May through September starting in 2003. This cap is based on an emission rate of 0.15 pounds of NO_X per mmBtu, which represents a cut of over 60 percent from the levels allowed by Title IV. Plant-by-plant and state-by-state emissions of NO_X are not assumed to equal 0.15 lbs/mmBtu; instead, they are projected on the assumption that utilities will minimize the costs of meeting the cap under an allowance system. This scenario is detailed in the Regulatory Impact Analysis (U.S. EPA 1998d).

3.2 Analysis of Emissions

This section presents the changes in electric utility emissions that are projected to take place as a result of implementing the provisions of S. 172. Nationwide changes by regulatory scenario are summarized in Exhibit 1. The geographic distribution of these changes is illustrated by Exhibits 2 through 7.

As seen in Exhibit 1, the full S. 172 scenario provides reductions in electric utility emissions of both SO_2 and NO_X, substantially beyond the reductions that Title IV would achieve by itself. Implementing only the SO_2 provisions of S. 172 would provide reductions in that pollutant that would be comparable to the full bill, while leaving NO_X emissions almost unchanged from Title IV levels. Similarly, implementing only the NO_X provisions of S. 172 would reduce NO_X emissions about as much as the full S. 172 without affecting SO_2 significantly.

Exhibit 1
Summary of U. S. Utility Emissions by Scenario (1,000 tons, 2010)

Scenario	NO_X Ozone Season	NO_X Total Annual	SO_2 Total Annual
1990 Actual[a]	2,900[a]	6,664	15,909
Title IV	2,320	5,316	9,692
S. 172 — Both SO_2 and NO_X Provisions	903	2,124	5,952
S. 172 — SO_2 Provisions Only	2,312	5,282	6,309
S. 172 — NO_X Provisions Only	888	2,147	9,662
NO_X SIP Call[b]	1,450[b]	4,254[b]	10,780[b]

Source: EPA analysis.

[a]1990 Actual ozone season emissions were approximated based on annual emissions and seasonal patterns projected for Title IV.

[b]SIP call emissions were estimated as of 2007.

Note: Slight differences in NO_X emissions as a result of shifting from "Title IV" to "S. 172 — SO_2 Provisions Only," or from "S. 172 — NO_X Provisions Only" to "S. 172 — Both SO_2 and NO_X Provisions", are caused by shifts in the use of power plants with differing NO_X emission rates, which result from the imposition of a stricter SO_2 cap, in the absence of a rigid NO_X cap. Similar small shifts in SO_2 emissions in response to changes in NO_X provisions result from changes in allowance banking and hence the timing of a fixed quantity of SO_2 emissions over time.

Exhibit 1 also shows the effects of the NO_X provisions of S. 172 relative to the NO_X SIP call. S. 172 provides somewhat greater reductions in ozone season NO_X than does the SIP call, due in large part to the fact that S. 172 imposes a nationwide cap while the SIP call is limited to 22 eastern states and the District of Columbia. Within just the 22-state SIP call region, S. 172 results in ozone season NO_X emission reductions slightly less than the SIP call (902 thousand tons as compared to 958 thousand tons). The difference between S. 172 and the SIP call is substantial on an annual basis because S. 172 applies a year-round cap while the SIP call's cap is effective only during the ozone season.

Geographic Distribution of SO_2 Emission Changes

Exhibits 2 and 3 show state-by-state electric utility SO_2 emissions comparisons under various scenarios. Exhibit 2 shows actual total annual emissions by state for 1990. Also shown are projections for 2010 without Title IV or S. 172, with Title IV, and with both Title IV and S. 172. Comparing the two upper maps (1990 and 2010 without Title IV) of Exhibit 2 reveals relatively small changes in utility SO_2 emissions over the 20 years from 1990 to 2010. Emissions are projected to fall in a few states for reasons unrelated to acid rain legislation, while increases are seen for many states (e.g., West Virginia, Tennessee, Maryland, Virginia, and Texas) as a result of growth in electricity generation. Title IV is projected to reduce electric utility emissions substantially, as can be seen by comparing the upper right and lower left maps in Exhibit 2. Further reductions, provided by S. 172's SO_2 provisions, are evident in the differences between the two lower maps.

These differences are highlighted in Exhibit 3, which shows the absolute and percentage reductions as S. 172 is added to Title IV. Under the provisions of S. 172, the map of *absolute differences* (reductions in tons/year) in SO_2 emissions resembles the maps of *total* emissions in the No Title IV and Title IV scenarios. The greatest reductions are found in the areas with the greatest baseline emissions: the Ohio River Valley region, with significant, though smaller, absolute reductions seen in the southeast and Pennsylvania. The *percentage* reductions in SO_2 emissions show a somewhat different pattern. Many of the larger percentage reductions occur in the northeast and southeast (e.g., in Pennsylvania and Alabama), while other large percentage reductions are seen in areas such as New England, the Great Plains, and the Northwest. In these cases, moderate reductions from low baseline levels

Exhibit 2: Comparison of Utility SO_2 Emissions

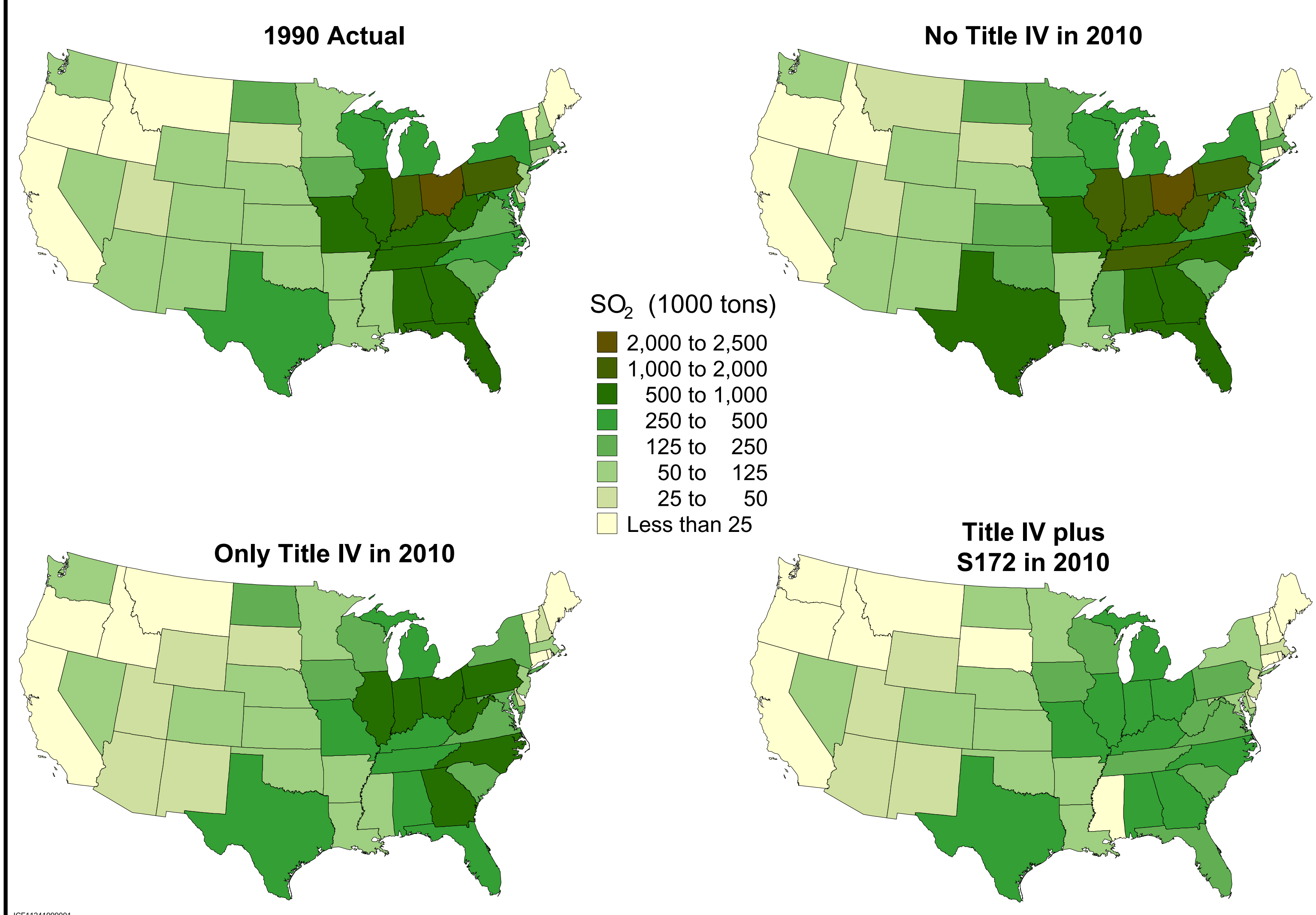
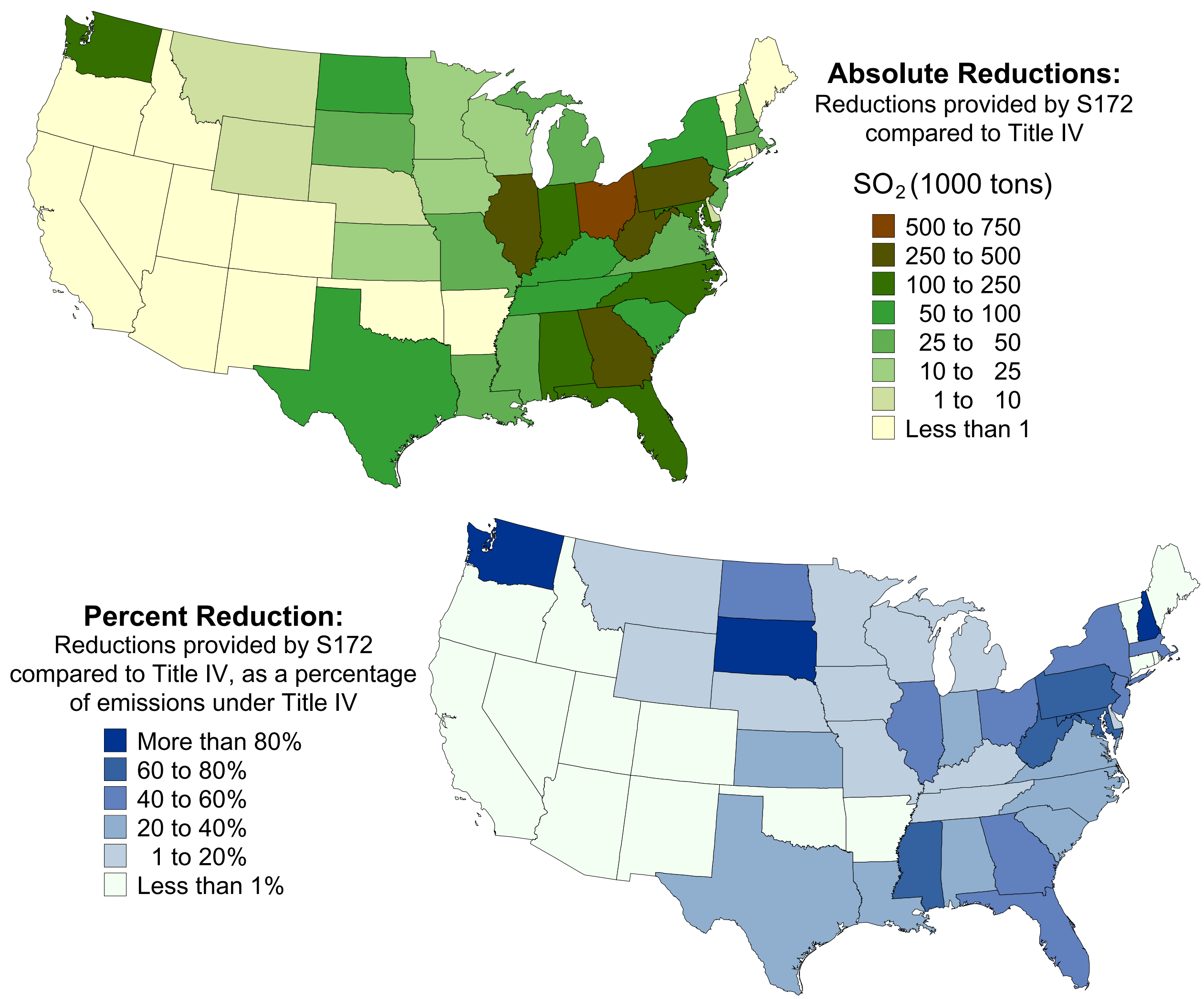


Exhibit 3: Change in Utility SO_2 Emissions

2010 Annual Utility Emissions by State



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result in large percentage changes. In no state do SO_2 emissions increase, relative to Title IV, as a result of S. 172.

Geographic Distribution of NO_X Emission Changes

Changes in NO_X emissions are important both on an annual and a seasonal basis, and so the distribution of NO_X emission reductions is presented below for the entire year and for the ozone season.

Annual Changes

Exhibits 4 and 5 follow the same format as the previous SO_2 maps, showing electric utility NO_X emissions for 1990, and projections under three regulatory scenarios. Without Title IV, growth in emissions is seen from 1990 to 2010, with the highest emissions in the Ohio River Valley and Texas.[4] As with SO_2, emissions under both Title IV and S. 172 are shown to be significantly lower in states across the country (see Exhibit 4). As seen in Exhibit 5, S. 172 would lead to a general pattern of emission reductions in the highest emitting regions. Smaller changes are seen in New England and along the west coast, where regulations other than Title IV have independently cut NO_X emissions. In no states do NO_X emissions increase as a result of S. 172.

Ozone Season Changes

Exhibits 6 and 7 show NO_X emissions and changes for the five-month ozone season (i.e., from May through September). NO_X emissions in the ozone season are reduced under S. 172. The largest absolute reductions occur in the Ohio River Valley region, with significant reductions in Pennsylvania and throughout the South. Emissions in New England, New York, and along the west coast remain essentially unchanged, again due to independent regulatory initiatives. Comparing S. 172 and Title IV, large percentage reductions are spread across wide areas of the country, including the Ohio River Valley. In no state do summertime NO_X emissions increase as a result of S. 172.

3.3 Scenario Analysis: Control Technology Changes

Control Options

Neither Title IV nor S. 172 prescribes how or to what degree specific electric utility units must reduce emissions. Instead, individual units have flexibility to choose compliance strategies within a broad cap or limit. The IPM runs used by EPA to project emissions allowed each unit a choice of techniques for removing NO_X and SO_2 from exhaust gases. Flue gas desulfurization or “scrubbing” could be chosen to reduce SO_2 emissions, and selective catalytic or non-catalytic reduction (SCR or SNCR, respectively) could be chosen for NO_X. Units also could choose to prevent the SO_2 or NO_X from entering the exhaust stream in the first place, by switching to lower-sulfur fuel, or installing low-NO_X burners (LNB), gas reburn, or other combustion modifications. Units also can be retrofit to newer technologies or shut down. Finally, units have the option of complying through the purchase of allowances. Units are assumed to choose the most cost-effective response, given their baseline emissions, demand for their output, prices of fuels and allowances, and other factors.

[4] This analysis does not reflect the effects of implementing the NO_X rules recently proposed in Texas. These rules, which become effective in May 2003, establish a NO_X trading program with emissions limits for affected sources of 0.14 lb/mmBtu in East Texas and 0.195 lbs/mmBtu in the remainder of the state.

Exhibit 4: Comparison of Utility NOx Emissions

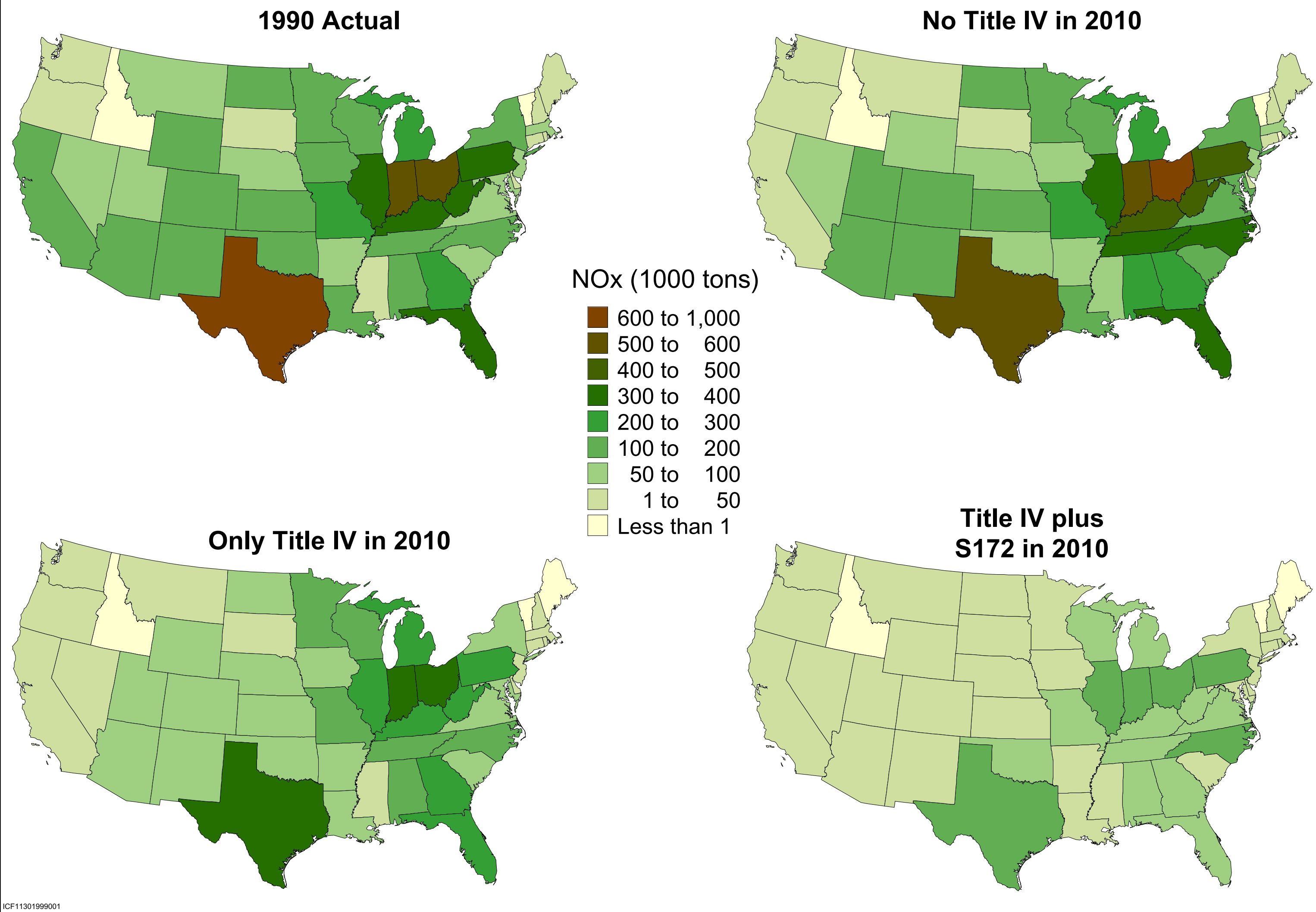
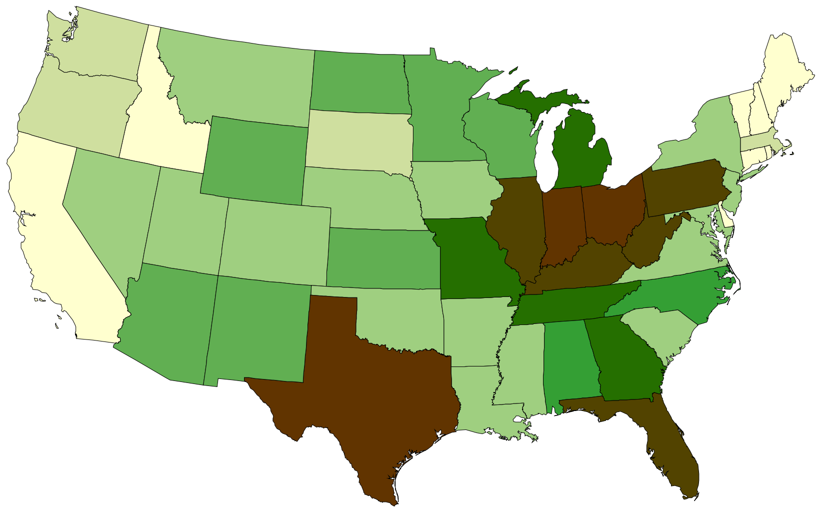


