SOUTHERN APPALACHIAN MOUNTAINS INITIATIVE

FINAL REPORT SUMMARY

AUGUST 2002

SOUTHERN APPALACHIAN MOUNTAINS INITIATIVE PARTICIPANTS

Governing Body

Director, Alabama Department of Environmental Management
Director, Environmental Protection Division, Georgia Dept. of Natural Resources
Secretary, Kentucky Natural Resources and Environmental Protection Cabinet
Secretary, North Carolina Department of Environment and Natural Resources
Deputy Commissioner, South Carolina Department of Health and Environmental Control
Commissioner, Tennessee Department of Environment and Conservation
Director, Virginia Department of Environmental Quality
Secretary, West Virginia Department of Environmental Protection Regional Administrator
U.S. Environmental Protection Agency – Region III
Regional Administrator, U.S. Environmental Protection Agency – Region IV
Superintendent of Blue Ridge Parkway, National Park Service
U. S. Forest Supervisor, Francis Marion and Sumter National Forests, U.S. Forest Service
Principal Scientist, Southern Company (Industry Representative)
Southeast Air Quality Manager, Environmental Defense (Environmental Representative)

Organizations

State of Alabama
Alabama Audubon Council
Alabama Power
Allegheny Power
American Electric Power
Appalachian State University
Appalachian Voices
Buncombe County, NC Extension Office
Buncombe County Metropolitan Sewerage District
Celanese Acetate, LLC
Center for Entrepreneurship Education and Development
Chevron
Clean Air Conservancy (OH)
Council of Industrial Boiler Owners
Dominion Power
Duke Energy
Duke Power
Eastern Band of the Cherokee Indians
Eastman Chemical Company
Ecusta, a Division of P.H. Glatfelter
Environmental Defense
State of Georgia
Georgia Power
Georgia State University
Great Smoky Mountains National Park
Jackson & Kelly, PLLC
Commonwealth of Kentucky
Land of Sky Regional Council
Mammoth Cave National Park
Mountaineer Chapter of Trout Unlimited
Mountain Air Quality Coalition
National Park Service
National Parks Conservation Association
NC State University
State of North Carolina
Oak Ridge National Labs
Progress Energy
Public Service Company of NC Inc.
Riverlink
Saturn Corporation
SEIF
Southeast States Air Resource Managers (SESARM)
Shenandoah National Park
State of South Carolina
South Carolina Wildlife Federation
Southern Alliance for Clean Energy
Southern Appalachian Man and Biosphere
Southern Company
Southern Environmental Law Center
State of Tennessee
Tennessee Valley Authority
University of North Carolina at Asheville
University of Tennessee
University of Virginia
U.S. Environmental Protection Agency
U.S. Forest Service
Commonwealth of Virginia
Virginia Conservation Network
Virginia Power
Virginia Trout Unlimited
State of West Virginia
West Virginia Citizens Action Group
West Virginia Highlands Conservancy
Western North Carolina Clean Air Campaign
Western North Carolina Air Control Agency

Contractors That Contributed to SAMI Research

ABT Associates, Inc.
Alpine Geophysics
Argonne National Lab
Air Resources Specialists
ASL Associates
BBC Research and Consulting
Boyce Thompson Institute, Cornell University
Duke University
E&S Environmental Chemistry
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ICF Consulting.Inc.
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Tetra Tech, Inc.
University of Alabama, Huntsville
University of Virginia

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BACKGROUND

The Federal Clean Air Act establishes air quality requirements to protect human health and welfare. It also requires that the air quality related values of national parks and wilderness areas be protected. The National Park Service and the United States Forest Service have an “affirmative responsibility” to review major new air pollution sources for likely impacts in the ten Southern Appalachian national parks and wilderness areas called Class I areas. Their comments to state air pollution permitting agencies on new and expanded facilities caused concern for economic development interests and also for the industries facing decisions on where to locate or expand plants in the Southern Appalachians. The deteriorating air quality in this region in the early 1990s also caused concern for the federal land managers, environmental interests, and the public. The air quality issues in the SAMI Class I areas often generated disagreements among states, land managers, and industry, sometimes leading to air quality permitting delays and uncertainty. In 1990 and 1992 the Department of the Interior published preliminary notices of adverse impacts for Shenandoah and Great Smoky Mountains National Parks.

SAMI Geographic Domain

FIGURE 1: The Geographic domain of the Southern Appalachian Mountains Initiative and location of Class I Areas.

The Southern Appalachian Mountains Initiative (SAMI) was founded to develop a better understanding of the complex air quality situation in the Southeast and to recommend ways to remedy existing and to prevent future adverse effects on the SAMI Class I areas (Figure 1). It is a voluntary consensus-based partnership of state and federal environmental agencies, federal land managers, industries, environmental groups, academia, and interested citizens. The eight states of the Southern Appalachians: Alabama, Georgia, Kentucky, North Carolina, South Carolina, Tennessee, Virginia and West Virginia collectively led the nearly decade-long effort. The SAMI Mission is:

> *“Through a cooperative effort, identify and recommend reasonable measures to remedy existing and prevent future adverse effects from human-induced air pollution on the air quality-related values of the Southern Appalachians, primarily those of Class 1 parks and wilderness areas, weighing the environmental and socioeconomic implications of any recommendations.”*

This document summarizes SAMI work on a variety of air quality issues. Areas determined to be outside the SAMI mission include the effect of carbon emissions and the effect of mercury emissions, as well as issues related to (global warming). SAMI also did not make recommendations related to human health effects.

INTEGRATED ASSESSMENT

Ozone = nitrogen oxide + volatile organic compounds + sunlight

Ozone is a colorless gas. At elevated levels it affects breathing in humans, particularly for children, elderly, and those with respiratory problems.

Acid Rain = sulfur dioxide + nitrogen oxide + water = sulfuric acid + nitric acid

Acid Deposition can occur as rain, cloudwater, or dry deposition of particles. Acid rain can acidify sensitive streams and forests.

Fine Particles = sulfate + nitrate + ammonia + organics + soil dust

Fine particles in the air scatter light and impair visibility. They can also affect breathing in humans.

FIGURE 2: A variety of human and natural resources contribute to the formation of ozone, acid rain, fine particles.