Exhibit 5: Change in Utility NOx Emissions

2010 Annual Utility Emissions by State



Absolute Reductions:

Reductions provided by S172 compared to Title IV

NOx (1000 tons)

- More than 200
- 150 to 200
- 100 to 125
- 75 to 100
- 50 to 75
- 25 to 50
- 5 to 25
- Less than 5

Percent Reduction:

Reductions provided by S172 compared to Title IV, as a percentage of emissions under Title IV

- More than 80%
- 60 to 80%
- 40 to 60%
- 20 to 40%
- 1 to 20%
- Less than 1%

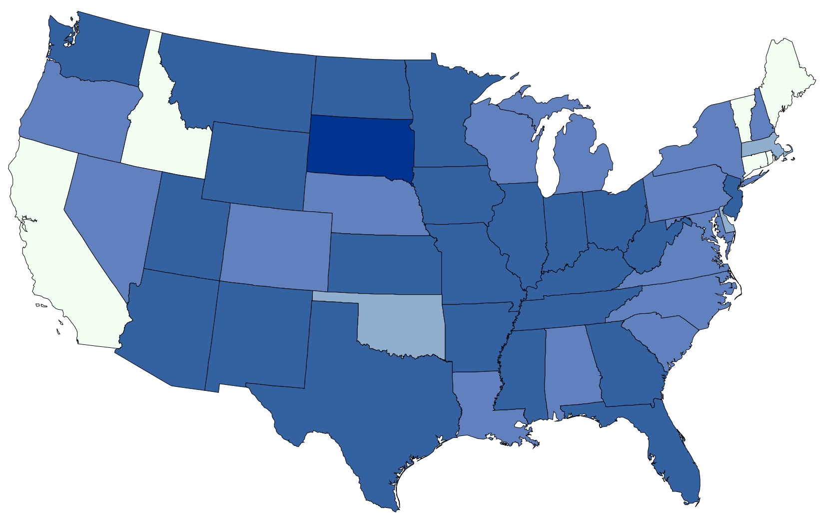


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Exhibit 6: Comparison of Ozone Season Utility NOx Emissions

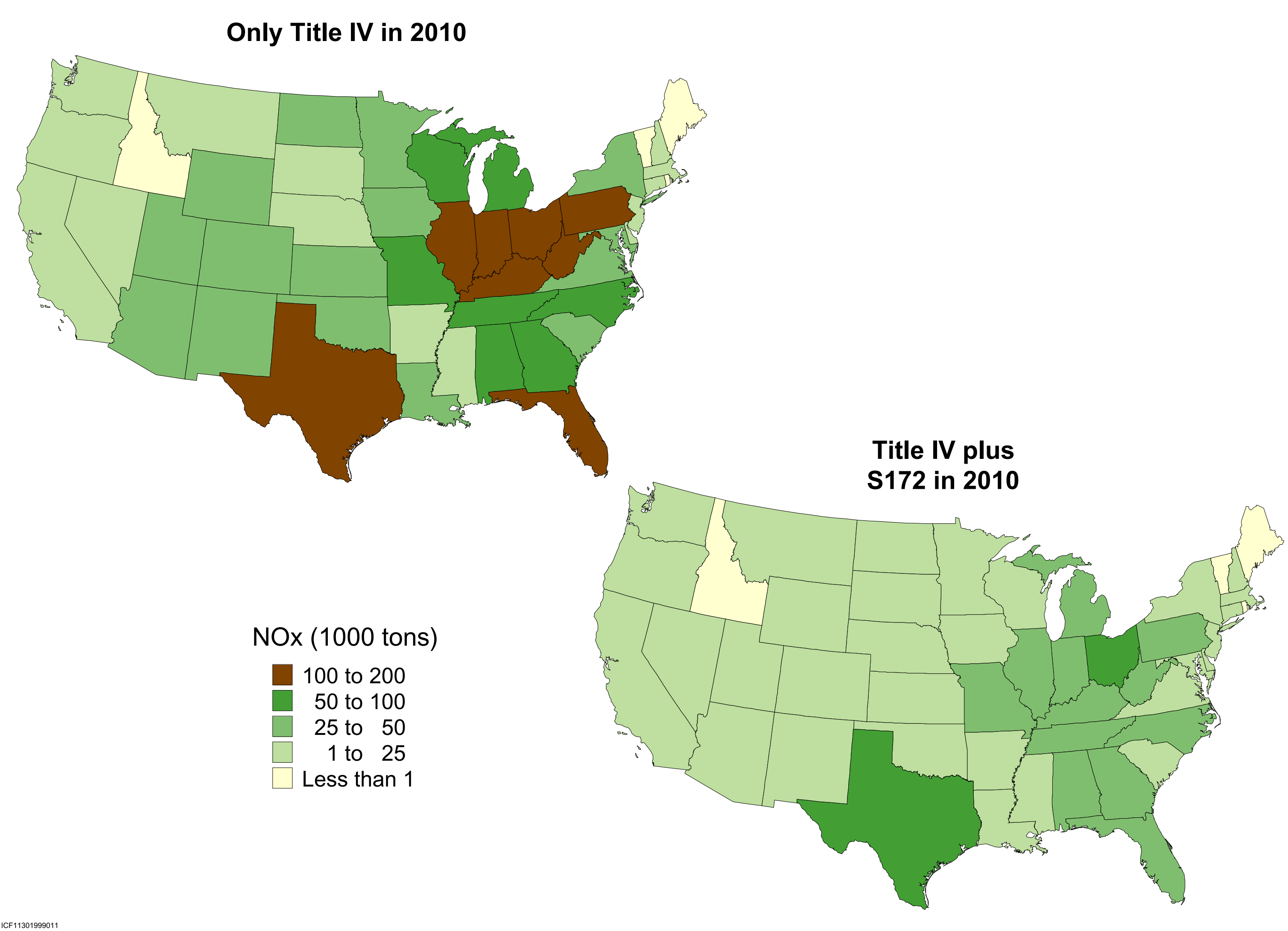
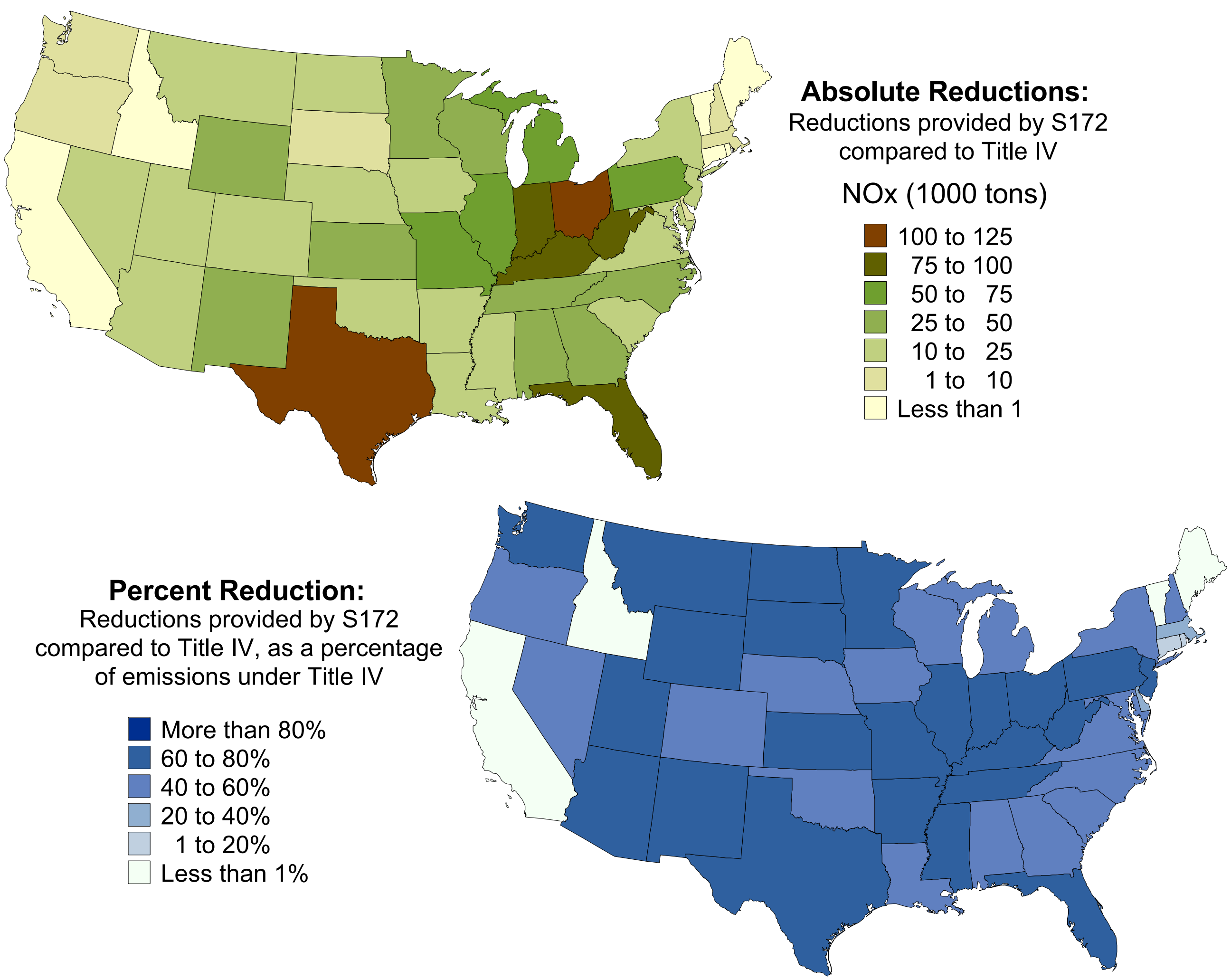


Exhibit 7: Change in Ozone Season Utility NOx Emissions

2010 Utility Emissions by State



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The major technology for removing SO_2 from exhaust gases, the scrubber, passes the SO_2-containing exhaust through a mist that contains dissolved limestone or other alkaline reagent. The reagent reacts with the sulfur in the exhaust and causes the sulfur compounds to precipitate out. The high maintenance costs and reliability problems that were once associated with this technology have been reduced very substantially, and the capital costs have declined as well. An important alternative to the use of scrubbers is the use of low-sulfur coal or the substitution of natural gas (which is essentially sulfur-free) for oil and coal.

Two major technologies currently available for controlling NO_X emissions from industrial boilers and electric utility generating units are Selective Catalytic Reduction (SCR) and Selective Non-Catalytic Reduction (SNCR). Both SCR and SNCR are classified as post-combustion technology because they reduce NO_X in the flue gas downstream of the combustion process. SCR reduces NO_X by reacting a reagent (usually ammonia) with NO_X on a catalyst to selectively reduce NO_X to elemental nitrogen (N_2) and water. The reduction effectiveness is strongly dependent on temperature, with most SCR in place today operating in moderate temperatures of 600°F to 800°F. Typical reductions that can be achieved range from 70 to 90 percent removal.

SNCR is similar to SCR in that it uses a reagent (typically urea or ammonia) which is injected into the flue gas. The reagent reacts with NO_X in a reduction process converting NO_X into elemental nitrogen (N_2) and water. Unlike SCR, however, a catalyst is not used to facilitate the reaction. Without a catalyst, much higher activation temperatures (typically exceeding 1,700°F) are required. Ensuring that the flue gases are at high temperatures requires the injection of the reagent well upstream from locations typically used by SCR installations. Typical reductions that can be achieved using SNCR range from 30 to 50 percent removal. SNCR is often more cost-effective than SCR for units that are used less, because much of the cost of SNCR can be avoided when the generating unit or the control technology is shut off. SCR, by contrast, is a capital-intensive technology that is cost-effective when it is in constant use.

Low NO_X Burners (LNB) and related technologies function very differently from SCR and SNCR in that they reduce the formation of NO_X through changes to the combustion process (in effect, lowering the peak temperature at which the fuel burns). These technologies operate continuously and are highly cost-effective in almost all cases. EPA's modeling of S. 172 assumed that they will be added to every coal plant that did not employ them in response to Title IV.

Repowering coal or oil and gas steam units to combined cycle units is a response to both NO_X and SO_2 limits. Because new combined cycle gas units have lower SO_2 and NO_X emissions, it is cost-effective to build new combined cycle units to meet the demand for additional generating capacity.

Projected Control Responses

Under S. 172 relative to Title IV, about 30 percent of the coal steam generating units (constituting 51 percent of coal steam capacity) are projected to *incrementally* install SCRs and another 30 percent of the coal steam generating units (24 percent of capacity) are projected to install SNCRs. Among oil and gas steam units, about 10 percent of the units (17 percent of oil and gas steam capacity) are projected to install SCRs. Another 30 percent of the units (11 percent of oil and gas steam capacity) are projected to install SNCRs in response to S. 172. About 10 percent of the total coal generating units (which represents 19 percent of coal steam capacity) are projected to *incrementally* install scrubbers by 2010 under

Exhibit 8
Modeled or Assumed Responses to S. 172 Relative to Title IV

		Capacity (MW)	% of Total Capacity	% of Coal Units	% of Coal Capacity
Coal	SCR	154,643	19%	30%	51%
	SNCR	72,245	9%	30%	24%
	Gas Reburn	380	~0%	~0%	~0%
	Scrubber	58,830	7%	10%	19%
				% of Oil/Gas Units	% of Oil/Gas Capacity
Oil/Gas	SCR	13,877	2%	10%	17%
	SNCR	9,246	1%	30%	11%
Combined	New	14,816	2%		
Cycle	Repowered	2,782	~0%		
	Fuel Switching	106,963	13%		
	Close Unit	438	~0%		

Source: EPA analysis.

Note: Numerous units select multiple strategies, e.g., SCR with fuel switching, or SCR with scrubbers. Thus, the sum of the capacities shown in Exhibit 8 exeeds the total capacity that responds to the S. 172. Fuel switching activity includes changing fuel consumption between different coal sulfur grades, coal to gas or oil/gas to gas as a result of repowering, and from oil to gas.

S. 172, relative to the Title IV case. The pollution control actions projected to be undertaken by the electric power generating sector in response to S. 172—relative to the Title IV case—are reported in Exhibit 8.

It is important to note that, of the various control options available to comply with NO_X emission reductions under either the SIP call or S. 172, this analysis finds that closing generating units is unlikely to be a widely exercised option. In fact, the SIP call was projected to result in a reduction of only 178 MW of generating capacity, while the NO_X provisions of S. 172 could result in a reduction of 438 MW of capacity. These values are on the order of a tenth of a percent of total capacity.

3.4 Analysis of Costs

The provisions of S. 172 are estimated to cost about $5.0 billion a year in 2010 (or $3.3 billion more per year than the annualized cost of implementing the NO_X SIP call). Exhibit 9 shows the total cost for the full bill, the SO_2 and NO_X components separately, and for the SIP call. Note that the sum of the estimated costs for controlling SO_2 and NO_X separately is over $300 million more per year than the cost of the integrated control program that controls both.

Exhibit 9 also provides a sense of the costs of these programs per ton of SO_2 and NO_X removed. Because full implementation of S. 172 would reduce both SO_2 and NO_X considerably, it is problematic to assign its costs on a per-ton basis for the individual pollutants. Using the scenario in which only the NO_X provisions of S. 172 are in effect, though, it is possible to compare a regulatory cost to a change in tons of NO_X alone (not counting an insignificant shift in SO_2 emissions of less than a third of one percent). As shown in Exhibit 9, the NO_X provisions of S. 172 reduce annual NO_X at a cost of $971 per ton. The SIP call, by comparison, reduces annual NO_X at a cost of $1,589 per ton. The lower cost per ton of NO_X removed under S.172 can be attributed primarily to large NO_X

Exhibit 9
Incremental Cost in 2010 Relative to Title IV
(1997 $)

Scenario	Annual Cost, (millions)	1,000s of Tons Removed of "Target" Pollutant	Cost/Ton "Target" Pollutant Removed Annually
S. 172 — Both SO_2 and NO_X Provisions	$4,991	3,740 (SO_2) 3,192 (NO_X)	[a]
S. 172 — SO_2 Provisions Only	$2,248	3,383	$664
S. 172 — NO_X Provisions Only	$3,077	3,169	$971
NO_X SIP Call	$1,688	1,062	$1,589

Source: EPA analysis.

[a]The full S. 172 scenario targets both SO_2 and NO_X, which makes the calculation of costs per ton much more complex because there is no unambiguous way to apportion the total cost between the two pollutants. For this reason, per-ton costs are shown only for the scenarios that target either SO_2 and NO_X alone. In these scenarios, the *de minimus* changes in the non-targeted pollutants are not considered in calculating the cost per ton of the "target" pollutant removed.

emission reductions achieved under a program that is both annual and includes all 48 of the contiguous United States. Similarly it is possible to measure the cost-effectiveness of the SO_2 provisions of S. 172 by comparing the cost of the SO_2-only scenario to the reductions in tons of SO_2 (because that scenario has almost no effect on NO_X). This cost-effectiveness is shown in Exhibit 9 as $664 per ton of SO_2.

One measure of the impact of S. 172 on consumers is the projected increases in electricity prices (based on the change in the marginal costs of generation, and not considering changes in the value of capacity). On average, the price of electricity would rise slightly less than 1.2 mills per kilowatt hour under S. 172, which is slightly less than two percent of typical retail prices. The tier of states from North Dakota to Texas and east incurs $4.6 billion of the total $5.0 billion in emission control costs, excluding costs for inter-regional allowance transactions.

Comparison of Emissions under the NO_X SIP Call with Emissions under S. 172

Because S. 172 is intended to reduce both acid deposition and ozone precursors during the warmer months of the years, it is worth comparing its effects to those of another regulatory initiative aimed at regional NO_X problems—the NO_X SIP call. The SIP call placed a cap on NO_X emissions from electric utility sources (as well as certain large industrial boilers) during the ozone season in the District of Columbia and 22 states in the eastern United States. As discussed above, S. 172 would place a cap on electric utility NO_X emissions on a nationwide, year-round basis. The two-for-one ratio for the use of NO_X allowances in the ozone season under S. 172 is intended to encourage larger reductions of NO_X in that season. As shown in Exhibit 10, ozone season NO_X emissions from electric utilities in the SIP call region would almost be as low under S. 172 as under the NO_X SIP call: 606 thousand tons as compared to 544 thousand tons. Ozone season emissions outside the SIP call region would be considerably lower under S. 172: 297 thousand tons compared to 906 thousand tons, which is a reduction of 609 thousand tons. These lower emissions outside the SIP call region would not only improve air quality in the rest of the country, but also are projected to lower NO_X and ozone transport into the SIP call region. On an annual basis, NO_X emissions in the SIP call region under S. 172 would be 864 thousand tons less than under the NO_X SIP call. Similarly, outside the SIP call region, S. 172 would result in 1,266 thousand tons more of NO_X emission reductions than would the SIP call.

Exhibit 10
NO_X Emissions by Region and Season Under SIP Call and S. 172 (Thousands of Tons)

Season	Region	SIP Call	S. 172	S. 172 Emission Reductions Exceed Those of SIP Call	Amount by Which S. 172 Reductions Exceed SIP Call Reductions (1,000 tons NO_x)
Ozone Season	SIP Region	544	606	No	[a]
	Non-SIP Region	906	297	Yes	609
	National	1,450	903	Yes	547
Annual	SIP Region	2,322	1,458	Yes	864
	Non-SIP Region	1,932	666	Yes	1,266
	National	4,254	2,124	Yes	2,130

[a]SIP call reductions exceed S. 172 reductions by 62 thousand tons in the SIP call region during the ozone season.

The upper map of Exhibit 11 presents ozone season NO_X emissions by state under the SIP call and S. 172, for the states in the NO_X SIP call region and the Ozone Transport Assessment Group (OTAG) region. The lower map of Exhibit 11 shows the differences between S. 172 and the SIP call. The slightly higher NO_X emissions for the states within the SIP call region under S. 172 compared to the SIP call might be offset by large reductions in states just outside the SIP call region. S. 172 also reduces NO_X emissions in the non-ozone season much more than would the NO_X SIP call.

Monitoring Costs

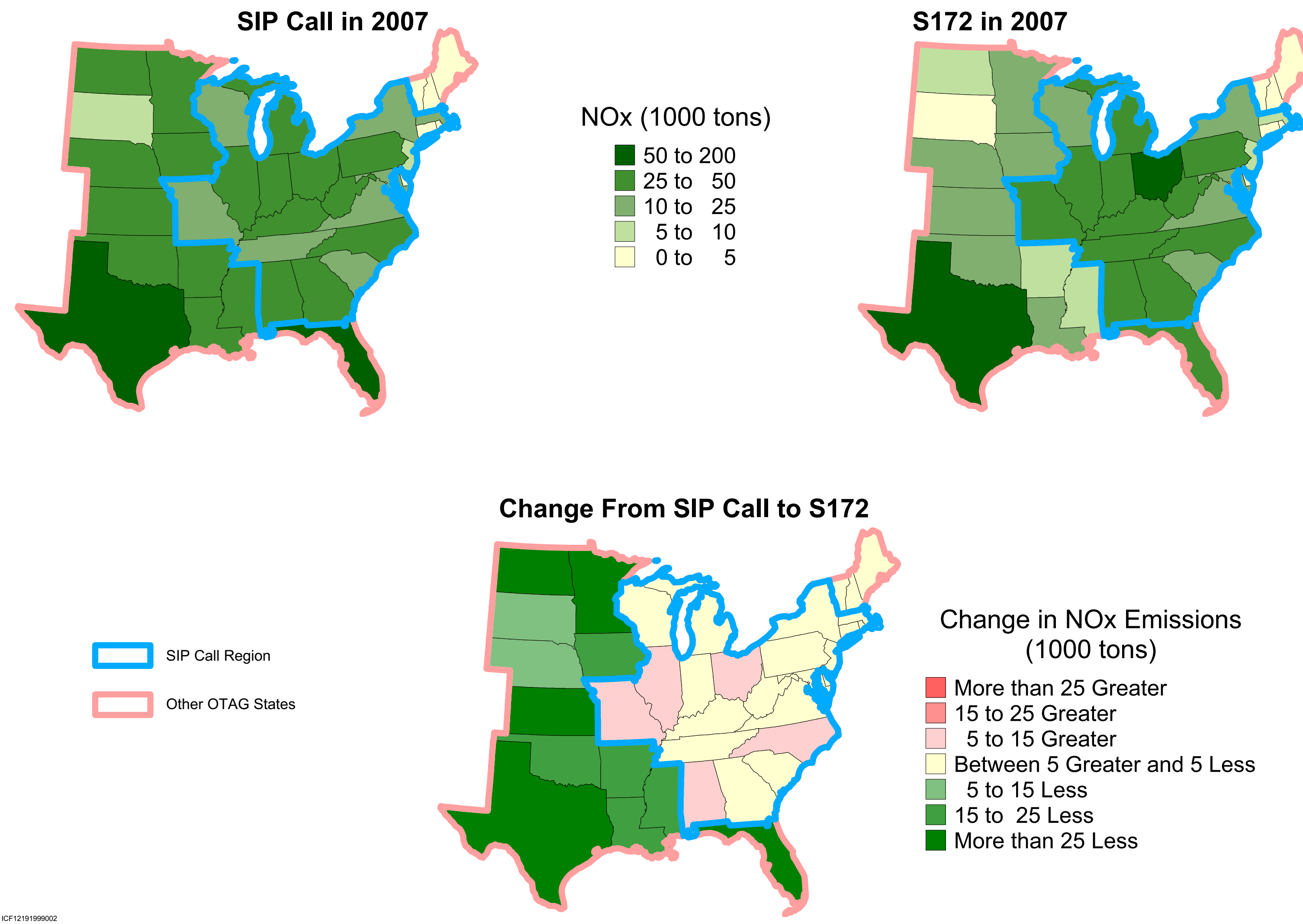
The analysis of the costs of S. 172 presented above does not include the costs of monitoring emissions. As discussed in this section, the omission of monitoring costs for SO_2 and NO_X is probably of minor importance, since most affected units are currently monitoring under Title IV or other provisions of the Clean Air Act (and, thus, the monitoring costs are in the baseline). Monitoring for mercury may introduce a larger departure from this baseline.

To estimate the costs of implementing S. 172 monitoring provisions, at least three issues must be considered: the number of units in the United States with capacity of 100 mmBtu/hr or more; the number of those units which would need to install continuous emission monitors (CEMs) and the number that could employ alternative emission reporting procedures; and the high and low ranges for costs of installing various measurement methods.

Units that burn solid fuels, such as coal, would use a full complement of CEMs (flow, NO_X, SO_2 and CO_2). In the SIP call context, full CEM costs were estimated to be about $67,000 per unit on an annual basis (including both annualized capital costs and operating costs). Larger or more frequently operated gas and oil units would likely use a NO_X and CO_2 CEM and a fuel flowmeter. SIP call analyses estimated the cost for these units to be about $54,000.

Smaller or less frequently operated gas and oil units would probably use an emission estimation methodology. For the SIP call, this cost was estimated to be approximately $6,000 annually per unit.

Exhibit 11: Comparison of Ozone Season NOx Emissions Between SIP Call and S172



In the United States, approximately 9,000 units have a capacity of 100 mmBtu/hr or more, and these units would be subject to the monitoring provisions included in S. 172. However, more than 2,000 of those units are owned by utilities that already monitor emissions under Title IV of the CAAA.

Mercury Related Issues

The mercury monitoring and control provisions included in S. 172 (Sec. 10) acknowledge the importance of better understanding the sources and effects of mercury emissions. Mercury emissions from coal-fired electricity generating plants are the largest unregulated source of mercury emissions in the United States, accounting for about one-third of anthropogenic mercury emissions to the air. Mercury emissions are transported through the air and deposited to water and land where humans and wildlife are exposed. Human exposure to mercury occurs primarily through eating contaminated fish. In a 1997 report to Congress, EPA identified mercury emissions from coal-fired power plants as the toxic air pollutant of greatest concern to public health.

This analysis of S. 172 does not provide cost estimates for implementing the mercury monitoring and control provisions of S. 172.[5] Nor does it estimate the benefits of mercury controls. Both gaps are limitations of the analysis of the total costs and benefits of implementing S. 172. The cost of a mercury emissions monitoring program, called for in S.172, would depend on the design of the program. In 1999, EPA required a sample of coal-fired power plants to perform stack tests, using a prescribed protocol, to determine the amount and species of their mercury emissions. The stack testing was estimated to cost $44,500 per unit. If all coal fired units needed to perform stack testing, the total cost of the mercury emissions monitoring would be approximately $53 million. The 1999 data that EPA collected is being used by the Agency to develop emission factors that could be applied to a mercury-in-coal analysis to estimate emissions. EPA estimated the annual cost of analyzing the mercury content of coal at $17,500 per unit, according to the Agency's schedule and protocol designed for the 1999 information collection (U.S. EPA 1998e). If all coal-fired plants with units which have an output capacity greater than 25 MW were required to perform mercury-in-coal analysis and EPA applied the emission factors to the results, the total cost of mercury monitoring for all these plants would be approximately $20 million per year.[6]

Some reductions in mercury emissions are projected to occur as ancillary benefits to controlling SO_2 and NO_X under S. 172. Mercury emissions in 2010 for utility sources are estimated to fall by almost ten percent, due in part to the mercury-reduction effects of SO_2 scrubbers. In addition, S. 172 encourages electric utilities to rely less on coal (which contains varying amounts of mercury) and somewhat more on mercury-free natural gas. This shift toward natural gas also would provide some ancillary CO_2 benefits, due to the lower carbon content of natural gas on a per-mmBtu basis.

EPA already has taken steps to better characterize the extent of mercury emissions from U.S. coal-fired power plants. In November 1998, EPA announced a year-long information collection request requiring each coal-fired electricity generating plant to conduct coal sampling analyses, at

[5] A recent EPA analysis indicated that controlling mercury emissions from U.S. power generation would cost between $1.4 billion and $2.3 billion, depending on the mercury control program's design and on other pollution policy options (U.S. EPA 1999a).

[6] S.172 suggests all power generating plants would monitor for mercury. However, no mercury is emitted when power is generated from natural gas, and when power is generated from oil, mercury emissions are negligible. The strategy and cost of monitoring mercury emissions from oil-burning power generation have not yet been analyzed.

an annual cost of $17,500 per unit (U.S. EPA 1998e). In addition, EPA required 75 to 100 randomly selected facilities to perform stack testing for quantity and species of mercury emissions once during the year-long duration of the information collection request, at a cost of $44,500 per unit. The total cost of this information collection effort is $16.8 million. The information collected will aid EPA's future decisions about the regulation of mercury emissions from power generation, and help the Agency and others to identify more effective mercury emission control technologies.

In a recently released report, the National Research Council of the National Academies of Science and Engineering evaluated the range of data on which risk assessments conducted by EPA and other regulatory agencies are based. The report also reviewed new findings that have emerged since the development of EPA's current reference dose in 1995 and initial results of major ongoing population studies (NRC 2000). Efforts to estimate the benefits of the S. 172 mercury monitoring and control provisions will benefit from the NRC study.

4. Analysis of the Environmental and Human Health Consequences of S. 172

This section presents results of analyses showing the effects of S. 172 on deposition, air quality, visibility, human health, and ecological response.

4.1 Air Modeling

An important measure of the effectiveness of S. 172 is the reductions it would provide in the deposition of sulfur and nitrogen in regions affected by acid precipitation. This question has been addressed through modeling the changes in the transport, transformation, and ultimate deposition of emissions from electric utilities. Two different models were used to cover the 48 contiguous states: the Regional Acid Deposition Model (RADM) focuses only on the East, while the Regulatory Modeling System for Aerosols and Deposition (REMSAD) was used to examine impacts in the West.[7]

Sulfur Deposition

Exhibit 12 shows rates of sulfur deposition projected to result in 2010 under S. 172, as contrasted with deposition from 1990 emissions and from projected emissions under Title IV. Compared to the 1990 case, the largest changes are projected for the Ohio River Valley and the mid-Atlantic states, as well as for New York and New England. Substantial reductions in sulfur deposition also are seen for the Southeast. Changes in the West are far more subtle, which is to be expected given the much lower baseline levels of SO_2 emissions there, and the smaller emission reductions projected as a result of Title IV and S. 172.

Title IV is projected to reduce total sulfur deposition by about 25 to 30 percent (from 1990 levels) in the areas surrounding the Ohio River Valley and by 10 to 30 percent in the downwind areas of Pennsylvania into New York, including a 19 percent decrease in deposition in the Adirondack Mountains, and a 21 percent reduction in the mid-Atlantic states.

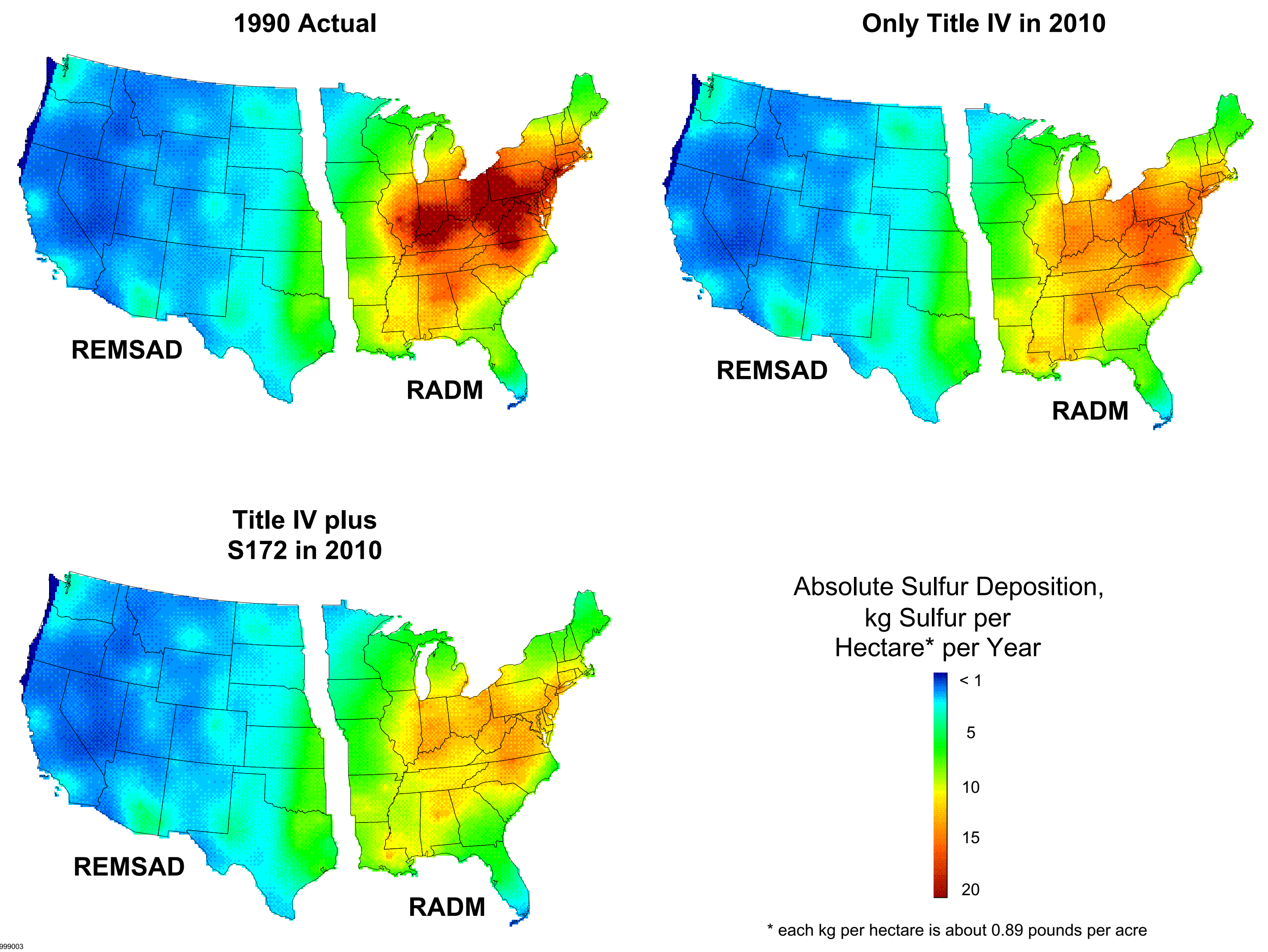
Under the provisions of S. 172, additional sulfur deposition reductions are projected to be of similar magnitude (in both absolute and percentage terms) to those achieved under Title IV. Therefore, S. 172 is projected to further reduce sulfur deposition from 1990 levels, leading to a total sulfur deposition reduction of 42 percent in the Ohio River Valley, 34 percent in the Adirondack Mountains, 40 percent in the mid-Atlantic region, and 26 percent in the southern Blue Ridge Mountains.

Nitrogen Deposition

The effects of S. 172 on nitrogen deposition may be seen by comparing the maps in Exhibit 13. The upper left-hand map shows annual nitrogen deposition levels projected by the air quality models REMSAD and RADM to result from actual 1990 emissions. Broad areas of the eastern United States are shown in Exhibit 13 with high deposition levels resulting from actual 1990 emissions. Title IV reduces deposition in the East by 2010 (as shown by the disappearance of almost all of the orange and red-orange areas). Title IV reduces total oxidized nitrogen deposition up to 20 percent in Illinois and areas northeast of Long Island. About a 15 percent drop in deposition is projected to occur along the Ohio River Valley. The downwind areas of Pennsylvania into New York are predicted to experience reductions of 10 to 25 percent. S. 172 is projected to further reduce these deposition rates, as shown on the lower map of Exhibit 13.

[7] These models have been used extensively by the EPA in other analyses, including the Section 812 Prospective Study (Appendix C in U.S. EPA 1999b).

Exhibit 12: Absolute Sulfur Deposition



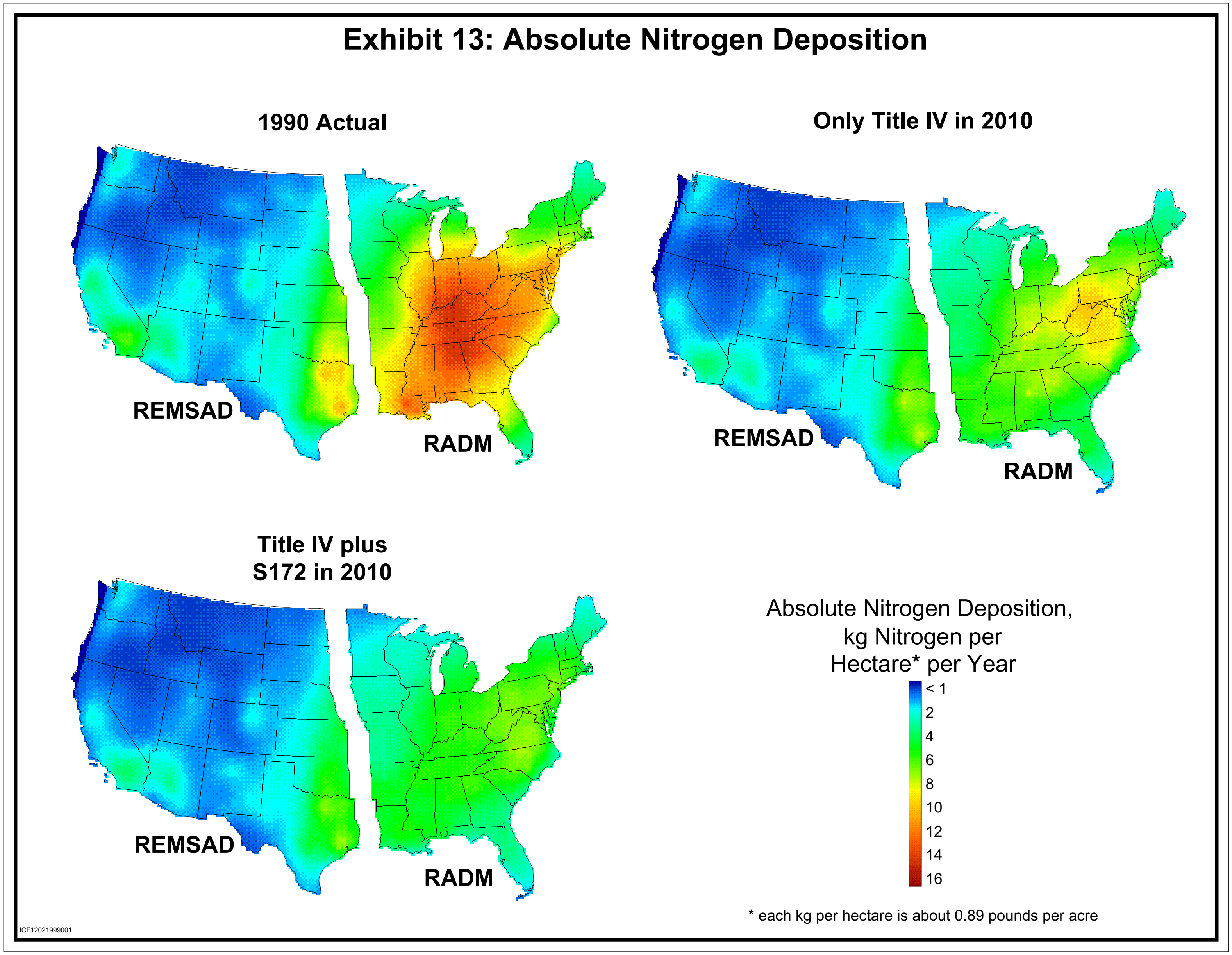


Exhibit 13: Absolute Nitrogen Deposition
1990 Actual
Only Title IV in 2010
REMSAD
RADM
REMSAD
RADM
Title IV plus
S172 in 2010
REMSAD
RADM
Absolute Nitrogen Deposition,
kg Nitrogen per
Hectare* per Year
< 1
2
4
6
8
10
12
14
16
* each kg per hectare is about 0.89 pounds per acre
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Exhibit 14 demonstrates that implementation of S. 172, together with Title IV, is projected to lead to reductions in annual nitrogen deposition (relative to 1990) of 25 percent in the Adirondack Mountains, 37 percent in the mid-Atlantic region, and 27 percent in the southern Blue Ridge Mountains. Projected changes in the West, as with sulfur deposition, are less noticeable.