SAMI assembled a series of linked computer models to examine some of the more important impacts of fine particles, ozone, and acid deposition (Figure 2) in the Southern Appalachian Class I areas. SAMI's Integrated Assessment model (Figure 3) tested a series of hypothetical emissions control scenarios and projected the effect of those controls through 2040. SAMI also estimated the cost of those controls and identified some of the social and economic implications of possible control strategies. This document reports the highlights of the SAMI work. Following is a brief description of each of the Assessment areas:

Emissions Inventories characterized pollutants and their sources. SAMI inventories project the emissions that contribute to ozone, fine particles, and acid deposition in the Eastern United States. The projected emissions are based on various emission reduction strategies for current and future years to 2040. Direct costs of emissions reduction controls were also assessed.

Atmospheric Modeling simulated air quality conditions for nine weeklong episodes during 1991-1995. Each episode consists of contiguous days chosen to represent a range of meteorological, emissions, and atmospheric chemistry conditions that contribute to air quality in the SAMI region. Atmospheric model simulations for the 1991-1995 episodes, 2010, and 2040 generated air quality response data for each emissions reduction strategy.

Environmental Effects Modeling evaluated the responses of forests, streams, and visibility to changes in fine particles, ozone levels, and acid deposition. From these response data, SAMI described how air quality and natural resources respond to changes in emissions.

Socioeconomic Assessment examined some of the social and economic implications of SAMI emissions reduction strategies. Of the large number of socioeconomic indicators possible, SAMI examined the impact on: Fishing; Recreational/Residential Visibility; Stewardship/ Sense of Place, and Lifestyles.

Direct Cost of Controls estimated the direct cost of the emission reduction strategies in the years 2010 and 2040. These cost were estimated in order to fully evaluate the environmental benefit of expenditures made to reduce pollutant emissions.

SAMI Integrated Assessment

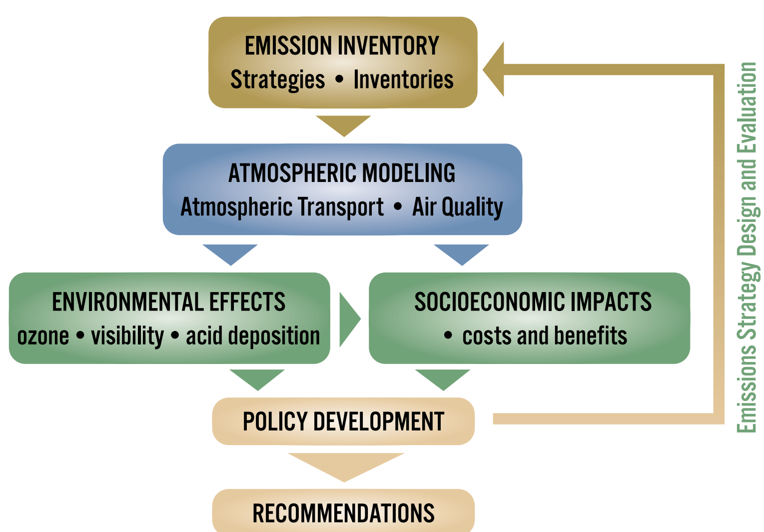


FIGURE 3: Flow chart of each level component of the Integrated Assessment

EMISSIONS INVENTORY AND STRATEGY DESCRIPTIONS

SAMI assembled an inventory of air emissions encompassing the eastern United States at the county level. From lawn mowers to locomotives, emissions were projected from 1990 through 2040 (Figure 4). Sulfur dioxide, nitrogen oxides, volatile organic compounds and ammonia are the predominant emissions contributing to ozone, to the fine particles that cause haze, and to acid deposition. Coal-fired electric utility plants are the largest source of sulfur dioxide. Highway vehicles and utilities are the largest sources of nitrogen oxides. Highway vehicles are also the largest human sources of volatile organic compounds. Agricultural sources are the largest contributors of ammonia gas.

Emissions for two families of strategies (“A” and “B”) were developed for 2010 and 2040 (Figure 5). Strategy A2 describes controls currently required under the Clean Air Act, including the acid rain controls, the 1-hour ozone standard, highway vehicle and fuel rules, and regional reductions of nitrogen oxides from utilities and large industrial sources. Some provisions of future programs such as the controls likely to be required under the fine particle standards, the 8-hour ozone standard, and the Regional Haze Rules were not included in the “A” strategies because of uncertainty surrounding the nature of the controls needed to meet these requirements. The B1, B2 and B3 strategies reflect increasingly stringent additional controls on all sources of emissions. For example, the B1 strategy requires an 80% reduction in industrial sulfur dioxide emissions by 2010 and 90% by 2040. B3 requires a 98% reduction by 2040. On-road mobile sources such as highway vehicles were projected to meet new “Tier 2” standards in 50% of the light duty mobile sources fleet under strategy B1 in 2010. For B3 SAMI projected the effect of converting all cars and light trucks to zero emission vehicles by 2040. Inventories for the B strategies were developed only for the eight SAMI States where the more stringent hypothetical controls were applied. None of those more stringent controls were applied to any states outside the SAMI region.

SAMI’s confidence in these emission projections varies. The utility growth and emission projections are probably the most certain in the inventory because they are closely monitored and because they come from defined point sources. There is much less certainty in ammonia emissions, which come largely from dispersed agricultural operations that are not closely monitored.

Population, Electricity Generation, and Vehicle Use Projections – SAMI States

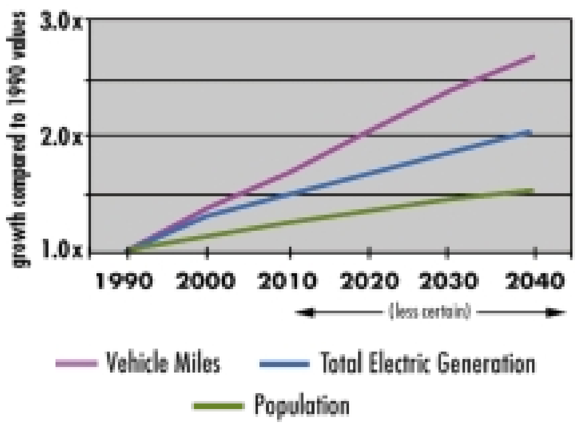
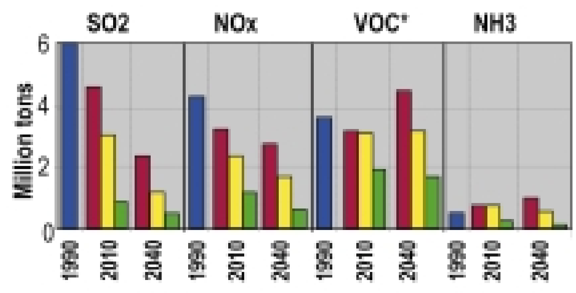


FIGURE 4: Projections of population, electricity demand and vehicle miles traveled in the SAMI States from 1990 to 2040.

Annual Emissions in 8 SAMI States



*Human sources of VOC only, not included natural sources of VOC

FIGURE 5: Four-pollutant comparison of emission levels between 1990, 2010 and 2040 selected strategies in the SAMI States

EMISSIONS INVENTORY KEY FINDINGS

1. The utility sector is the largest source of sulfur dioxide and showed the greatest reductions in sulfur dioxide in response to the SAMI strategies (Figure 6).
2. Collectively in the SAMI states annual average sulfur dioxide emissions are projected to decrease 23% by 2010 with current programs compared to 1990. However, emissions increases are projected in North Carolina, South Carolina and Virginia because of growth and because of trading programs. (Note: Recent legislation may affect this finding in North Carolina.)
3. The utility and highway vehicle sectors are the largest sources of nitrogen oxides and show the greatest reductions in response to the SAMI strategies (Figure 7).
4. Highway vehicles are the major source of organic compounds due to human activity. Natural sources, such as vegetation, are larger sources of volatile organic compounds, especially during summer months.
5. The largest sources of ammonia are animal feeding operations and fertilizer applications.
6. Under existing regulatory programs, volatile organic emissions will increase between 2010 and 2040 by 39% and ammonia emissions increase by 34% in response to the SAMI strategies.

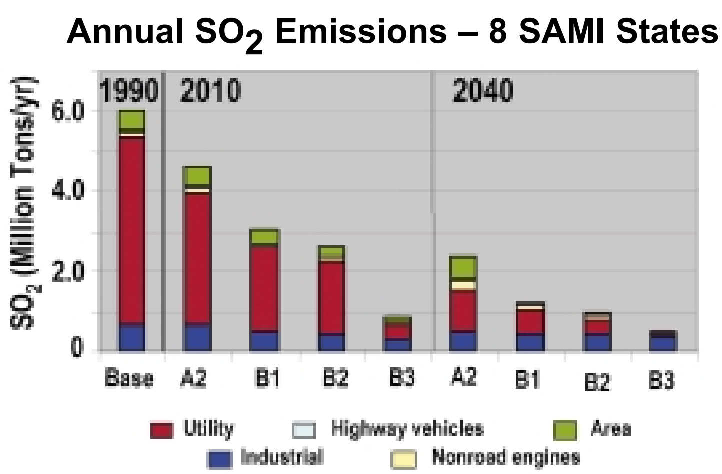


FIGURE 6: Comparison of annual SO_2 emissions by source sectors.

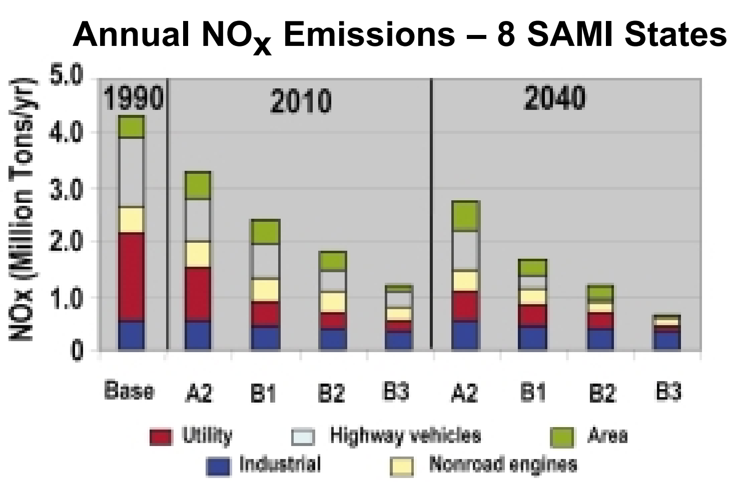
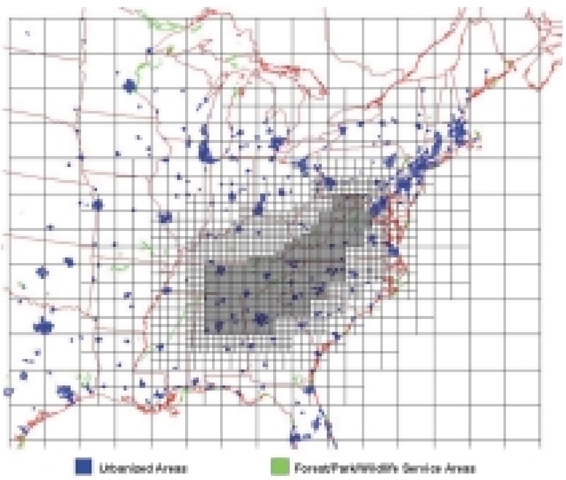


FIGURE 7: Comparison of annual oxides of nitrogen emissions by source sectors.

ATMOSPHERIC MODELING AND GEOGRAPHIC SENSITIVITY ANALYSIS

SAMI demonstrated three new atmospheric modeling approaches (Figure 8) that add credibility to the SAMI results. One is a method for sorting weather events from five years of records into categories and then selecting typical episodes to represent each type of weather pattern. This approach made very complex modeling possible within time and budget constraints. Another new approach is a “one atmosphere” atmospheric model that allowed SAMI to simultaneously examine acid deposition, ozone, and haze-causing fine particles. Previous efforts focused on one of these pollutants at a time, ignoring potentially important interactions between pollutants in the atmosphere. Finally, SAMI examined the effect of air pollution emission changes in individual states and the resulting relative impact on Class I national parks and wilderness areas. This information will aid policy decisions about which emission reductions will be the most useful.