Exhibit 14
Total Sulfur and Oxidized Nitrogen Deposition by Region (kg/ha)

Region	Total Sulfur		
	1990 Actual	Title IV (2010)	S. 172 (2010)
Adirondacks	9.81	7.94	6.45
Poconos	14.90	11.73	8.58
Mid-Atlantic	19.95	15.67	11.99
Blue Ridge	14.97	13.53	11.03

Region	Oxidized Nitrogen		
	1990 Actual	Title IV (2010)	S. 172 (2010)
Adirondacks	5.83	5.15	4.39
Poconos	8.02	6.96	5.72
Mid-Atlantic	9.67	8.48	6.14
Blue Ridge	7.47	6.71	5.46

Source: EPA analysis.

Concentrations of $PM_{2.5}$

Concentrations of $PM_{2.5}$ are reduced when emissions of NO_X and SO_2 decrease. The effects of the S. 172 reductions in the emissions of these gases on total $PM_{2.5}$, relative to the effects of Title IV, are shown in Exhibit 15. Though there are improvements throughout almost all of the country, the largest projected improvements would occur in the mid-Atlantic and the Southeast. The effects of Title IV in 2010 relative to actual 1990 emissions, and the effects of S. 172 in 2010 in combination with Title IV, are shown for the East in Exhibit 16.

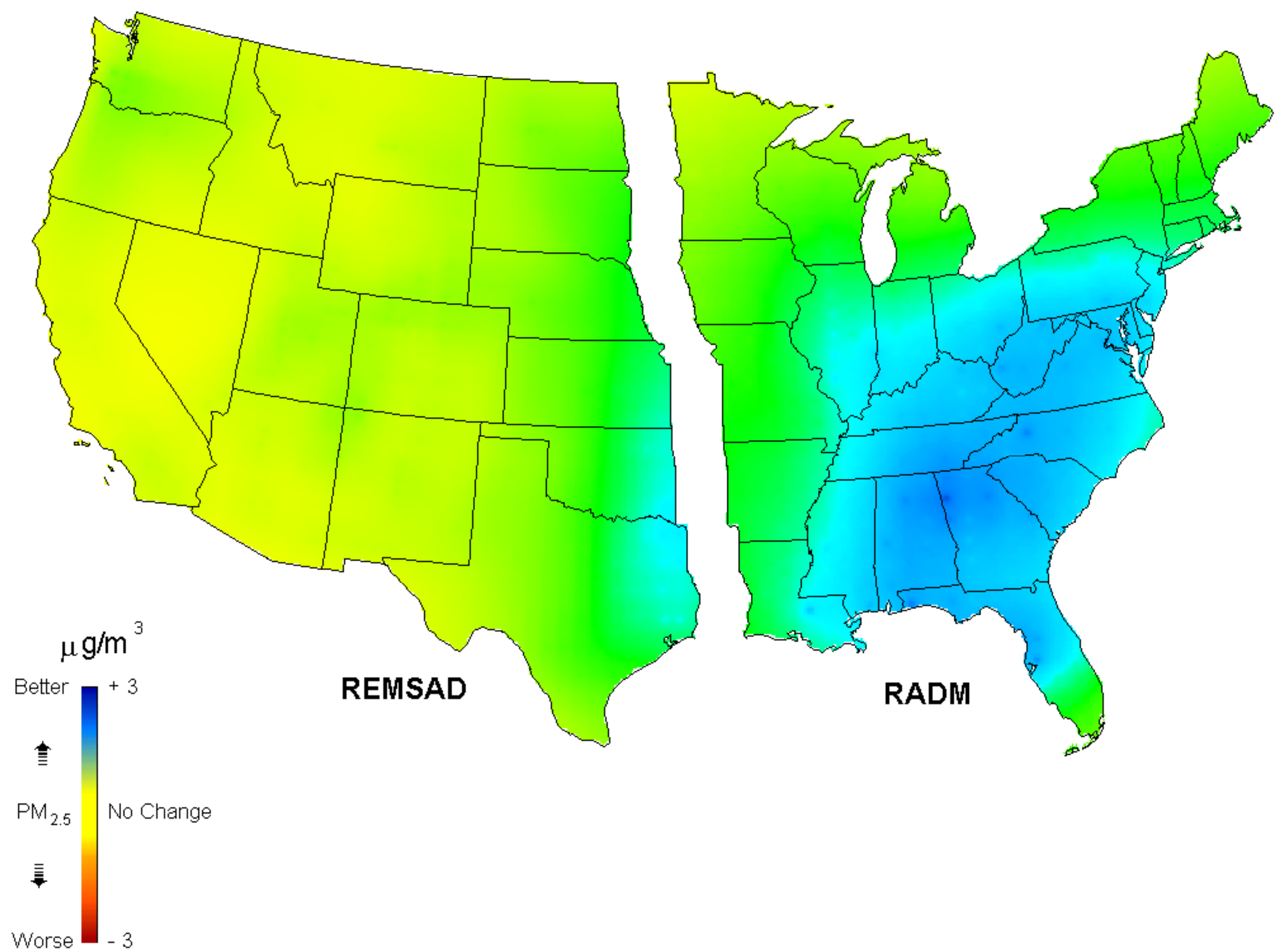
Title IV reduces $PM_{2.5}$ concentrations in the ambient air by about 20 percent in the areas surrounding the Ohio River Valley. S. 172 is projected to achieve a broad regional reduction of annual average $PM_{2.5}$ concentrations over the eastern United States of 20 to 40 percent beyond Title IV. Much of the country east of the Mississippi would experience reductions of two to three micrograms per cubic meter of air.

Visibility

Because $PM_{2.5}$ scatters and absorbs light, reducing concentrations in the air generally improves visibility. Therefore, the greater reductions in PM concentrations provided by S. 172 compared to Title IV lead to improvements in visibility. For this reason, Exhibit 17 (which shows annual average visibility improvements under S. 172 compared to Title IV) looks similar to Exhibit 15 (changes in PM concentration). Given that changes of one or two “deciviews” constitute noticeable improvements in visibility, it is notable that much of the East is projected to have improvements of three to four deciviews beyond the improvements provided by Title IV.[8] These improvements are estimated to be greatest along the Appalachians, including the Blue Ridge and the Great Smoky Mountains – areas where visibility has been deteriorating.

[8] The deciview is a measure of visibility which captures the relationship between air pollution and human perception of visibility. When air is free of the particles that cause visibility degradation, the DeciView Haze Index is zero. The higher the deciview level, the poorer the visibility; a one to two deciview change translates to a just noticeable change in visibility for most individuals. (See Pitchford and Malm 1994.)

Exhibit 15: Improvements in Annual $PM_{2.5}$ Provided by S172 Relative to Title IV



$PM_{2.5}$ (SO_4+NO_3+NH_4) Concentration (μg/m^3) in 2010

Exhibit 16: Improvements in Annual $PM_{2.5}$ Provided by Title IV and S172

From 1990 Base

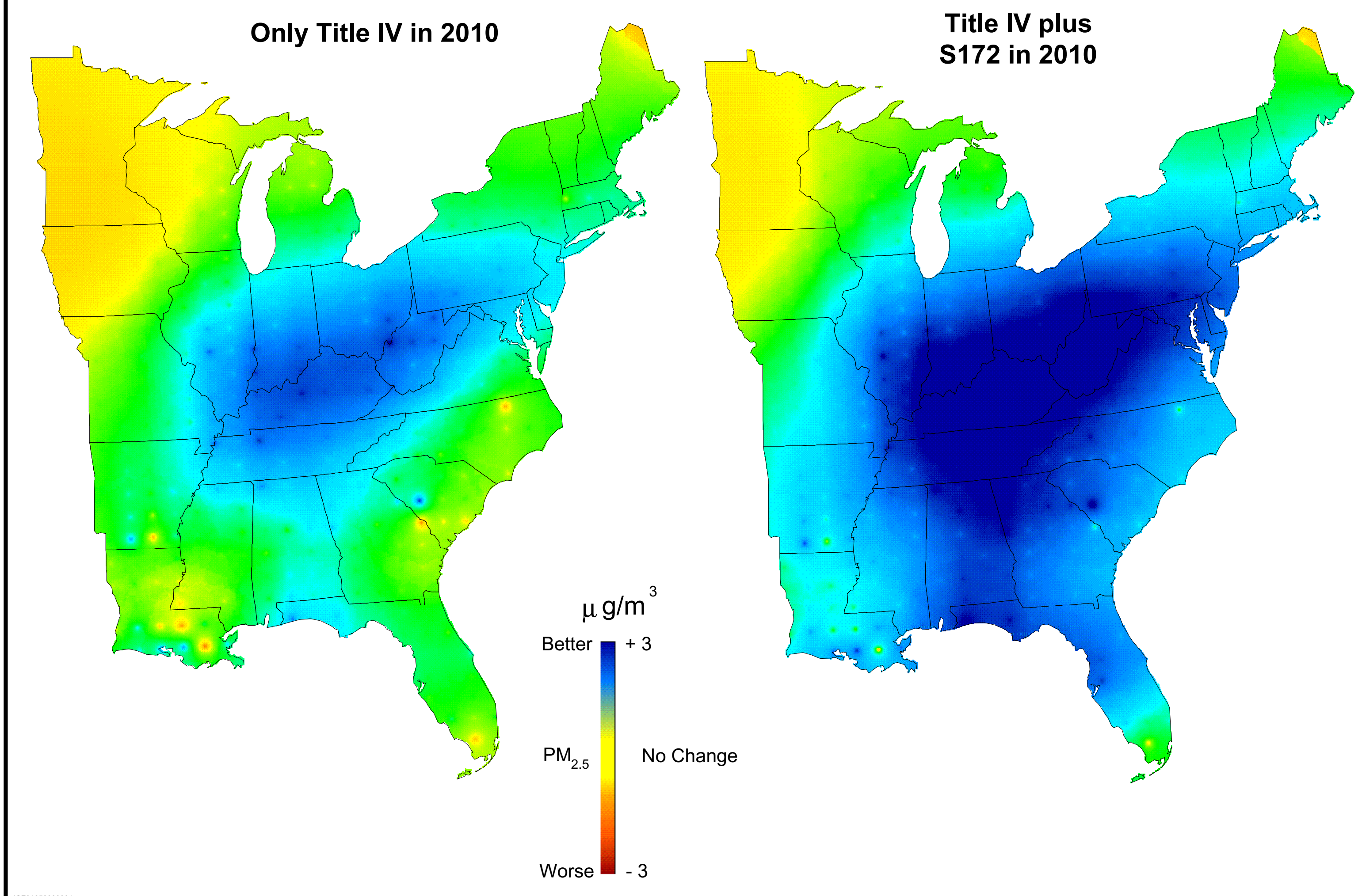
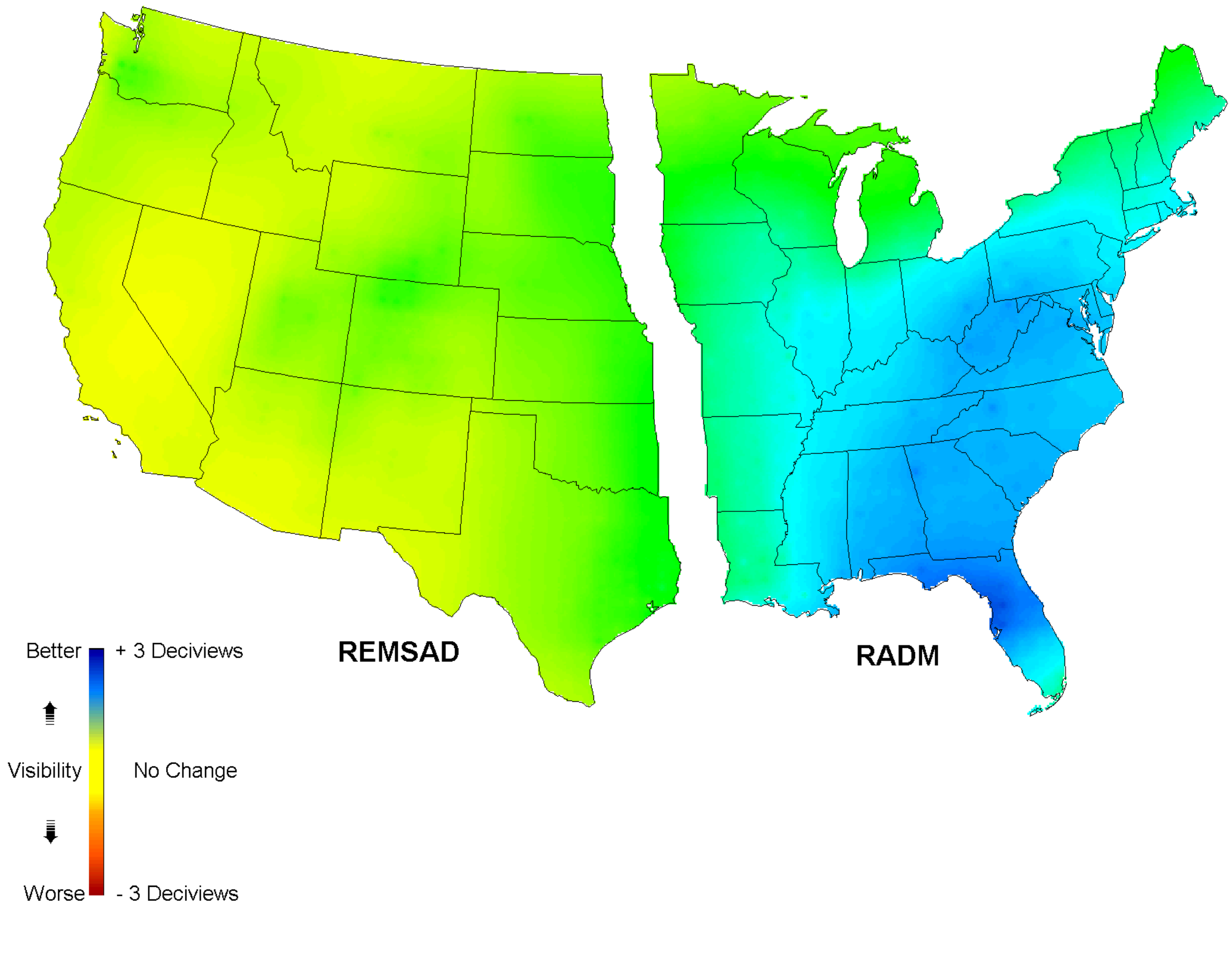


Exhibit 17: Improvements in Annual Visibility in 2010 Provided by S172 Relative to Title IV



Visibility improvements in the East are highlighted in Exhibit 18 where RADM was used to focus on visibility levels and changes for days with unusually poor visibility. The left-hand map of Exhibit 18 shows the episodic improvements in visibility provided by Title IV, relative to actual 1990 levels, for a day at the lowest "decile" in terms of visibility. This is the day of the year that ranks 36th in terms of impaired visibility (i.e., 90th percentile). For most of the East, Title IV produces changes of 1 to 3 deciviews. As shown by the right-hand map of Exhibit 18, S. 172 together with Title IV is projected to result in significant visibility improvements throughout the East, particularly during the 10 percent worst visibility days.

Ozone

Substantial effort has gone into ozone modeling during the past several years (U.S. EPA 1998d). Modeling efforts characterized current ozone and NO_X emissions related to regional ozone transport and resulting ozone levels when measures are taken to reduce NO_X emissions in 22 eastern states and the District of Columbia during the summer months. Therefore, no further ozone modeling was performed for this analysis. Rather, NO_X emission analyses are used as a surrogate in light of these recent ozone analyses.

Exhibit 10 in section 3.4 compares NO_X emissions under S. 172 with estimates of emissions under the SIP call. The exhibit shows national utility emissions and the results for the 22-state SIP call region on an annual basis and for the ozone season. Because the direction and overall magnitude of the NO_X emission reductions under S. 172 are similar to those required under the SIP call, EPA considers the ozone modeling conducted for the SIP call to be a reasonable indication of the ozone effects in the East resulting from utility NO_X reductions under S. 172. Furthermore, based on this, the benefits of ozone reductions under S. 172, although not included in this analysis, can be assumed to be at least equal to the ozone benefits estimated for the SIP call.