SAMI Atmospheric Modeling Domain



Georgia Institute of Technology

FIGURE 8 Atmospheric modeling domain for the urban-to-regional multiscale – one atmosphere (URM-1-ATM) model

In general, SAMI found that emissions reductions applied in a particular state will generate the most benefit in that state. In every case, Class I areas are also affected by surrounding states and by emissions originating outside the eight SAMI states. SAMI estimated the effect of emission changes from each SAMI state and the surrounding non-SAMI regions to air quality in the ten SAMI Class I areas (Figure 9). These results help answer questions about the sources of emissions that cause environmental effects to Class I ecosystems. Interestingly, the areas contributing emissions that are likely to generate ozone problems are different than the areas that contribute to acid deposition problems or haze. The type of nitrogen oxide emissions is also important when seeking to reduce ozone. Once required emissions reductions from utilities and large industrial sources are implemented, reducing emissions from ground level sources such as highway vehicles, construction equipment, and lawn mowers will be increasingly important.

Annual SO_4 Fine Particles Response to 10% Reduction in SO_2 Emissions from 2010 A2 Strategy

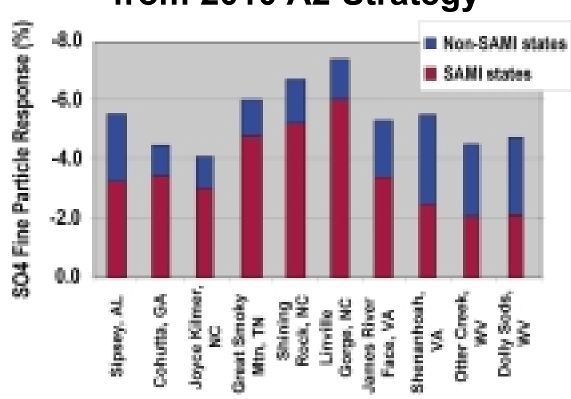


FIGURE 9: Annual Sulfate Fine Particle Responses at SAMI Class I areas to 10% Sulfur Dioxide reductions from 2010 A2 strategy in SAMI states and non-SAMI states

ATMOSPHERIC MODELING KEY FINDINGS

1. In general, the largest air quality changes in response to SAMI emissions reduction strategies occur on the days with the poorest air quality and in the areas with the poorest air quality.
2. Most reductions in haze-producing fine particles were due to reductions in sulfate particles. In response to the SAMI strategies, the changes in other types of small particles were minimal.
3. The sulfate portion of acid deposition was reduced by SAMI strategies while the nitrogen portion of acid deposition was little changed in response to SAMI strategies.
4. The greatest benefits from reducing sulfur dioxide and nitrogen oxides emissions generally occur within the State where the reductions are made (Figure 10).
5. On most of the days that SAMI modeled, the greatest benefits of reducing sulfur dioxide and nitrogen oxides emissions occur in the SAMI States.
6. On most of the days that SAMI modeled, local sources have greater contributions to ozone and fine particle mass than to acid deposition.
7. Once currently required nitrogen oxide reductions are installed at industries and power plants, reducing ground-level nitrogen oxide emissions from mobile and area sources will produce greater benefits in reducing ozone than will reducing elevated sources of nitrogen oxides.

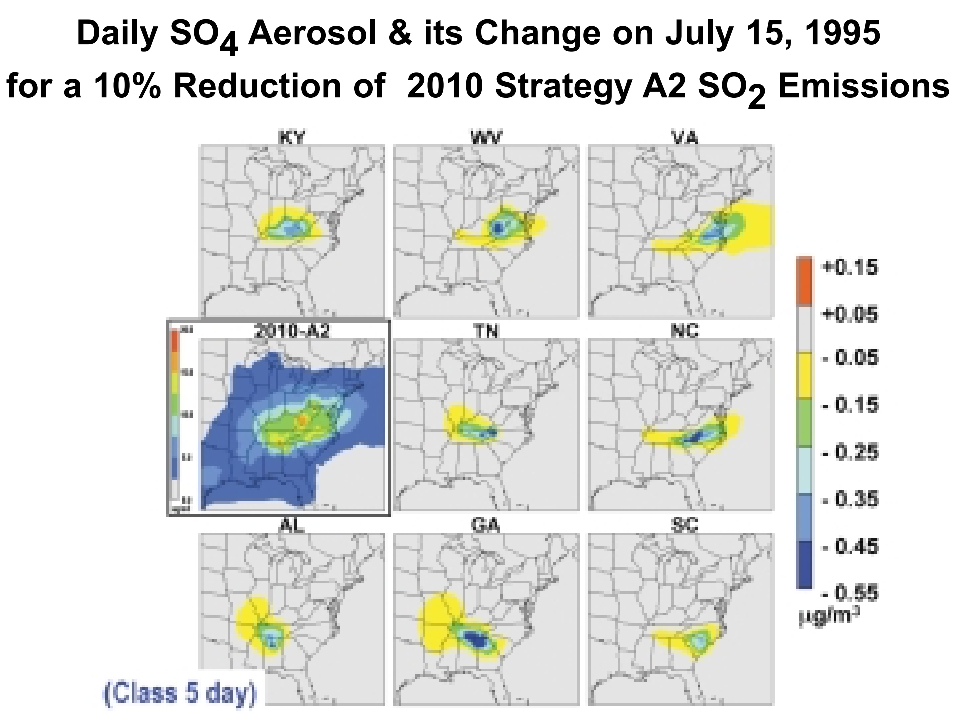


FIGURE 10: Sulfate fine particle mass modeled for July 15, 1995, using emissions for the 2010 A2 strategy and changes in sulfate fine particle mass in response to 10% reductions in sulfur dioxide emissions from the 2010 A2 strategy for each of the eight SAMI states.

VISIBILITY

SAMI confirmed the widely held impression that sulfate particles account for the greatest portion of the haze affecting our national parks and wilderness areas. Sulfur dioxide emissions that produce sulfate particles come largely from coal combustion. Most of those emissions currently come from electric generating plants. Industrial and dispersed area sources contribute a smaller amount. SAMI projects the greatest improvement in visibility when sulfur dioxide emissions are reduced. The greatest improvements are projected to happen on the haziest days. In 2010 SAMI projected average annual visibility in the SAMI Class I areas to improve less than two miles under the A2 (existing programs) strategy. Up to 15 miles in visibility improvement is expected with the most stringent B3 strategy by 2010 (Figure 11). As a point of comparison, the National Park Service suggests that the "natural" condition in Great Smoky Mountains National Park is a visibility of 113 miles on the clearest days. Average annual visibility is currently 25 miles in this park with the visibility being better on some days and worse on others.

The first priority to improve visibility is to reduce sulfur dioxide emissions from coal combustion in SAMI states and in surrounding regions. Ammonium nitrate particles also contribute to haze. Those particles are affected by the amount of ammonia in the air. As sulfur dioxide emissions are reduced in the future, controlling ammonia emissions will become increasingly important to improve visibility. The leading ammonia sources are animal feeding operations and agricultural fertilizers. SAMI recommends that States work with the agricultural community to reduce ammonia emissions for improvement of visibility as well as for reducing nitrogen deposition.

Organic compounds are the second largest contributor to visibility impairment in the SAMI Class I areas. At these rural sites, organic emissions from natural sources such as trees are greater contributors to organic particles than are emissions from human activities such as highway vehicles. At the SAMI Class I areas, visibility improved very little with reductions in organic carbon emissions from human activities.

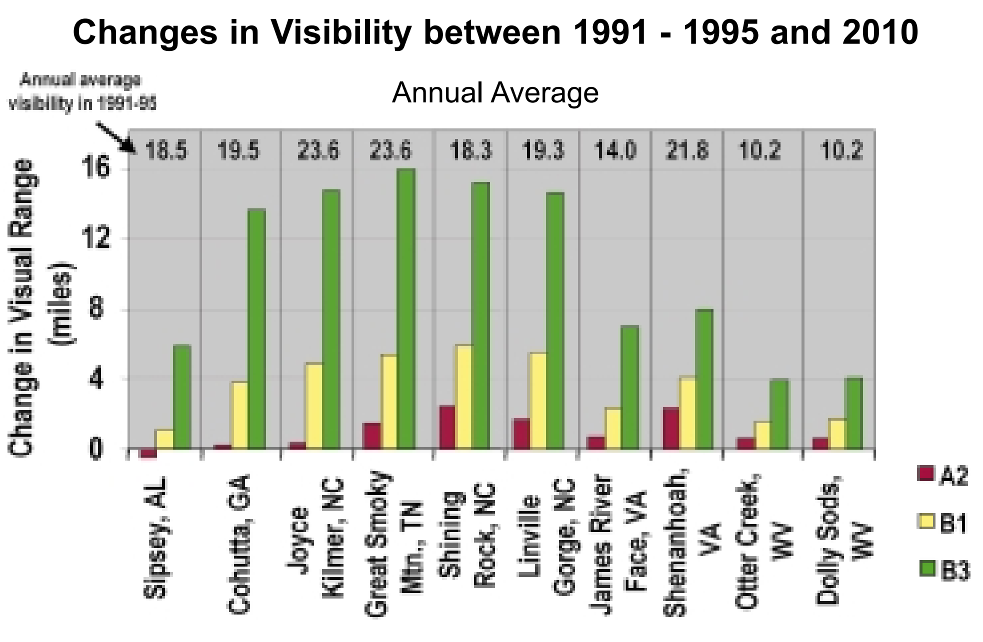


FIGURE 11: Changes in Annual Average Visibility between 1991-1995 and 2010 at 10 Class I areas in response to SAMI Strategies

VISIBILITY KEY FINDINGS

1. To reduce haze, reducing sulfur dioxide from coal burning is the highest priority. As sulfur dioxide emissions are reduced, reducing ammonia emissions, mostly from agricultural sources, will become increasingly important in reducing haze.
2. For days with similar amounts of pollution in the air, the day with higher humidity will be hazier.
3. The largest improvements in visibility are projected to occur on days with the poorest visibility and in areas with the poorest visibility.
4. Across the ten SAMI national parks and wilderness areas, the annual visibility in 2010 is projected to increase by less than 2 miles under the A2 (existing programs) strategy, by 1-6 miles under the B1 strategy, and by 4-15 miles under the most stringent B3 strategy (see Figure 12 for sample visiblity improvements at the Great Smoky Mountains National Park).
5. The greatest improvements in visibility with the SAMI "B" strategies are projected for those SAMI parks and wilderness areas that are mostly influenced by emissions from the SAMI states (Figure 13). The B strategies were applied only to SAMI states but sensitivity analyses indicate significant contributions from other regions.

Great Smoky Mountains National Park – July 15, 1995

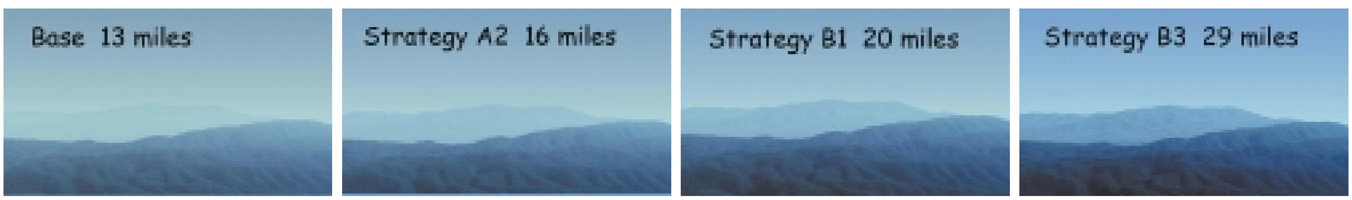


FIGURE 12: Visibility on July 15,1995, at Great Smoky Mountains National Park as projected by the WINHAZE software tool and projected visibility on July 15, 1995 under the 2010 A2, B1, and B3 strategies.