4.2. Results of S. 172 for Human Health and Environmental Endpoints

Human Health Benefits

This analysis of human health benefits is based upon improvements in air quality in 2010 for specific geographic areas of the United States. These air quality improvements are expected to result from increased emission reductions included in the provisions of S. 172. The estimated 2010 benefits of S. 172 assume full implementation of Title IV (i.e., the benefits calculated below are in addition to those resulting from Title IV implementation). The health benefits of the air quality improvements for people living in these geographic regions are estimated based upon peer-reviewed epidemiological and economics literature using quantification methods and assumptions consistent with those used in other recent EPA analyses (U.S. EPA 1999c). See Appendix 3 for more detail on the quantification methods and assumptions. In 2010 under S. 172, the value of annual human health benefits in the United States due to the reductions in $PM_{2.5}$ resulting from the reductions in SO_2 and NO_X emissions will total an estimated $59.5 billion. (This health benefit total takes into account all the reasons for avoiding health impacts, not only those that are easily measured in dollars. For example, it includes the value of reducing pain and suffering as well as the savings in health care expenses.) Of the total, $6.4 billion in annual health benefits accrue to the 30 percent of the U.S. population that reside in the West, where SO_2 emissions are substantially lower even on a per capita basis than

Exhibit 18: Improvements in Episodic Visibility Provided by Title IV and S172

The 10% Worst Visibility Days in 2010 from 1990 Base

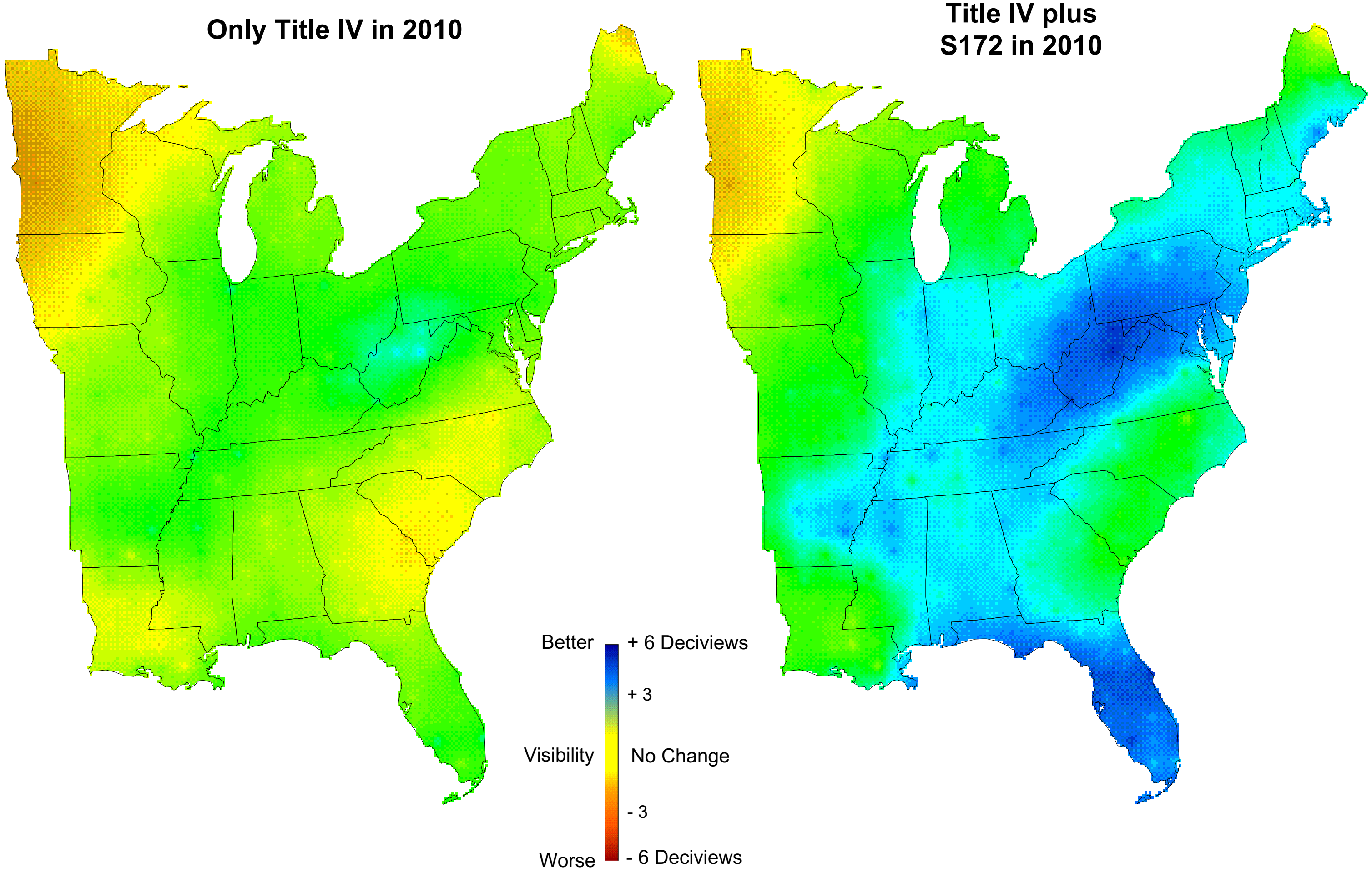
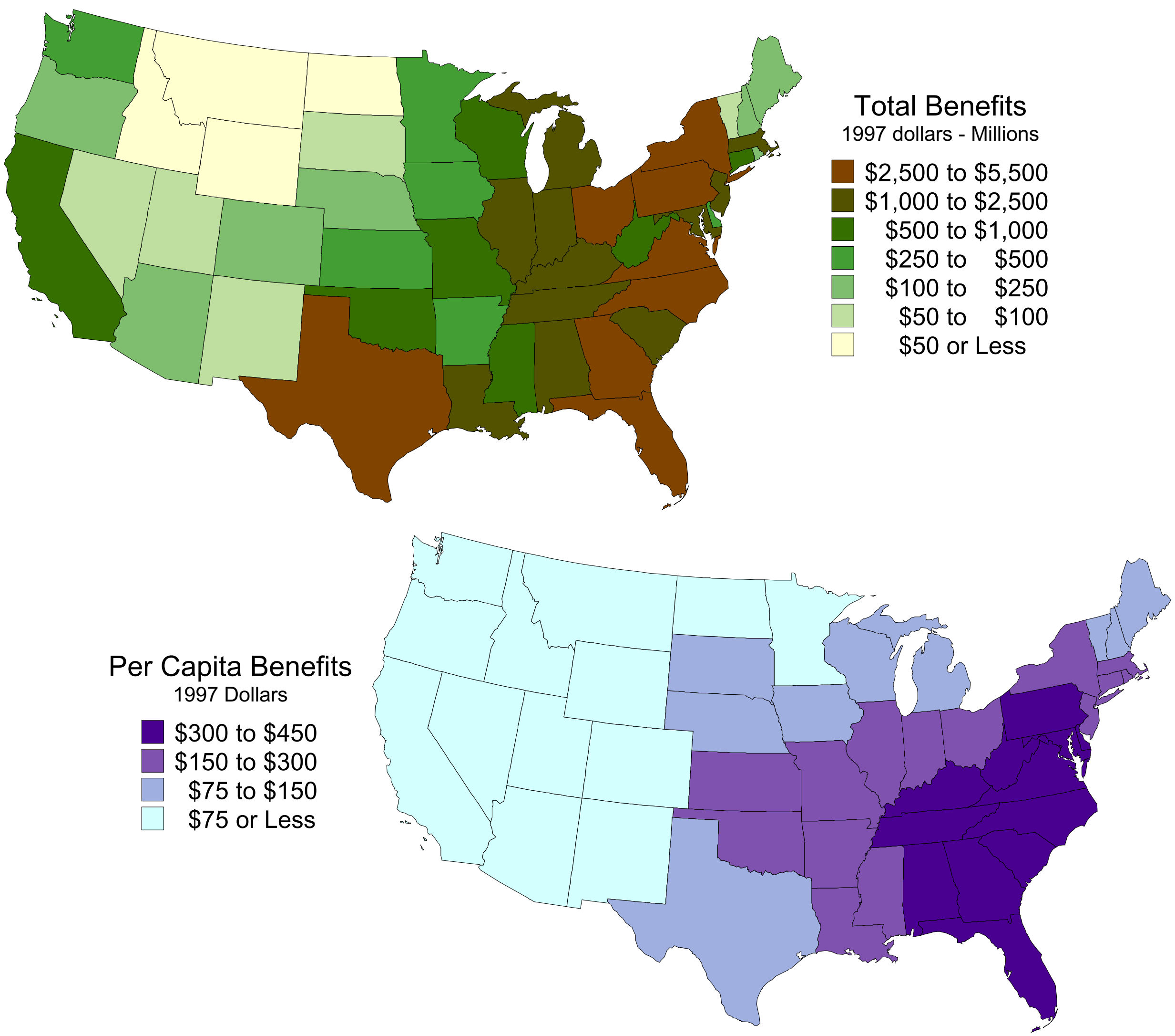


Exhibit 19: $PM_{2.5}$- Related Health Benefits of S172 in 2010



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in the East. The geographic distribution of health benefits is shown by the two maps of Exhibit 19. The map on the upper left shows total health benefits projected for each state. The greatest health benefits are projected to accrue in Florida, New York, Pennsylvania, and Georgia, where large populations combine with large changes in air quality. Nine other states are projected to have benefits greater than $2 billion per year—Alabama, Illinois, Maryland, New Jersey, North Carolina, Ohio, Tennessee, Texas, and Virginia. These estimates should be interpreted cautiously because they are based on the assumption that a unit change in PM concentrations have the same per capita effects on human health in all locations. They are, however, indicative of the projected geographic distribution of the health benefits of S. 172. The other map on the lower right of Exhibit 19 presents per capita health benefits, which are directly related to the projected improvements in $PM_{2.5}$ concentrations shown in Exhibit 15. The breakdown of health benefits, by category and region, is presented in Exhibits 20 and 21.

Exhibit 20
Estimated Mean Annual Health Benefits from $PM_{2.5}$ Reductions in 2010 with Full Implementation of S. 172

Health Effect	Cases Avoided (1,000s)	Value (millions of 1997$)
Mortality	10.6	$57,165.6
New Cases of Chronic Bronchitis	5.4	$1,710.8
Respiratory Hospital Admissions	1.7	$17.7
Cardiovascular Hospital Admissions	1.4	$19.5
Asthma Emergency Room Visits	2.0	$0.6
Acute Bronchitis	17.6	$1.0
Upper Respiratory Symptom Days	286.8	$6.6
Lower Respiratory Symptom Days	188.1	$2.8
Shortness of Breath	36.6	$0.3
Work Loss Days	1,506.0	$153.6
Minor Respiratory Symptom Days	8,086.0	$380.0
Total		$59,458.4

Source: U.S. EPA analysis.

Exhibit 21
Geographic Distribution of $PM_{2.5}$ Health Benefits from S. 172

Geographic Area	Health Benefits (millions of 1997$)
Eastern United States	$53,107
Western United States	$6,351
Total United States	$59,458

Source: U.S. EPA analysis.

Alternative Estimates of Mortality Benefits

The human health benefits estimates presented in this section were computed using a methodology based on a fixed value per avoided death (i.e., value of statistical life, or VSL) and a concentration-response function based on research by Pope et al. (1995). These are the bases for the pri-

Exhibit 22
Alternative Estimates of Premature Mortality

Quantification Approach	Deaths Avoided (1,000s)	Value (millions of 1997$)
Primary Estimate: Pope et al. Mortality Effect and VSL Valuation	10.6	$57,166
Alternative 1: Pope et al. Mortality Effect and VSLY Valuation	10.6	$34,935
Alternative 2: Dockery et al. Mortality Effect and VSL Valuation	22.9	$123,479

Source: U.S. EPA analysis.

mary PM mortality benefits estimates in recent EPA analyses (U.S. EPA 1999c), but EPA also has considered other plausible interpretations of available literature. One alternative is to calculate the benefits based on the expected life years saved (VSLY), and another is to use a different source for the concentration-response function (Dockery et al. 1993). Comparisons of the estimated mortality-related benefits using these alternative approaches are presented in Exhibit 22. The differences between these alternative approaches and the approach used for the primary estimates are discussed in detail in Appendix 3.

These alternative estimates highlight the considerable uncertainty in any attempt to quantify the benefits of a reduction in pollution. EPA has listed the primary sources of uncertainty in these kinds of estimates (U.S. EPA 1999c, Table VII-8). In addition, there are many effects that are known to exist but cannot be quantified with available information. Quantified and unquantified benefits are listed in Appendix 3.

Visibility Benefits

The following discussion is limited to those visibility benefits that are projected to occur due to S.172's reductions in pollution-related visibility impairment at national parks in the eastern United States (resulting from regional air pollution controls). Some improvements in visibility are projected throughout the United States, but the improvements projected in the East are the most significant. Improvements are measured in deciviews. Valuations are based on studies of households' willingness-to-pay for visibility improvements at Class I national parks, but probably also reflect values for other recreational and scenic areas in the same regions. Households are willing to pay more for visibility improvements at parks near where they live, but study results show that households also value visibility at parks throughout the country (Chestnut and Rowe 1990a). As shown in Exhibit 23, the emission controls included in S. 172 are projected to reduce atmospheric concentrations of the sulfate and nitrate particles that impair visibility, resulting in annual visibility improvements of $1.22 billion at eastern national parks in 2010.

Exhibit 23
Estimated Mean Annual Visibility Benefits at Eastern Class I National Parks in 2010 with Full Implementation of S. 172

Geographic Area of Visibility Improvement	Average Annual Deciview[a] Improvement	Annual Visibility Benefit to All U.S. Households (millions of 1997$)
Class I National Parks in the Southeast	1.5	$1,108
Class I National Parks in the Northeast	0.8	$109
Total		$1,217

Source: U.S. EPA analysis.

[a]Deciview is a measure of visibility. The mean is weighted by park visitation.

The projected visibility improvements are substantially greater in the East because of the greater reduction in SO_2 emissions that would be achieved. SO_2 emissions also are a significant source of visibility impairment in the central and western states, but SO_2 emissions there are much lower to begin with than in the East, so a 50 percent national reduction would not have as large an impact. However, because there are so many Class I national parks in the West, even small improvements in visibility could have significant value.

Surface Water/Watersheds

The surface water chemistry modeling for this analysis used PnET-BGC, an established, peer-reviewed biogeochemical model (Kram et al. 1999). PnET-BGC was used to evaluate the response of stream chemistry in an acid-sensitive forest watershed to changes in atmospheric deposition that are expected to occur in response to decreases in NO_X and SO_2 emissions projected to result from Title IV and S. 172.

Results of stream water chemistry modeling at the Hubbard Brook Experimental Forest, New Hampshire, are shown in Exhibit 24. The Hubbard Brook Experimental Forest was chosen for this analysis because it is a premier acid deposition research site in the United States, with the longest continuous datasets on acid deposition and aquatic ecosystem response. The Hubbard Brook site is both well-studied and of great interest to the acid deposition research community, as acid rain in North America was first identified at the Hubbard Brook site. Clearly, this surface water chemistry analysis focuses on one site and one parameter, and so should not be construed as representing a broader region. Modeling of the acidification of additional watersheds in response to various emission scenarios is underway.

Stream water at Hubbard Brook continues to be acidic, despite significant decreases in atmospheric sulfur deposition as a result of existing legislation, including the 1970 CAA and the 1990 Amendments. This lack of recovery in water quality is due to continuing high inputs of atmospheric sulfur and nitrogen deposition, coupled with the depletion of calcium and magnesium from soils that has resulted from long-term leaching by acidic deposition. Model projections, illustrated in Exhibit 24, suggest that S. 172 will accelerate the recovery of stream water quality (i.e., will lead to an increase in acid neutralizing capacity (ANC) when compared to conditions with and without the CAAA).

PnET-BGC also was used to evaluate potential changes and sensitivities in stream nitrate at Hubbard Brook in response to a series of emission control scenarios. These scenarios included (1) without NO_X controls from Title IV; (2) with NO_X controls from Title IV; (3) with about a 60 percent reduction in ozone season utility NO_X emissions (representative of the SIP call); (4) with a 60 percent reduction in total annual utility NO_X emissions (representative of the NO_X provisions of S. 172); and (5) with a 60 percent reduction in total annual nitrogen deposition, which approximates a 60 percent reduction in annual utility NO_X emissions plus aggressive controls on mobile sources of NO_X.

THE PnET-BGC MODEL

PnET-BGC simulates the concentrations and transport of major elements in forest vegetation, soil and water (Aber et al. 1997, Aber and Driscoll 1997). The model uses measured and estimated data on meteorology and atmospheric deposition. The model is run for several hundred model years prior to the advent of anthropogenic atmospheric deposition to allow the forest, soil and water to come to steady-state conditions. The model simulates estimates of changes in atmospheric deposition from 1850 to current. Future scenarios of changes in atmospheric deposition are simulated using projections provided from simulations with the Regional Acid Deposition Model (RADM) based on model runs of air emission controls (1990 Clean Air Act Amendments and S. 172). Simulated outputs were provided by RADM for 2010 for all scenarios and for 2007 for the NO_X SIP call, and deposition levels were held constant thereafter. For this analysis PnET-BGC was applied to the Hubbard Brook Experimental Forest, New Hampshire. Hubbard Brook has forest watersheds that have been seriously affected by acidic deposition. Long-term data on atmospheric deposition, vegetation, soils and stream water are available for the site. Hubbard Brook is part of the National Science Foundation Long-Term Ecological Research (LTER) Program.

Exhibit 24

Sulfur and Nitrogen Deposition and Projected Response in Stream Sulfate and Acid Neutralizing Capacity (ANC) at Hubbard Brook, NH

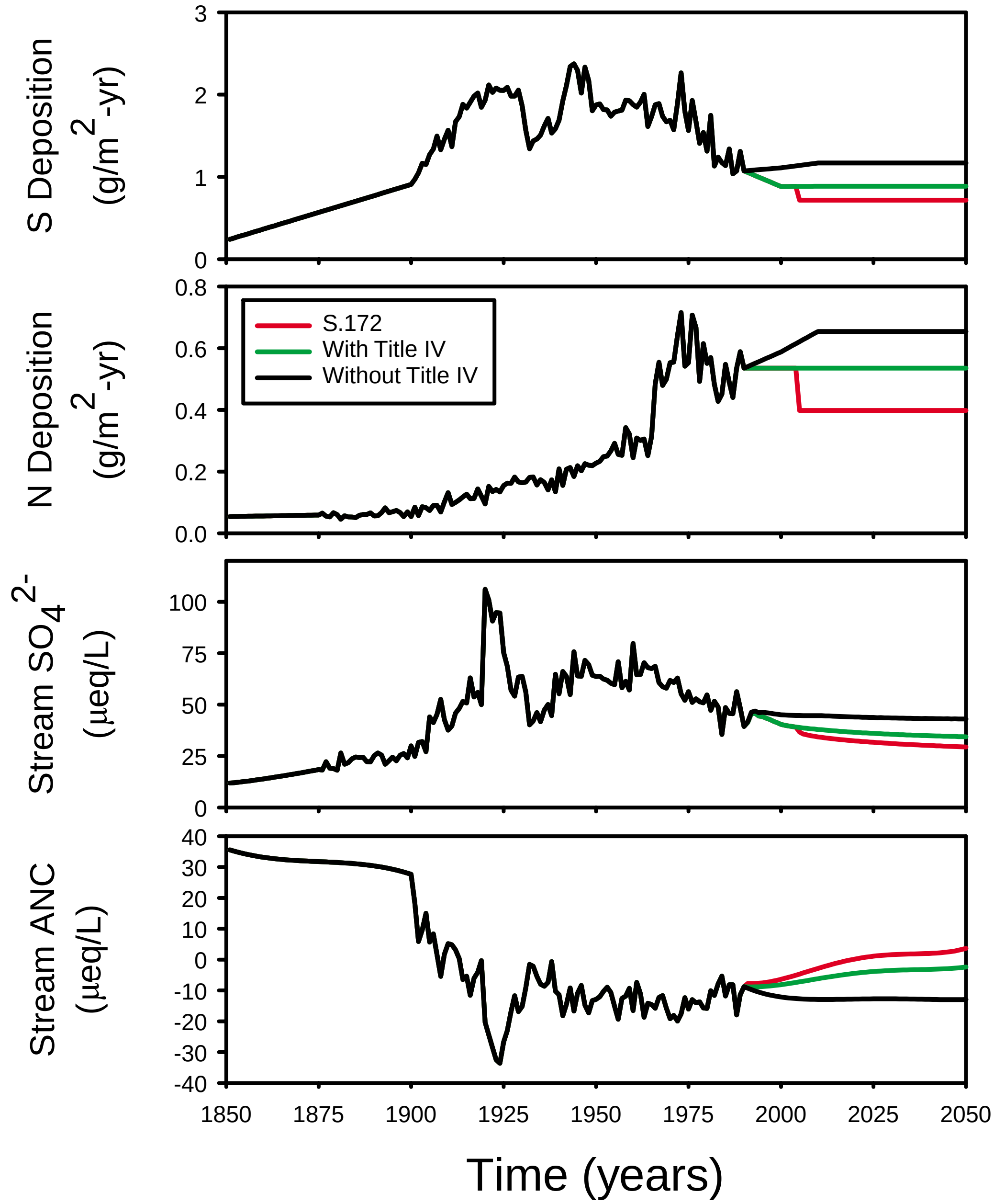
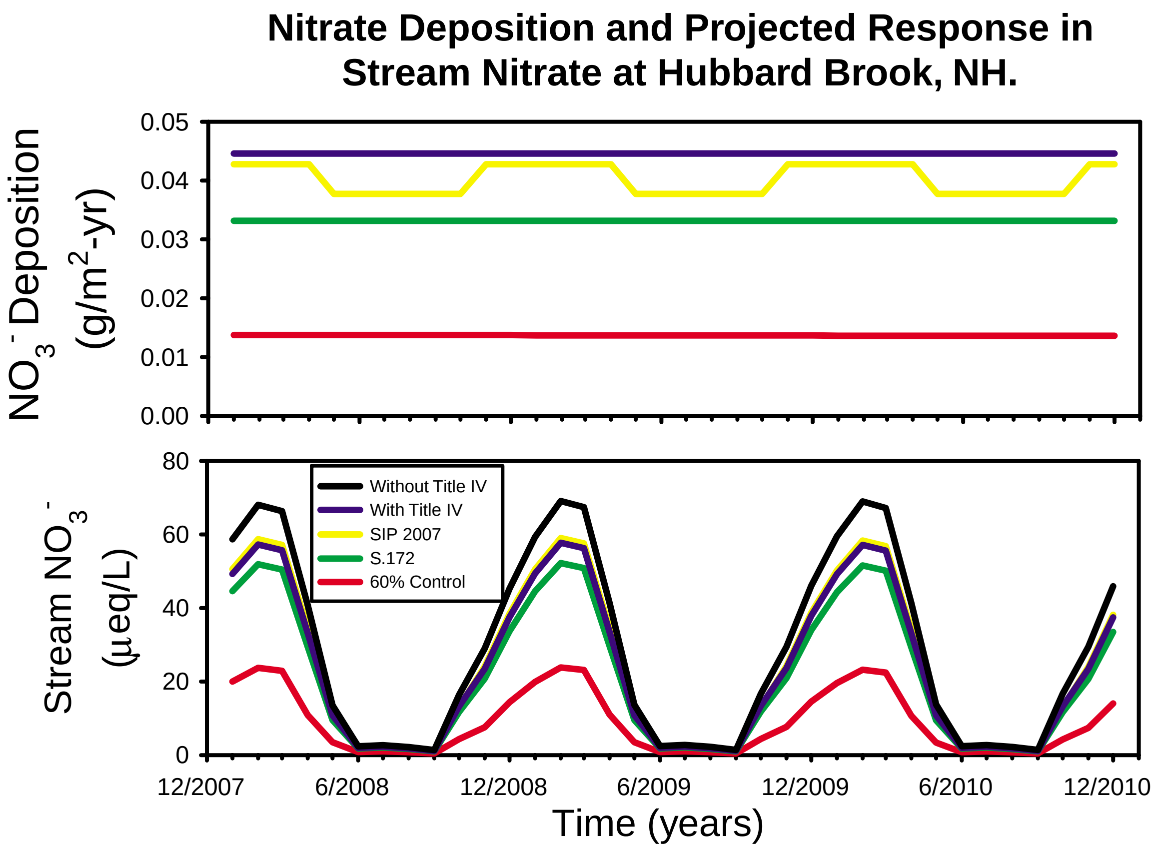