Light Extinction by Particulate Species – Annual Average

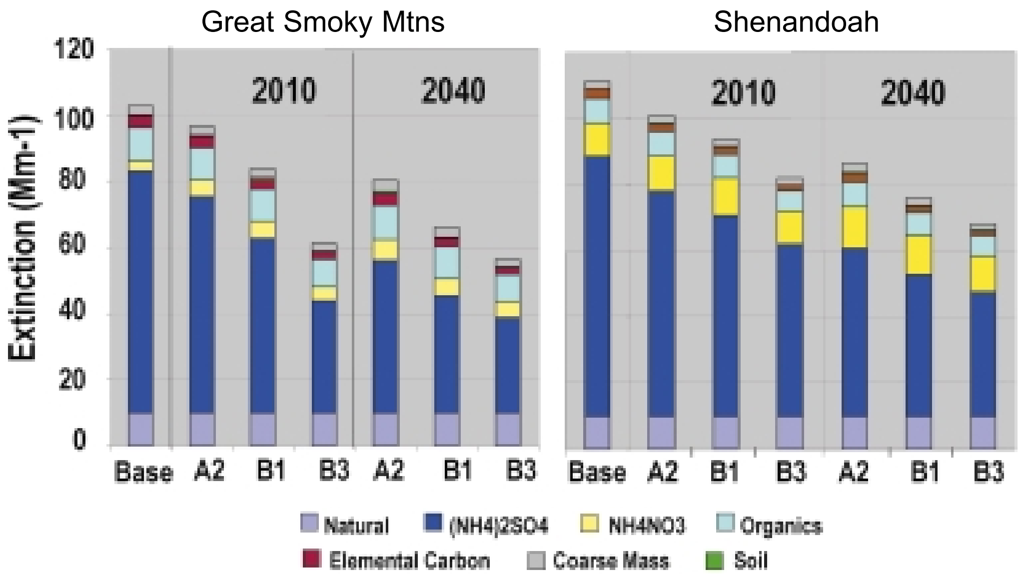


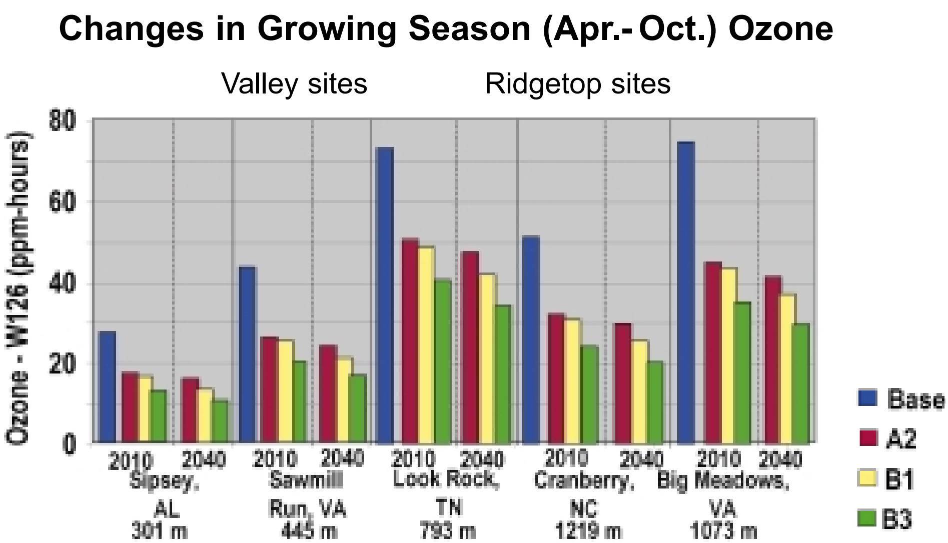
FIGURE 13: Annual Average Light Extinction at Great Smoky Mountains and Shenandoah National Parks in 1991-1995 and in 2010 and 2040 in response to SAMI strategies

OZONE EFFECTS ON FORESTS

Forest trees and vegetation respond to ozone across their entire growing season (generally from April to October). SAMI strategies reduced peak ozone values. The largest reductions in growing season ozone were between the base year and the A2 strategy in 2010 (Figure 14). SAMI simulated the effect of those ozone changes on individual trees as well as on entire forests.

Some tree species are more affected by ozone than others and over time they are at a competitive disadvantage. For example, sensitive species include tulip-popular and black cherry whereas spruce and hemlock are relatively unaffected by ozone. The shift in forest stand dynamics brought about by this change in competitiveness is the major ozone effect observed in this analysis. SAMI projected no tree death as the result of ozone exposure and the changes in tree size were generally small. The largest improvement that SAMI projected was a 22 percent increase in cross sectional area for loblolly pine for the most stringent B3 strategy in 2040 at a site in northern Alabama. Loblolly pine is an important commercial species but it does not grow in large numbers in most Class I parks and wilderness areas. High elevation spruce-fir forests are relatively insensitive to ozone compared to faster growing species such as loblolly pine and tulip-poplar. Tulip-poplar is an important species in some old growth forests, including some in national parks and wilderness areas.

The ozone changes that SAMI tested in strategies B1 and B3 were not large, in part because these strategies were applied only to emissions in the SAMI states. Particularly in the north and south of the SAMI region, SAMI analyses indicate that effects from regions outside the eight SAMI states are important for ozone as well as for other pollutants. Based on the SAMI forest simulations, the largest adverse impact on Class I areas from ozone is a shift in natural processes caused by some species being more competitive than others as ozone levels are changed. SAMI did not assess the effect of leaf injury to plants or health effects for visitors to the parks. SAMI concluded that nitrogen oxide emission reductions are needed to reduce ozone effects on certain tree species in certain Class I areas.



Growing season ozone higher at ridgetop sites than valley sites.

FIGURE 14: Cumulative growing season (April-October) ozone exposures (W126) in 1993-1995 and in response to SAMI strategies at example forested sites in the SAMI's region.

OZONE KEY FINDINGS

1. The major ozone effect on forests is changing competitiveness between tree species. Trees that are not sensitive to ozone do better over time than sensitive species. SAMI modeling indicates that tree mass in a forest does not greatly change in response to changes in ozone.

2. Changes in competitiveness did not change the type of forest over the range of conditions tested by the SAMI strategies. The effect of these changes in competitiveness is small and occurs in the context of other forest changes that occur naturally over time.

3. Within the Class I areas the strategies tested by SAMI did not reduce exposures to approach natural conditions. A change in abundance of certain species, such as tulip-poplar in parks and wilderness areas remains a concern to some SAMI stakeholders.

4. Nitrogen oxide emissions reductions will be required if ozone exposures are to be reduced.

5. With lower ozone, SAMI projected measurable improvements in tree mass at a site in northern Alabama for the loblolly pine-hardwood forest up to a maximum of 22.7 percent in 2040.

6. Even small changes in tree mass indicate that ozone exposures may be having an adverse impact to the natural processes in Class I areas.

7. Forests are dynamic and forest composition changes over time. In response to ozone changes under SAMI strategies, changes in tree mass in forests in the SAMI region is likely to be small (Figure 15). One forest type is unlikely to overtake another. Tree mortality in direct response to ozone is not expected.

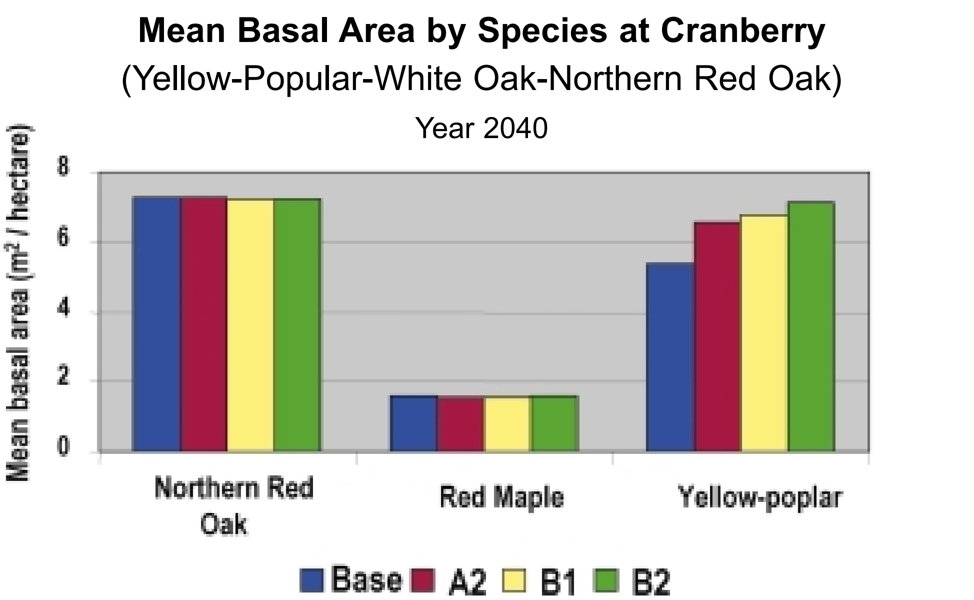


FIGURE 15: In response to SAMI strategies, changes in basal area of species with known sensitivity to ozone are projected to be small.

ACID DEPOSITION EFFECTS ON STREAMS AND FORESTS

Most forests and streams in the SAMI region are not adversely affected by current levels of acid deposition. The forests and streams that are affected are generally located in areas with base-poor bedrock (like sandstone and granite) and with elevations above 3000 feet (Figure 16). Virginia, West Virginia, North Carolina, and Tennessee have several areas that fit this description. The SAMI strategies produce reductions in sulfate deposition resulting from reductions in sulfur dioxide emissions primarily from coal combustion. Those strategies produce small changes in deposition of nitrogen compounds and in deposition of cations such as calcium and magnesium.

Area in SAMI region most likely to have streams with low Acid Neutralizing Capacity (ANC)

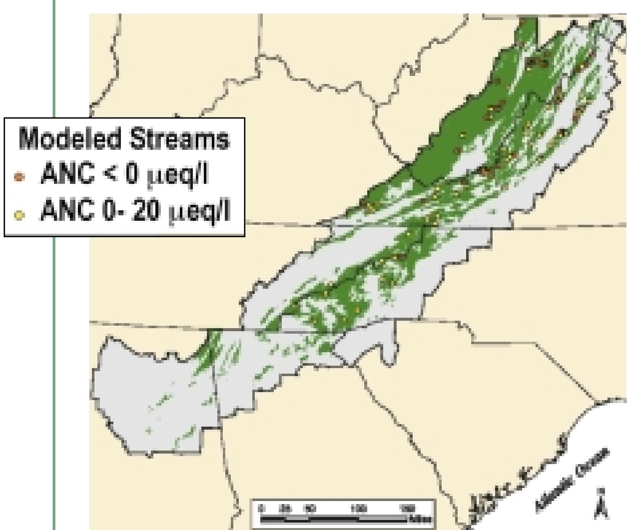


FIGURE 16: Areas in the SAMI region most likely to have streams with acid neutralizing capacity (ANC) less than 20 microequivalents per liter (μeq/l).

SAMI assessed the effect of acid deposition both on forest soils and on streams. Appalachian spruce and fir forests are more susceptible to the effects of acid deposition than are other types of forests. These sensitive forests tend to occur at high elevations where acid cloud deposition regularly adds to wet and dry deposition. Nitrogen deposition is particularly important in spruce-fir forests. In 2010 total nitrogen deposition to the spruce-fir forests in Great Smoky Mountains National Park is projected to decrease by 4% under the A2 strategy and by 11 % under the B3 strategy (Figure 17). SAMI concluded that it is important to reduce emissions of nitrogen oxides and ammonia to reduce nitrogen deposition in order to reduce acid deposition stress and to provide more protection for high elevation spruce-fir forests.

The SAMI acid deposition stream assessment found that in the range of controls evaluated in strategies B1 and B3, few streams changed sensitivity class. For example, few streams moved from being unable to support brook trout to being able to support brook trout. However, reductions in emissions that improve the acid neutralizing capacity of some streams in West Virginia, Virginia, Tennessee and North Carolina will improve fish habitat in many streams including some in Class I areas. SAMI concluded that it is important to reduce sulfur dioxide, nitrogen oxide and ammonia emissions to reduce adverse affects on sensitive streams in those states. The sources of these emissions are fossil fuel combustion by mobile and stationary sources as well as agricultural animal feeding operations and some agricultural fertilization practices.

Total Nitrogen Deposition in 2010

Example Class I Areas

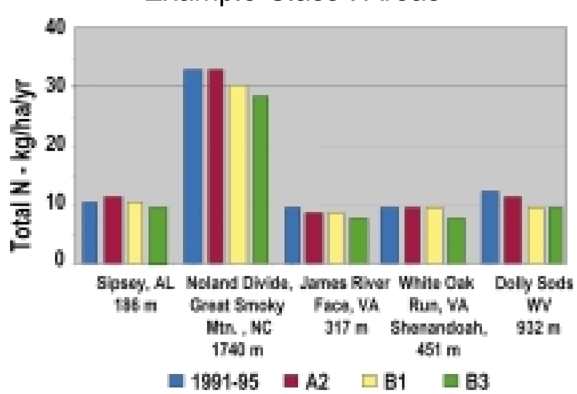


FIGURE 17: Total annual average Nitrogen Deposition in 1991-1995 and in 2010 under SAMI strategies for 5 example sites in Class I areas