Exhibit 25



NOx SIP Call - 10% reduction in annual N deposition (corresponds to 60% reduction of summer utility NOx emissions)
S.172 - 25% reduction in annual N deposition (corresponds to 60% reduction of annual utility NOx emissions)
60% control - 60% reduction in annual N deposition (all sources: sensitivity run)

Model calculations, displayed in Exhibit 25, show predictions of seasonal patterns in stream nitrate concentrations at Hubbard Brook under these different emission control scenarios. Stream nitrate concentrations exhibit a pattern of high concentrations during the winter and spring months, followed by lower concentrations in the summer. This seasonal pattern is largely due to plant uptake of nitrogen during the summer growing season. High concentrations of nitrate during spring correspond with the most acidic conditions of the year. These model calculations reveal that large reductions in NO_X emissions are necessary to substantially decrease concentrations in stream nitrate because large quantities of nitrogen have accumulated in the forest from high historical inputs of atmospheric nitrogen deposition and ammonium (about one third of atmospheric nitrogen deposition). Note that ozone-season reductions of utility NO_X emissions have limited effects on stream nitrate because reductions in deposition largely occur during the growing season when vegetation strongly retains nitrogen inputs. Adverse effects of nitrogen on acid-sensitive forested watersheds are minimal during warm months and more prevalent during spring months. To decrease stream nitrate during the acidic spring period, it is necessary to decrease nitrate deposition during the winter and spring periods.

Materials

Although no quantitative modeling of the effects of specific emission reductions on materials is available, there is ample evidence that SO_2 and NO_X emissions contribute to many types of materials damage that can be expected to be reduced if these emission reductions are implemented. This conclusion is based on the range and magnitudes of reductions as shown from the air quality models and the literature on the subject. Wet and dry deposition cause deterioration in marble and limestone which reduces the longevity and aesthetic value of building facades and monuments made of these materials. These emissions also are linked to damage to galvanized steel and painted surfaces, including automobiles. PM formed as a result of these emissions also contributes to soiling that affects households and commercial activities. The air quality models show that reductions in ambient concentrations and deposition that are linked to these types of materials damage would be significant as a result of the emission reductions required by S. 172.

5. Summary and Conclusions

As described in the sections above, this analysis projects that reductions in SO_2 and NO_X emissions called for in S. 172 would result in significant human health benefits, improved visibility, improved aquatic and forest ecosystems, and reduced damage to structures and cultural resources. The annual benefits in 2010 from improved human health are estimated at $59.5 billion.[9] This estimate includes $6.4 billion in benefits for the western part of the United States. Visibility benefits are valued at almost $1.2 billion per year, including significant improvements in the Shenandoah and the Great Smoky Mountains National Parks. As indicated in Exhibit 26, benefits have also been estimated using the alternative approach of valuing a statistical life year (VSLY). Using this approach, the annual benefits in 2010 from improved health and improvements in visibility are estimated at $37.2 billion and $1.2 billion, respectively.

These benefits exceed the estimated annual costs of implementing the bill, which are estimated to be about $5.0 billion in 2010 (or $3.3 billion greater than the cost of implementing the NO_X SIP call). These costs will result in an increase in the average household electricity bill of about a dollar per month.

Beyond this summary comparison of benefits to costs, the analysis points to a number of policy implications. The implications are noted below, followed by a summary of the limitations of the analysis.

- **NO_X Allocation/Cap and Retirement by Season** – Under S. 172, NO_X emissions during the seven non-ozone season months count against the NO_X allowance cap on a 1-allowance-for-1-ton basis; ozone season summer emissions count against the cap on a 2-allowances-for-1-ton basis. This provision is intended to encourage a larger

Exhibit 26
Summary of Costs and Benefits Using Two Mortality Benefit Approaches[a] (Billions of 1997$)

Benefit/Cost Category	Primary Benefits Estimate (VSL)	Alternative Estimate (VSLY)
A Mortality Benefits (deaths avoided)	$57.2	$34.9
B Other Monetized Health Benefits[b]	2.3	2.3
C Total Monetized Health Benefits	59.5	37.2
D Monetized Visibility Benefits	1.2	1.2
E Total Monetized Benefits	60.7	38.4
F Cost	5.0	5.0
G Net Monetized Benefits	55.7	33.4

a For an explanation of these two quantification approaches, see pages 35 through 38 (in Section 4), and pages 54 through 61 (in appendix 3).

b "Other Monetized Health Benefits" are morbidity effects (e.g., fewer new cases of chronic bronchitis, fewer asthma ER visits). Calculations are as follows: A plus B equals C; C plus D equals E; E minus F equals G

[9] All dollar estimates are in 1997 dollar amounts.

reduction in NO_X emissions in summertime to address ozone, as well as to reduce emissions in the winter and spring months to address ecological problems. In the modeling results, the 2-allowances-for-1-ton ratio led to greater emission reductions during the ozone season, but not substantially greater: the reduction in NO_X provided by S. 172 was about 61 percent for the ozone season, and about 59 percent for the winter/spring period. The most likely reason that the 2-for-1 ratio had such a small relative effect on emission reductions by season is that two of the most important NO_X control technologies, Low NO_X Burners (LNB) and Selective Catalytic Reduction (SCR), have operating costs that are low compared to their capital costs. Once an SCR unit has been installed, there is very little incentive not to operate it year-round. Similarly, plants that install LNB will operate them year-round no matter how different the incentives are for reducing NO_X in different seasons. Thus, the percentage of emissions reduced tends to be the same in every month for most units.

- **Compatibility of SO_2 Reduction with Title IV** – S. 172 includes a 50 percent reduction in the current Title IV cap on electric utility SO_2 emissions, reducing the cap from 8.95 million tons per year to 4.47 million tons per year. The legislation achieves this reduction by requiring that, beginning in 2005, two allowances be retired instead of one for each ton of SO_2 emitted. The approach is simple and straightforward, and because all allowances banked prior to 2005 can still be used on a one-for-one basis, it is minimally disruptive to the current cap-and-trade program. However, under the current SO_2 allowance program, allocations are developed for each affected source into perpetuity while under S. 172, allowances must be reallocated every five years on the basis of power generation.

- **Environmental Indicators to Assess Response to Changes in Deposition** – Currently, Title IV (Acid Deposition Control Program) includes no provisions requiring revision of the emission cap based on new scientific findings. Some see this as a limitation in the current Title IV Program. S. 172 includes several provisions linking environmental indicators with emissions and deposition. Under S. 172, EPA would have to submit reports to Congress identifying scientifically credible environmental indicators to protect various regions of the country from acid deposition and to determine whether emission reductions required are sufficient to achieve the objectives. S. 172 would authorize the Administrator to take action as appropriate, including lowering the emission caps.

- **Environmental Monitoring** – Evaluating the long-term environmental response to the emission reductions of S. 172 will require the continuation and expansion of networks and data collection efforts currently focused on environmental changes related to Title IV. These include long-term monitoring of air quality, wet and dry deposition, and ecological changes (e.g., the ANC of streams and lakes, the chemistry of soils, and the health of critical plants and animals).

Limitations of the Analysis

As with any detailed analysis of a complex proposal, the results presented in this report are subject to various limitations.

- The analysis does not include a separate analysis of the costs associated with mercury monitoring, and refers to the current mercury EPA Information Collection Request instead (U.S. EPA 1998e). Also, the analysis does not investigate costs of mercury-specific controls because levels of mercury emission control are not specified in S. 172.
- This report is based on an analysis of costs and benefits for a single year, 2010, taken to be representative of full implementation. However, because of the banking provisions of the bill, the emission reductions continue beyond 2010, and the benefits and costs are likely to be somewhat higher after 2010.
- This report does not include an analysis of impacts on carbon dioxide emissions of S. 172 provisions.
- The atmospheric modeling included in the analysis employs different models for the eastern and western United States. This decision was based on utilizing the best available modeling approaches used in previously peer-reviewed EPA reports, to get results for the 48 states.
- Discussion of ecological impacts is limited in this analysis. Several ongoing analyses within EPA and the academic scientific community are assessing ecological responses to emission and deposition scenarios in various geographic regions. These analyses will be very relevant to discussions surrounding S. 172 or other scenarios that affect future emission levels. The results from these analyses will be synthesized into the National Acid Precipitation Assessment Program's (NAPAP) Year 2000 Report to Congress.
- In addition to the benefits monetized, other benefits of S. 172 not quantified within the scope of this analysis include all improvements in coastal and surface waters and forested ecosystems, reduced damage to buildings and monuments, and the health and welfare benefits associated with ozone reductions. (For a list of potential benefits, see Exhibit A3-2.)
- This analysis uses methodologies that have well-documented uncertainties, concerning emission estimates, air quality modeling, control-cost estimates, the impact of emission reductions on human health, on visibility, on acidic deposition and the related environmental effects, as well as uncertainties concerning the valuation of benefits. Detailed discussions of the uncertainties associated with this type of analysis can be found in the Section 812 Prospective Report (U.S. EPA, 1999b). These uncertainties are summarized in Exhibit 27.

Exhibit 27

Summary of Key Sources of Uncertainty and Their Impact on Costs and Benefits[a]

Source of Uncertainty	Description of Alternative Parameter Inputs	Impact on Annual Estimates in 2010	
		Costs of S.172	Benefits of S. 172
Measurement error and uncertainty in the physical effects and economic valuation steps	Alternative estimate of the long-term concentration/response relationship between chronic $PM_{2.5}$ exposure and premature mortality, and alternative approach to valuing changes in premature mortality. See detailed discussion of these alternatives in Appendix 3.	None	The effect of the use of alternative input assumptions ranges from a \$22.2 billion decrease in the annual estimated mortality benefits for 2010 to a \$66.3 billion increase from the preferred estimate (\$57.2 billion).
Measurement error and uncertainty in direct cost inputs	No sensitivity analyses were conducted for this report. Sensitivity analyses conducted for the NO_X SIP call RIA showed relatively little sensitivity of cost estimates to changes in discount rates, control effectiveness, trading system operation, or electricity demand growth forecasts. Because they were not specific to the provisions of S. 172, estimated costs of controlling and monitoring mercury emissions were excluded from this report's estimates of total costs.	Including consideration of mercury monitoring and control would add to costs. Costs for controlling other pollutants could be over- or underestimated.	Benefits of mercury emission reductions would increase total benefits by an undetermined amount; small changes in benefits may also result from uncertainties and error in estimates of the timing and geographic distribution of reductions in other pollutants.
Value of statistical life-based estimates do not reflect age at death	Estimates of the incremental number of life-years lost from exposure to ambient PM and a value of statistical life-year, in place of number of statistical lives and the value of statistical life	None	Reduction in annual PM mortality benefits of \$22.2 billion, out of total monetized annual benefits of \$60.7 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 Section 4 and Appendix 3)	None	Increase in value of PM mortality benefits of \$66.3 billion, compared to total monetized annual benefits of \$60.7 billion
Regulatory Baselines	Uncertainty over the status of the NO_X SIP call at the time of the analysis led to the exclusion of its costs and emission effects from the baseline.[b]	Exclusion of the EGU portion of the NO_X SIP call from baseline added approximately \$1.7 billion to estimated annual costs.	Exclusion of NO_X SIP call PM-related benefits from the baseline increased the estimated benefits of S. 172 by approximately \$0.5 to \$2.0 billion; PM health and welfare benefits of the NO_X SIP call were estimated at between \$0.6 and \$2.4 billion per year; of these benefits, approximately 82 percent or between \$0.5 and \$2.0 billion can be attributed to NO_X reductions from EGUs.[b]

Exhibit 27 (cont'd)

Summary of Key Sources of Uncertainty and Their Impact on Costs and Benefits[a]

Source of Uncertainty	Description of Alternative Parameter Inputs	Impact on Annual Estimates in 2010: Costs of S.172	Impact on Annual Estimates in 2010: Benefits of S. 172
Uncertainties in emissions, air quality, and deposition estimation steps	Uncertainties include the use of two different models for eastern and western halves of the country.	None	Effects of other uncertainties, e.g., ecological benefits, were not quantified; total benefits are probably underestimated.
Omission of potentially important benefits categories from primary estimate	Non-quantified categories of benefits are discussed in Section 4, and summarized in Appendix 3 (Exhibit A3-2). These categories include ozone mortality, morbidity, labor productivity, agricultural and materials damage effects; PM-related soiling and residential visibility effects; and ecosystem effects of changes in acidic deposition.	None	Including additional benefit categories would increase benefits. The SIP call's annual ozone benefits are estimated to be between \$0.3 and \$2.3 billion, and ozone benefits of S. 172 are projected to be incremental to the SIP call's ozone benefits because S. 172 is projected to reduce national NO_X emissions in the ozone season by 547,000 tons more than the SIP call's EGU reductions.

Source: US EPA.

a The Section 812 Prospective Report provides a detailed discussion of the types of uncertainties presented in this table.

b EGU = electricity generating unit. S. 172 affects only EGUs; the SIP call covered both EGUs and non-EGUs. These comparisons focus only on the EGU portion of the SIP call's costs and benefits.

Appendix 1 – Analytical Tools and Assumptions Used in Analysis

A1.1 IPM Background: Coverage and Structure of Analysis

The version of the Integrated Planning Model (IPM) used by EPA represents the U.S. electric power market in 21 regions in the contiguous United States (see Figure 1). These regions correspond in most cases to the regions and sub-regions used by the North American Electric Reliability Council (NERC). These regions also are recognized by other agencies, including DOE and Federal Energy Regulatory Commission (FERC), involved in electricity generation, measurement, and management. IPM models the electric demand, generation, transmission, and distribution within each region, as well as the transmission grid that connects the regions. EPA's recognition of the transmission limitations that exist in moving electric power on the national grid was a major determinant in the Agency using the 21-region modeling framework.

All existing utility power generation units are covered in the model, as well as independent power producers and cogeneration facilities.[1] The model also covers units that electric utilities have committed to build in the near future, if there is significant evidence that the utility is moving to build the capacity.[2] Data on the existing boiler and generation population, which consists of close to 8,000 records, are maintained in EPA's National Electric Energy Data System (NEEDS).[3]

The model can provide estimates of air emission changes, incremental electric power system costs, changes in fuel use and prices, and other impacts resulting from electric power industry approaches to air pollution control. It provides basic information necessary to consider consumer price impacts, employment changes, and other types of economic impacts.

Although IPM has the capability to look annually over a long planning horizon, EPA uses IPM to look at the intermediate term. The model forecasts how electric power will be generated in 2001, 2003, 2005, 2007, and 2010 in the modeling runs that it produces.

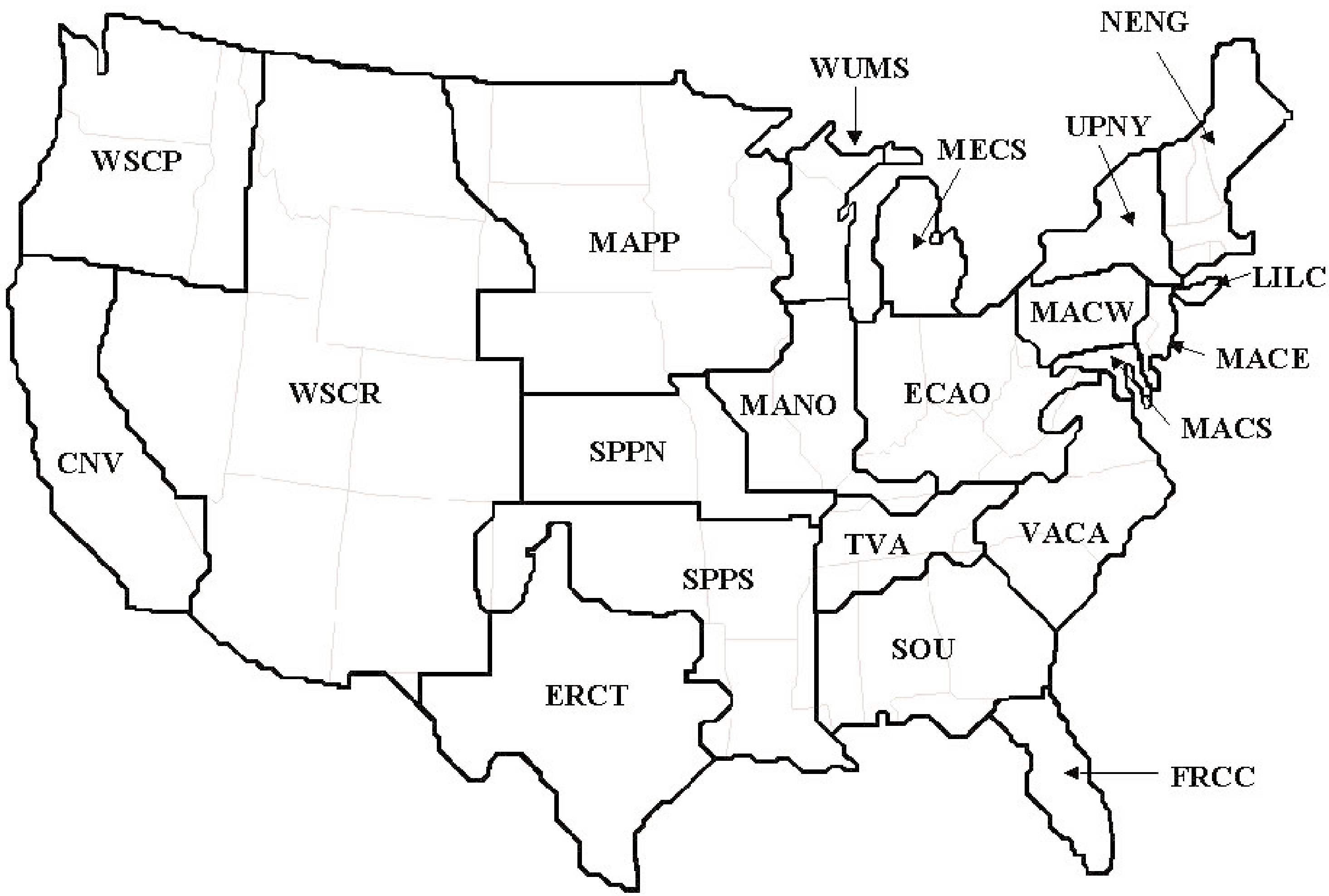
In order to make the modeling more time and cost-efficient, individual boiler and generator data are aggregated into "model" plants. EPA's application of the model has focused heavily on understanding the future operations of coal-fired units, which will have the greatest air emissions among

[1] The NEEDS (National Electrical Energy Data System) that supports EPA's application of IPM includes utility information from many different publicly available databases, including the EIA 860, NERC ES&D, EPA ARDB, EPA NADB, EIA AEO 1998, and EPA EGU. Non-utility data in NEEDS come from the EPA EGU, UDI's Control Technology data, and many publicly available state-level data sets. The population for non-utility units is limited to those units with firm capacity contracts to the grid, plus all units 25 MW or larger that contribute electricity to the grid via non-firm arrangements. The NEEDS also contains information from other databases, studies, and reports, some of which are proprietary. Key source databases are documented in more detail in Appendix 2 of U.S. EPA 1998b; other data sources are cited where relevant throughout this document.

[2] The EIA 860 for 1996, the NERC ES&D 1997, and the EIA AEO 1998 were the key sources for data on "committed" units (units companies commit to build in future). Only those units whose construction is considered reasonably certain were included in the modeling population. This includes units already under construction, as well as units fully licensed, approved, and financed, but not yet under construction. More detail on the selection of committed units is provided in Appendix 2 of U.S. EPA 1998b.

[3] This data set and other information on EPA's application of IPM can be found on the Internet at the following address: http://www.epa.gov/capi.

Figure 1
Integrated Planning Model (IPM) Used by EPA Represents the U.S. Electric Power Market in 21 Regions in the Contiguous United States



the fossil fuel-fired units.[4] The operation of non-fossil fuel-fired generation capacity, including nuclear and renewables, also is simulated at a higher degree of aggregation.[5]

A1.2 Assumptions

EPA used IPM to estimate utility emissions. With this optimization model, EPA forecasts emissions for the 48 contiguous states and the District of Columbia. All existing electric power generation units are covered in the model, as well as independent power producers and other cogeneration facilities that sell wholesale power, if they were included in the NERC database for reliability planning. The model considers future capacity additions by both utilities and independent power producers. In addition, this model is capable of producing baseline air emission forecasts and estimates of air emission levels under various control scenarios at the national, NERC region, and sub-regional levels. A full explanation of the IPM model and the assumptions EPA used for this analysis may be found in "Analyzing Electric Power Generation under the CAAA," (U.S. EPA1998b) and in Appendix A of the Section 812 Prospective Study (U.S. EPA 1999b).

[4] In IPM for existing fossil fuel-fired units in 2001, 1,127 coal steam boilers, 284 combined cycle units, 700 oil/gas steam boilers, and 1,783 combustion turbines are aggregated into 489, 54, 91, and 81 model plants, respectively. In addition, the model can select 28 new combined cycle units, 27 new coal units, and 28 new combustion turbines in building new generating capacity. The cost of new capacity depends on its location. The model plants are designed to group units that share key attributes. These attributes include heat rate, initial NO_X rate, size, boiler configuration, technology, and region. State is used as an attribute if a unit is in the eastern United States.

[5] In IPM for existing non-fossil fired units in 2001, 3,548 hydro units, 102 nuclear units, 143 pump storage units, and 243 other units are aggregated into 30, 20, 15, and 29 model plants, respectively. In addition, one geothermal unit and 27 wind turbine units are provided for the model to build new generating capacity. The cost of new capacity depends on its location.

[6] This document was updated in March 1998 to describe model refinements made for IPM Version 7.1 and the latest base case forecasts. (U.S. EPA March 1998b.)

Appendix 2 – Emission Scenario Construction

The emission scenario construction and analysis in this document starts by utilizing the existing body of knowledge developed for the CAA Section 812 Prospective Study (U.S. EPA 1999b). The 812 Study analysis examines the emissions of seven air pollutants: volatile organic compounds (VOC), nitrogen oxides (NO_X), sulfur dioxide (SO_2), carbon monoxide (CO), particulate matter with an aerodynamic diameter of ten microns or less (PM_{10}), particulate matter with an aerodynamic diameter of 2.5 microns or less ($PM_{2.5}$), and ammonia (NH_3). Changes in emissions of these pollutants were projected based on two emissions control scenarios: (a) a pre-1990 Clean Air Act Amendments (CAAA) scenario assuming that no additional controls would be implemented beyond those that were in place when the CAAA were passed; and (b) a post-CAAA scenario incorporating the effects of controls authorized by the 1990 Amendments. Comparison of the resulting projections revealed the predicted impact of the CAAA on emissions. In addition, these estimates provided the basis for the subsequent cost estimation and air quality modeling.

In the Section 812 Prospective Study, EPA based its pre- and post-CAAA emission estimates on projections from 1990 base year emission estimates. For all of the pollutants, except PM, the Agency selected emission levels from Version 3 of the National Particulates Inventory (NPI) to serve as the baseline. For both PM_{10} and $PM_{2.5}$, however, EPA updated NPI estimates to reflect the emissions from the National Emission Trends (NET) inventory. Once the base year levels were finalized, the 1990 emissions were projected to 2000 and 2010 under both the pre- and post-CAAA scenarios.

The Section 812 Prospective Study analysis estimated future emissions for all major source categories: industrial point sources, utilities, nonroad engines/vehicles, motor vehicles, and area sources. For all non-utility sources, emission projections relied on analysis that incorporated growth forecasts and future year control assumptions about rule effectiveness and control efficiency. In this analysis, EPA projected non-utility growth based largely on anticipated changes in economic activity, and treated the rule effectiveness and the rate of control efficiency as the key differences between the pre- and post-CAAA scenarios.

For the analysis of S. 172, the Agency used the Section 812 Prospective Study's post-CAAA scenario as the basis, replacing the utility emissions with the emissions developed as discussed below. EPA projected emissions by adjusting 1990 base year emissions to reflect projected economic activity levels in 2000 and 2010, and applying future year control assumptions. The resulting estimates largely depended upon three factors: (a) how the base year inventory was selected; (b) what indicators were used to forecast growth in electricity demand; and (c) what specific regulatory programs were incorporated in the pre- and post-CAAA scenarios. These three factors are addressed in Tables A-1 through A-3 of the CAA Section 812 Prospective Study (U.S. EPA 1999b). Table A-1 of the Section 812 Prospective Study highlights the approach EPA used to establish the base year inventory. The indicators the Agency relied on to forecast growth and predict future activity levels, along with the analytical approach EPA used to project emissions, are shown in Table A-2. The Section 812 Prospective Study's regulatory scenarios are summarized in Table A-3.

For the Section 812 analysis, EPA matched each unit in the IPM file to the 1990 National Particulates Inventory (NPI) (Pechan 1994;

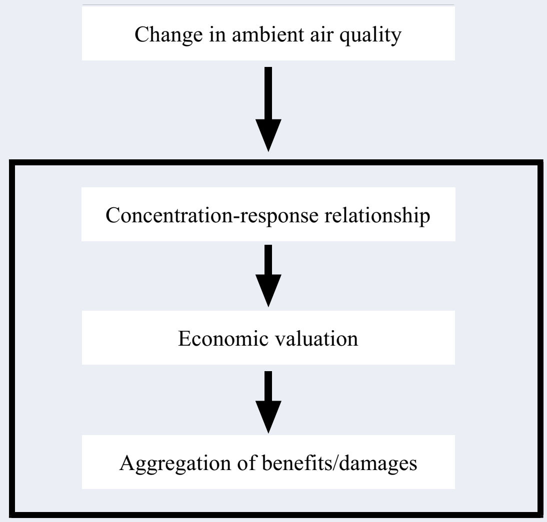
Pechan 1995) based on the Office of the Regulatory Information System (ORIS) plant and boiler code. For units that were matched, stack parameters and location coordinates were taken directly from the NPI. VOC, CO, PM_{10}, and $PM_{2.5}$ emissions were calculated using AP-42 emission rates (standard EPA emission factors that are developed from stack tests and engineering calculations) and control efficiencies as reported in the NPI. NH_3 emissions were calculated for ammonia slippage where boilers were forecast to install selective catalytic reduction (SCR) as the control technique to reduce NO_X emissions.

Of the factors that influence EPA's emissions projections for 2000 and 2010, the most significant is the suite of air pollution regulations and programs incorporated in the pre- and post-CAAA scenarios. As described above, the scenarios in this analysis build on the Section 812 Prospective Study's post-CAAA scenario, which assumes pre-CAAA control measures existing in 1990 and incorporates emission controls associated with the 1990 Amendments. Due to the necessity of developing emission scenarios early in the Section 812 Prospective Study's analysis process, the exact provisions of some regulatory programs could not be foreseen.

Appendix 3 – Air Quality Benefits Estimation Method

The general method used to estimate the value of benefits in this analysis is the damage function approach (DFA). This approach is consistent with both the underlying scientific principles of injury assessment and the economic theory of environmental impact valuation. The DFA uses available scientific and economic information to determine how changes in pollution emissions affect things of value to society, including human health and natural and anthropogenic resources. The DFA has been used frequently for these types of assessments and is generally regarded as the preferred approach. The damage function refers to a quantitative relationship between changes in pollution concentrations and damage to human health and the environment. When pollution is reduced, this approach is used to estimate benefits (i.e., the reduction in damages).

Exhibit A3-1
Damage Function Approach



The DFA as applied for this analysis is illustrated in Exhibit A3-1. A necessary input to the DFA is an estimate of the change in ambient air quality expected to result from a specified policy. The DFA then determines the implications of this change by:

- using concentration-response parameters to compute changes in physical impacts such as health events,
- applying economic values to physical impacts, and
- aggregating benefits across all affected individuals and all relevant time periods.

There is a large body of literature in the physical and social sciences that provides potential inputs to the DFA for estimating the benefits of reductions in ambient concentrations of air pollutants. There are many ways that the literature can be interpreted and many questions are not fully answered; however, EPA has conducted many similar benefits assessments, and the process has been reviewed in detail several times, including recent reviews by the EPA Science Advisory Board for the cost benefit assessment of the Clean Air Act (U.S. EPA 1999b) and for the Regulatory Impact Analysis (RIA) of the Tier 2 motor vehicle/gasoline sulfur rules (U.S. EPA 1999c). The quantification approaches have evolved and incorporated new research findings as they have become available. The specific quantification methods used here to estimate the benefits of reductions in ambient $PM_{2.5}$ concentrations follow the same approach as that used in the RIA for the Tier 2 Rules, completed in December 1999 (U.S. EPA 1999c).

This analysis follows the methods used for the "primary" estimates of PM health and welfare effects in the Tier 2 RIA. The Tier 2 RIA explored in much more detail the impact of alternative assumptions on its primary estimates. We focus here on only two alternative estimates, which the Tier 2 RIA showed had a very significant impact on the total PM health benefits. These alternative estimates highlight the considerable uncertainty in any such effort to quantitatively assess the benefits of a reduction in pollution emissions. The physical and economic relationships are complex and the available literature does not answer all the relevant questions. Those effects that can be quantified are estimated with some inevitable uncertainty. In addition, there are many effects that are known to exist but cannot be quantified with available information. This analysis for S. 172 has not quantified all the effects that may be possible to quantify due to limitations in the scope of the analysis. Exhibit A3-2 lists the effects quantified for the S. 172 analysis, all of which also have been quantified in other EPA analyses. The exhibit also lists the effects that have been quantified in other EPA analyses, either as primary estimates or as alternative estimates, but are not quantified here. Effects that have not been quantified by EPA in recent analyses also are listed.

A3.1 Concentration-Response Parameters for Human Health

Concentration-response parameters allow the estimation of the change in the frequency of each health event that would be expected as a result of changes in ambient pollution. For this application, the quantified events are changes in frequencies of human health events associated with changes in annual average $PM_{2.5}$ concentrations. Concentration-response parameters for $PM_{2.5}$ were selected from the available epidemiological literature and are summarized in Exhibit A3-3. These were calculated by taking the relative risk per $\mu g/m^3$ $PM_{2.5}$ and applying it to the annual baseline incidence rate for each of the health events. Results from multiple studies, if available for a given health event, were pooled to obtain a central estimate. Results from studies that focused on a subpopulation (e.g., children from 7 to 14) were applied only to that subpopulation, which is a cautious approach that may underestimate the benefits of $PM_{2.5}$ reductions.

The estimated change in PM air pollution for this assessment is all in the $PM_{2.5}$ size range. U.S. EPA reports concentration-response estimates from the literature for $PM_{2.5}$, PM_{10} and $PM_{10\text{-}2.5}$ (U.S. EPA 1999c). For this assessment we have used concentration-response estimates for $PM_{2.5}$ and PM_{10} only. The PM_{10} estimates are used with the assumptions that a change in $PM_{2.5}$ causes the same magnitude change in PM_{10} since $PM_{2.5}$ is part of PM_{10} and that the health effects of $PM_{2.5}$ are the same on a per unit basis as those of PM_{10}. If anything, these assumptions are likely to understate the health effects of the $PM_{2.5}$ change because $PM_{2.5}$ is expected to be at least as harmful as PM_{10}, if not more harmful. We assume there is no change in $PM_{10\text{-}2.5}$, which affects the estimates only for respiratory hospital admissions.

Though the effect of air pollution on mortality risk is small in terms of the number of premature deaths it causes, any change in mortality risk is likely to have substantial value to society. Therefore, it is useful to note a few specifics about the basis of the mortality risk estimates used in this application. Evidence of an association between $PM_{2.5}$ and premature mortality comes from two types of studies: short-term and long-term exposure studies. Short-term exposure studies estimate the relationship between day-to-day fluctuations in air pollution concentrations and day-to-day fluctuations in mortality in a given location. Long-term exposure studies estimate the relationship between long-term average pollution concentrations and population survival rates across different locations. Both types of studies have found statistically significant relationships

Exhibit A3-2
Effects of Ambient Pollutants on Human Health and Welfare in the United States That Would be Reduced by S. 172

Pollutant	Health or Welfare Effect Category	Primary Quantified and Monetized Effects for S. 172	Quantified and Monetized in Other EPA Analyses but not for S. 172[a]	Quantified and/or Monetized in Alternative Estimates in Other EPA Analyses but not for S. 172[a]	Not Quantified by EPA in Recent Analyses
$PM_{2.5}$	Health	Premature mortality for adults Bronchitis Hospital admissions Emergency room Work loss days Respiratory symptoms		Infant mortality	
$PM_{2.5}$	Welfare	Visibility at Class I NP		Household soiling Residential visibility	
Ozone	Health		Chronic asthma Hospital admissions Emergency room Respiratory symptoms	Premature mortality	Acute lung damage and inflammation Chronic lung damage Increased susceptibility to infection
Ozone	Welfare		Decreased worker productivity Decreased yields for commercial crops Decreased yields to commercial forests		Decreased yields for fruits and vegetables Damaged aesthetics of ornamental plants and forests Damage to ecosystem functions

Exhibit A3-2 (cont.)
Effects of Ambient Pollutants on Human Health and Welfare in the United States That Would be Reduced by S. 172

Pollutant	Health or Welfare Effect Category	Primary Quantified and Monetized Effects for S. 172	Quantified and Monetized in Other EPA Analyses but not for S. 172[a]	Quantified and/or Monetized in Alternative Estimates in Other EPA Analyses but not for S. 172[a]	Not Quantified by EPA in Recent Analyses
Acidic Sulfate and Nitrogen Deposition	Welfare		Impacts to recreational fishing		Impacts to commercial fishing Impacts to commercial forests Impacts to recreation in terrestrial ecosystems Damage to ecosystem functions Damage to monuments and other materials
Nitrogen Deposition	Welfare			Cost of reducing nitrogen loadings in east coast estuaries	Impacts to commercial fishing Impacts to agriculture and forests Impacts to recreation in estuarine ecosystems Impacts to ecosystem functions

a. These effects were quantified as part of the primary or alternative estimates in either the Section 812 Study of the Clean Air Act (U.S. EPA, 1999a) or the RIA for the Tier 2 Rules (U.S. EPA, 1999b), but their quantification was beyond the scope of this analysis for S. 172. To the extent that S. 172 reduces these pollutants, benefits in these categories can be expected in addition to those benefits that have been quantified for S. 172.

Exhibit A3-3
Selected Parameters for Human Health Events Associated with $PM_{2.5}$

Health Event Category	Sources	Population Affected	Annual Concentration-Response[a] per $\mu g/m^3$ Annual Average $PM_{2.5}$
Mortality	Pope et al. (1995)	Adults age 30 and over	8.08×10^{-5}
Alternative Mortality Estimate	Dockery et al. (1993)	Adults age 25 and over	1.55 ´ $\times 10^{-4}$
Chronic Bronchitis (New Cases)	Abbey et al. (1993;1995) Schwartz (1993)	Adults age 30 and over without chronic bronchitis	4.28×10^{-5}
Respiratory Hospital Admissions	Schwartz (1994a,b,c; 1995; 1996) Burnett et al. (1999) Thurston et al. (1994) Moolgavkar et al. (1997)	All	7.37×10^{-6}
Cardiovascular Hospital Admissions	Burnett et al. (1999) Schwartz (1997;1999) Schwartz and Morris (1995)	All	6.31×10^{-6}
Asthma-related Emergency Room Visits (net)	Schwartz et al. (1993)	Under age 65	1.03×10^{-5}
Upper Respiratory Symptom Days	Pope et al. (1991)	Asthmatic children ages 9 to 11	4.49×10^{-1}
Lower Respiratory Symptom Days	Schwartz et al. (1994)	Children ages 7 to 14	7.99×10^{-3}
Shortness of Breath	Ostro et al. (1995)	African-American asthmatic children ages 7 to 12	1.72×10^{-1}
Work Loss Days	Ostro (1987)	Adults ages 18 to 65	1.09×10^{-2}
Minor Acute Symptom Days	Krupnick et al. (1990) Ostro and Rothschild (1989)	Adults ages 18 to 65	5.84×10^{-2}
Acute Bronchitis in Children	Dockery et al. (1996)	Children ages 8 to 12	1.20×10^{-3}

a. These are calculated from reported relative risks adjusted to 1 $\mu g/m^3$ and evaluated at the mean baseline incidence for each health effect for each population.

between $PM_{2.5}$ and mortality risk, but the long-term exposure studies are especially important because they suggest that the mortality risk associated with $PM_{2.5}$ air pollution represents a significant shortening of life for those affected.

The largest long-term exposure study (Pope et al. 1995) shows a $PM_{2.5}$ effect that is about four times larger than that found in the short-term exposures studies (e.g., Schwartz et al. 1996). A smaller long-term exposure study found even larger mortality effects associated with $PM_{2.5}$ (Dockery et al. 1993). Although the two types of studies have strengths and weaknesses, the fact that both types of studies find a significant effect of $PM_{2.5}$ on mortality supports the conclusion that it is a causal relationship.

The primary concentration-response parameter for $PM_{2.5}$-related mortality used in this assessment is based on the Pope et al. (1995) results. It is applied to adults age 30 and over and is calculated using the nonaccidental mortality rate for this age group. Because these mortality risks are associated with long-term exposures to $PM_{2.5}$, it is reasonable to expect that the full benefit of the reduction takes some time to occur. However, the study does not provide evidence about how much time this might take. In a recent assessment, EPA made an adjustment for this time lag based on the assumption that the mortality risk changes associated with a change in $PM_{2.5}$ concentrations in a given year occur over five years. The assumed time profile of the changes is 25 percent in the first year, 25 percent in the second, and 16.7 percent in each of the next three years. The value of mortality risk reductions in future years was then discounted at 5 percent a year (U.S. EPA 1999c). EPA acknowledged that the accuracy of this adjustment is uncertain and looked at the implications of alternative assumptions. A longer lag lowers the benefit and a shorter lag increases the benefit. This assessment uses the assumptions on which EPA's primary estimate is based (U.S. EPA 1999c).

Another way to quantify a change in mortality risk is to estimate the number of life years saved. This approach takes into account the remaining life expectancy of those at risk, which may vary depending on the population at risk, but based on available information it is difficult to determine the life years saved as a result of reductions in air pollution. U.S. EPA (1999b) reports that, based on reasonable assumptions applied to the results of Pope et al. (1995), the number of years saved per mortality prevented as a result of reductions in $PM_{2.5}$ may be about 14 years.

The results of the Dockery et al. (1993) study are used as an alternative estimate of the mortality effect of change in $PM_{2.5}$ concentrations. Their results suggest a 1.55×10^{-4} increase in annual per capita mortality risk for every 1 $\mu g/m^3$ change in $PM_{2.5}$ concentrations which is applied to individuals age 25 and older. These results suggest an effect that is almost twice as large as the results based on the Pope et al. (1995) study. The Dockery et al. estimate of the relationship between PM exposure and premature mortality is a plausible alternative to the Pope et al. estimate and was used by EPA as an alternative estimate of mortality risk from changes in PM in the Tier 2 RIA (U.S. EPA 1999c). The SAB has noted that "the study had better monitoring with less measurement error than did most other studies" (EPA-SAB-COUNCIL-ADV-99-012 1999). However, the Dockery study had a more limited geographic scope (and a smaller study population) than the Pope et al. study. The demographics of the Pope et al. study population, (i.e., largely white and middle-class), also may produce a downward bias in the Pope PM mortality coefficient, because short-term studies indicate that the effects of PM tend to be significantly greater among groups of lower socioeconomic status. The Dockery study also covered a broader age category (25 and older compared to 30 and older in the Pope study) and followed the cohort for a longer period (15 years compared to 8 years in the Pope study). For these reasons, the Dockery study is considered to be a plausible alternative estimate of the premature mortality risk associated with changes in PM concentrations.

A3.2 Monetary Valuation Estimates for Human Health

Monetary valuation estimates for health events consider the many potential economic and social consequences associated with the adverse health effects that result from air pollution, including medical costs, work loss, out-of-pocket expenses, and pain and suffering. While the economic valuation estimates used to assess potential benefits may include medical costs, they must not be interpreted in their totality as savings to the health care system. More appropriately, these estimates must be considered as the value that society places on decreases in our risk of experiencing the health event.

The economic measure of value that captures all the reasons why people value reductions in health risks is called willingness to pay (WTP). It is a measure of the monetary tradeoffs people are willing to make in exchange for reductions in risks of mortality or morbidity. Unlike many goods and services that people can purchase and enjoy, the prevention of health risks cannot be directly purchased in the marketplace. As a result, there are no price and quantity data from which WTP values can be easily estimated, so the importance to the public of avoiding the health events may be ignored or misunderstood in the decision-making process unless alternative sources of information are used.

Over the last four decades, economists have developed and refined a number of techniques to estimate the economic value of avoiding health effects. These techniques estimate values by examining how people trade off money for changes in health risks. Most empirical methods for valuation fall into two categories: those that rely on observed market behavior (revealed preference methods) and those that do not (stated preference methods). An example of the revealed preference method is the wage-risk approach, which involves the analysis of wages in relation to occupational risks to determine the value of avoided mortality. More than 20 wage-risk studies were used to determine what monetary value should be assigned to a change in mortality risk. These studies provide estimates of the tradeoffs observed in the labor market between wages and the risks of on-the-job fatalities (Viscusi 1992).

Contingent valuation method (CVM) surveys are an example of the stated preference method. In this method, surveys are used to measure people's preferences for various goods in the context of a hypothetical market. The prevailing view is that stated preference methods can generate valid and reliable valuation estimates if they are carried out meticulously and in the appropriate context. Because these techniques are based on surveys rather than direct observation of actual behavior, however, their validity is sometimes debated.

The results of a number of stated preference studies were used to determine WTP values for many of the morbidity health effects (i.e., effects short of death) included for $PM_{2.5}$. For several health events (e.g., hospital admissions) there are no empirical estimates of WTP, so cost-of-illness estimates were used. These estimates, which reflect only the out-of-pocket costs of a health event, clearly understate WTP because they do not consider impacts on the value of nonwork activities and quality of life. The selected estimates of the monetary value of mortality and morbidity health events are shown in Exhibit A3-4. These estimates are

Exhibit A3-4
Monetary Estimates for Health Events

Health Event	Primary Estimate per Incident (1997$)
Mortality[a] - VSL	$5,900,000
VSL, adjusted for life years saved[b]	$3,600,000
Chronic Bronchitis (new case)	$319,000
Respiratory Hospital Admission[c]	$10,600 (COI)[d]
Cardiac Hospital Admission[c]	$13,600 (COI)
Emergency Room Visit	$280 (COI)
Upper Respiratory Symptom Day	$23
Lower Respiratory Symptom Day	$15
Shortness of Breath	$7
Work Loss Day	$102 (COI)
Minor Acute Symptom Day[c]	$47
Acute Bronchitis	$55

a. Both of the monetary value estimates for mortality risk are applied to the presumed 5-year lag in the reductions in mortality risk: 25 percent in the 1st and 2nd years, and 16.7 percent in each of the 3rd, 4th, and 5th years. With a 5 percent discount rate, this results in an effective mean value of $5.4 million and $3.3 million per mortality prevented, respectively.

b. The VSLY is calculated assuming a VSL of $5.9 million originally for 35 remaining years, a 5 percent discount rate, and a constant value per year. Adjusted to a 14-year life expectancy and a 5 percent discount rate this gives $3.6 million.

c. A few health events (hospital admissions and minor acute symptom days) are calculated as pooled estimates of somewhat different (but mostly overlapping) events that have slightly different average monetary values. The values reported here are the weighted means, using the same weights as those used to pool the event estimates.

d. COI indicates that the estimate is based on the cost of illness rather than the willingness to pay approach.

consistent with the monetary value estimates used in the RIA for the Tier 2 Rules (U.S. EPA 1999c).

Total monetized human health benefits are dominated by the benefits of reduced mortality risk. Mortality-related benefits account for over 90 percent of total monetized health benefits. However, the adoption of a value for the projected reduction in the risk of premature mortality is the subject of continuing discussion within the economic and public policy analysis community within and outside the Administration. In response to the sensitivity on this issue, we provide estimates reflecting two alternative approaches. The primary benefits estimate uses a Value of a Statistical Life (VSL) approach developed for the Clean Air Act Section 812 benefit-cost studies (U.S. EPA 1999b). This VSL estimate of $5.9 million (1997$) was derived from a set of 26 studies identified by EPA using criteria established in Viscusi (1992) as those most appropriate for environmental policy analysis applications.

An alternative age-adjusted approach was also developed for the Section 812 studies and addresses concerns with applying the VSL estimate—reflecting a valuation derived mostly from labor market studies involving healthy working-age manual laborers—to PM-related mortality risks that are primarily associated with older populations and those with impaired health status. This alternative approach leads to an estimate of the value of a statistical life year (VSLY), which is derived directly from the VSL estimate. It differs only in incorporating an explicit assumption about the number of life years saved and an implicit assumption that the valuation of each life year is not affected by age. The mean VSLY is $360,000 (1997$); combining this number with a mean life expectancy of 14 years yields an age-adjusted VSL of $3.6 million (1997$).

Both approaches are imperfect, and raise difficult methodological issues which are discussed in depth in the recently published Section 812 Prospective Study (U.S. EPA 1999b), the draft EPA Economic Guidelines, and the peer-review commentaries prepared in support of each of these documents. For example, both methodologies incorporate assumptions (explicit or implicit) about which there is little or no definitive scientific guidance. In particular, both methods adopt the assumption that the risk versus dollar trade-offs revealed by available labor market studies are applicable to the risk versus dollar trade-offs the general population would make in an air pollution context.

The primary benefits estimate uses the VSL approach, reflecting the application of what EPA considers to be the most reliable valuation of premature mortality available in the current economic literature. In addition, the independent outside economics experts of the Science Advisory Board Environmental Economics Advisory Committee recently conveyed new advice to EPA indicating support for EPA's continued reliance—pending the results of additional research—on the VSL approach for its primary analysis[1] and raising additional issues concerning the validity and reliability of the VSLY approach.[2] While there are several differences between the labor market studies EPA uses to derive a VSL estimate and the $PM_{2.5}$ air pollution context addressed here, those differences in the affected populations and the nature of the risks imply both upward and downward adjustments. For example, adjusting for age differences (or health status) may imply the need to adjust the $5.9 million VSL downward, but the involuntary nature of air pollution-related risks and the lower level of risk-aversion of the manual laborers in the labor market studies may imply the need for upward adjustments. In the absence of a comprehensive and balanced set of adjustment factors, it is reasonable to continue to use the $5.9 million value while acknowledging the significant limitations and uncertainties in the available literature. Furthermore, EPA prefers not to draw distinctions in the monetary value assigned to the lives saved even if they differ in age, health status, socioeconomic status, gender or other characteristics of the adult population.

Those who favor the alternative, age-adjusted approach (i.e., the VSLY approach) emphasize that the value of a statistical life is not a single number relevant for all situations. Indeed, the VSL estimate of $5.9 million (1997$) is itself the central tendency of a number of estimates of the VSL for some rather narrowly defined populations. When there are significant differences between the population affected by a particular health risk and the populations used in the labor market studies—as is the case here—they prefer to adjust the VSL estimate to reflect those differences. While acknowledging that the VSLY approach provides an admittedly crude adjustment (for age though not for other possible differences between the populations), they point out that it has the advantage of yielding an estimate that is not presumptively biased.

Proponents of adjusting for age differences using the VSLY approach fully concur that enor-

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[1] Science Advisory Board. 2000. *An SAB Report on EPA's White Paper Valuing the Benefits of Fatal Cancer Risk Reductions,* EPA-SAB-EEAC-00-013, U.S. EPA Science Advisory Board, Washington, D.C., July 27, 2000, page 1: "Despite limitations of the VSL estimates, these seem to offer the best available basis at present for considering the value of fatal cancer risk reduction. We therefore recommend that the Agency continue to use a wage-risk-based VSL as its primary estimate, including appropriate sensitivity analyses to reflect the uncertainty of these estimates."

[2] SAB, ibid., page 7: "Inferring the value of a statistical life year ... requires assumptions about the discount rate and about the time path of expected utility of consumption. The Committee agrees with the judgement expressed [by EPA] ... that the theoretically appropriate method is to calculate [willingness to pay] for individuals whose ages correspond to those of the affected population, and that it is preferable to base these calculations on empirical estimates of WTP by age. The Committee urges that more research also be conducted on this topic."

mous uncertainty remains on both sides of this estimate—upwards as well as downwards—and that the populations differ in ways other than age (and therefore life expectancy). But rather than waiting for all relevant questions to be answered, they prefer a process of refining estimates by incorporating new information and evidence as it becomes available.

A3.3 Economic Valuation of Changes in Visibility Aesthetics

Visibility directly affects people's enjoyment of a variety of daily activities. Individuals value visibility in the places they live and work, in the places they travel to for recreational purposes, and at sites of unique public value, such as national parks. Consumer values for changes in visual air quality can be divided into use and nonuse values. Use values are related to the direct effect on the individual's well-being from experiencing various visibility conditions. This could be during everyday activities like driving to work as well as any number of outdoor recreation or sightseeing activities. Nonuse values for visibility are the values an individual holds for protecting visibility for use by others now and in the future, and for knowing that visibility is being protected regardless of current or future use.

Increases in PM concentrations cause increases in light extinction. Light extinction is a measure of how light is absorbed or scattered as it passes through the atmosphere. More light extinction means that the clarity of visual images and visual range is reduced, ceteris paribus. Recent analyses of visibility have been using a new measure of haziness that was developed by Pitchford and Malm (1994), which they call the deciview. The deciview is an index of visibility conditions that is near zero for pristine conditions and increases as visibility is degraded. A change of a single deciview represents a small but perceptible scenic change to the human observer.[3] The deciview scale is based on the observation that the apparent magnitude of the change in visual air quality to the human observer is roughly proportional to the percentage change in visual range. A deciview is approximately equivalent to a 10 percent change in visual range.

EPA included benefits for visibility improvements at Class I areas[4] in the primary estimates of benefits in the Tier 2 RIA (U.S. EPA 1999c), and a similar estimation approach is followed here. The benefits are believed to consist of both use values and non-use values. Non-use values seem to be an important component of value for recreational areas, particularly national parks.

The results of air quality modeling for the S. 172 analysis show substantially greater visibility improvements in the eastern United States (generally an improvement of greater than one deciview in annual average conditions) than in the central or western areas of the country (generally less than half a deciview improvement in annual average conditions). This analysis therefore focuses on visibility improvements at Class I national parks in the East. However, even though the visibility changes in other parts of the country are smaller, there are many more Class I national

[3]A change of less than one deciview is measurable with instruments that measure light extinction, but may not be perceptible to the human eye. In some locations, the average annual change in visibility expected as a result of S. 172 is less than one deciview. However, this does not mean that these changes are not real or significant. Our assumption is that individuals can place values on changes in visibility that may not be perceptible. This is quite plausible if individuals are aware that many regulations lead to small improvements in visibility which when considered together amount to perceptible changes in visibility.

[4]The Clean Air Act designates 156 national parks and wilderness areas as Class I areas for visibility protection; about half are national parks and the others are primarily Forest Service wilderness areas.

parks in the West and even small visibility improvements could provide substantial visibility benefits to U.S. households. There also is evidence that people value visibility aesthetics in places where they live and spend most of their time. EPA has included estimates of benefits from visibility improvements in residential areas in some alternative estimates of benefits, because there is some uncertainty about the quantitative reliability of studies that provide the basis for these estimates (U.S. EPA 1999c). Therefore, the visibility benefits estimates presented for S. 172 should be considered a lower bound.

The visibility benefits estimates are based on a 1988 survey on visibility values for national parks (Chestnut and Rowe 1990a, 1990b), using the contingent valuation method (CVM). There has been a great deal of controversy and significant development of both theoretical and empirical knowledge about how to conduct CVM surveys in the past decade. In EPA's judgment, the Chestnut and Rowe study contains many of the elements of a valid CVM study and is sufficiently reliable to serve as the basis for monetary estimates of the benefits of visibility changes in recreational areas.[5] This study serves as an essential input to the estimates of the benefits of recreational visibility improvements in the primary benefits estimates.

The National Parks Visibility Values survey asked respondents what they would be willing to pay each year per household to have average visibility conditions at national parks in specific regions change by a specific amount. The change in visibility was defined for the respondents with pictures showing the expected change in views associated with the improvement, or avoided decrement, in visibility at a well known national park in a region. Other Class I national parks in each region were shown on a map. Separate household WTP estimates for the visibility improvements were then calculated for households within and outside of the region, because these were found to be statistically significantly different. WTP estimates were also adjusted to national average income, because the respondents reflected an above average income group and income was also associated with responses. The visual range scenario information presented to the study respondents and the adjusted WTP responses for the national parks in the southeastern United States are presented in Exhibit A3-5.

The Chestnut and Rowe study measured values for visibility improvements in Class I national parks in three regions: Southeast, Southwest and California. The values were for all the parks within a region, and since it was for regional air quality improvements, respondents may well have been thinking about scenic areas more extensive than the specific parks shown on the map. For this analysis, visibility improvements vary somewhat within regions. The results of the Chestnut and Rowe study are therefore applied by allocating the regional WTP for visibility improvements to individual park locations in proportion to visitation at the parks. Estimates for the Southeast region also are transferred to the Northeast region on the assumption that the WTP is proportional to park visitation. However, these values are not as defensible as the estimates for the Southeast because some unverified assumptions must be made about

[5]An SAB advisory letter (EPA-SAB-COUNCIL-ADV-00-002 1999) indicates that "many members of the Council believe that the Chestnut and Rowe study is the best available," however, the council did not formally approve use of these estimates because of concerns about the peer-reviewed status of the study. EPA believes the study has received adequate review and has been cited in numerous peer-reviewed publications (Chestnut and Dennis 1997).

Exhibit A3-5
Results from National Parks Visibility Valuation Survey for the Southeast Region

Starting Annual Average Visibility in Deciviews[a]	Ending Annual Average Visibility in Deciviews[a]	Visibility Change in Deciviews[a]	In Region WTP (1997$)[b]	Out of Region WTP (1997$)[b]
27.5	20.6	6.9	$65	$34
27.5	16.5	11.0	$81	$53
27.5	36.7	9.2	$74	$47

a. The original study reports visual range (VR) in kilometers. The conversion equation to deciviews is as follows: deciviews = 10 X ln(391/VR). The first two scenarios showed an improvement in visibility and the WTP questions were for obtaining the improvement. The third showed a deterioration in visibility and the WTP question was WTP to prevent the deterioration. These are technically slightly different economic welfare measures, but for the purposes of summarizing the results of this study we treat them as comparable measures.

b. The original WTP estimates are in 1990 dollars. Their 1997 equivalent was determined by multiplying by 1.228 which is the ratio of the 1997 to the 1990 CPI values. The WTP estimates reported here have been adjusted to national mean household income based on the finding of an income elasticity of about 0.9. The study sample had a somewhat higher average income than the national average.

how to transfer results from one region to another.

The method for applying the results from the Chestnut and Rowe study to other changes in visibility at Class I national parks is based on the approach developed by Smith et al. (1999). This approach takes into account an assumed underlying utility function that accounts for the income effects of having to spend more or less resources on alternative goods given a budget constraint. The visibility values are extrapolated to the specific change in visibility for this analysis using an assumed Constant Elasticity of Substitution (CES) utility function. One of the parameters needed for this function is the income elasticity for visibility. The benefits estimates here incorporate Chestnut and Rowe's finding that a 1 percent increase in income is associated with a 0.9 percent increase in WTP for a given change in visibility. From the CES utility function, the following WTP function for visibility improvements can be derived:

$$WTP\ (Q_{0ik} - Q_{1ik}) = M - [M^{\rho} + \Sigma\gamma_{ik}(Q_{0ik}{}^{\rho} - Q_{1ik}{}^{\rho}) + \Sigma\delta_{ik}(Q_{0jk}{}^{\rho} - Q_{1jk}{}^{\rho})]^{1/\rho},$$

where

ρ = 1 - income elasticity

Q_{0ik} = starting visual range at k^{th} park in i^{th} region

Q_{1ik} = ending visual range at k^{th} park in i^{th} region

M = household income

γ_{ik} = parameter corresponding to WTP for visibility at the k^{th} park in i^{th} region for in-region residents

δ_{ik} = parameter corresponding to WTP for visibility at the k^{th} park in i^{th} region for out-of-region residents.

The γ and δ parameters are calculated for in-region households and for out-of-region households, respectively, for each of the park regions from the results of the Chestnut and Rowe study using the following relationships. These parameters are then adjusted to specific parks using the fraction of total park visitation in the region that is for each park.

$$\gamma i = \frac{(M - WTP_i^{in})^{\rho} - M^{\rho}}{(Q_{0i}^{\rho} - Q_{1i}^{\rho})}$$

$$\delta i = \frac{(M - WTP_i^{out})^{\rho} - M^{\rho}}{(Q_{0i}^{\rho} - Q_{1i}^{\rho})}$$

One major source of uncertainty for the visibility benefit estimate is the benefits transfer process used. Judgments used to choose the functional form and key parameters of the estimating equation for WTP for the affected population could have significant effects on the size of the estimates. Assumptions about how individuals respond to changes in visibility that are either very small, or outside the range covered in the Chestnut and Rowe study, could also affect the results.

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