ACID DEPOSITION KEY FINDINGS

1. Most streams in the SAMI region are not affected by acid deposition. The streams that are affected tend to be at elevations over 3000 feet and in areas with geologies that have limited ability to neutralize acid precipitation as it moves through the soil.
2. Stream changes as a result of the SAMI strategy emission reductions occur over decades and result in small changes in the number of streams that are at risk from acid deposition. Streams with very low ability to neutralize the acid in acid deposition will benefit the most from the changes projected by the SAMI modeling.
3. Under all strategies that SAMI tested, sulfate deposition as a result of emissions from coal-burning sources is projected to decrease substantially. With the SAMI strategies, changes in deposition of nitrogen from burning all fossil fuels and from agricultural sources are projected to be smaller.
4. Under the SAMI strategies, with controls only applied to SAMI states, few streams are projected to change sensitivity class. Therefore few additional streams will be able to support trout above the current conditions (Figure 18).
5. Southern Appalachian spruce-fir forests are more affected by acid deposition than northern hardwood and mixed hardwood forests. Soils in spruce-fir forests already contain high levels of organic acidity. In addition, nitrogen and sulfur deposition are high, due to the high volumes of precipitation and frequent cloud cover at high elevations where these forests occur.
6. Changes in forest soil chemistry in response to SAMI strategies are likely to be small, since changes in nitrogen deposition under SAMI strategies were small.
7. Streams most likely to improve under the SAMI strategies occur in West Virginia, Virginia, and at higher elevations in Eastern Tennessee and Western North Carolina. If stream conditions are otherwise suitable for supporting native brook trout, increasing acid neutralizing capacity will improve brook trout habitat for some streams in these areas. Nitrogen oxide and ammonia reductions from fossil fuel burning and agricultural operations will benefit certain sensitive streams in these same areas.

Stream Acid Neutralizing Capacity (ANC) in the SAMI Region

2040 SAMI Strategies Compared to 1991-1995

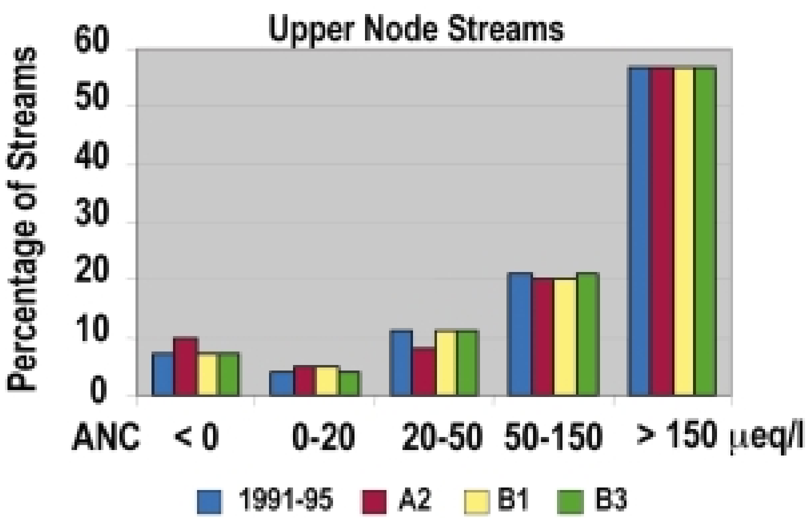


FIGURE 18: Stream Acid Neutralizing Capacity (ANC) for upper node stream in the SAMI region in 2040 under SAMI strategies (generally an ANC of 20 is needed to support trout).

DIRECT COST OF EMISSIONS REDUCTION STRATEGIES

SAMI estimated the direct cost of controls for strategies tested in the Integrated Assessment including costs for installing and running pollution control equipment over the life of the controls, on an annual basis. For example, the cost of controlling sulfur dioxide (mostly from coal combustion) in strategy B1 in 2010 was $1.9 billion per year. Emission reductions resulting from those strategies were estimated at 1.6 million tons per year (or $1200 per ton of reduction). In 2040 the B3 costs for sulfur dioxide control were $4.6 billion per year. Emission reductions resulting from those strategies were estimated at 1.8 million tons per year (or $2600 per ton of reduction). For other pollutants, uncertainties about the estimates for mobile and area source categories in particular led to a wide range in direct cost estimates (Figure 19).

The utility sector costs projections are more certain than the costs estimated for other sectors. The non-road sector is the least certain. Results for 2010 are more certain than for 2040. The costs associated with SAMI strategies are less certain as the strategies become more stringent.

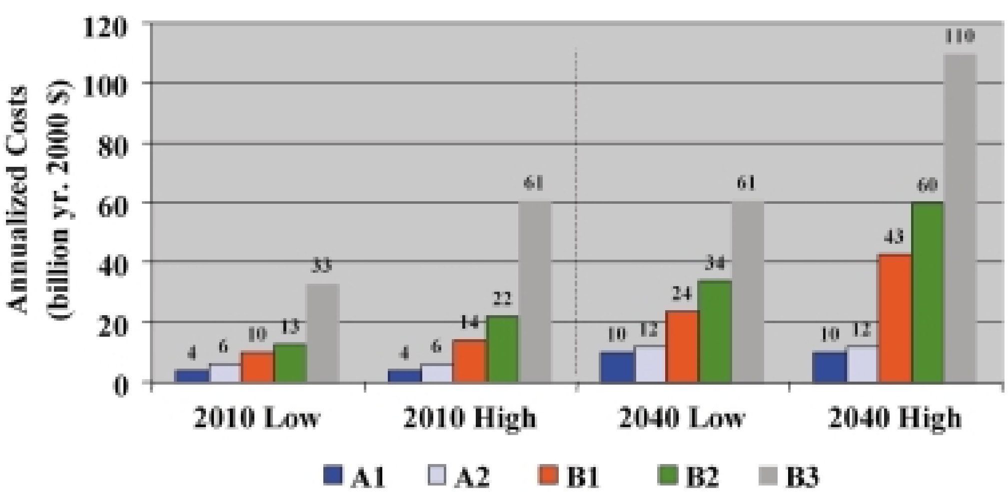


FIGURE 19: Cost for all source sectors combined for 2010 and 2040. SAMI projects the cost to between the Low and High ranges.

DIRECT COST KEY FINDINGS

1. In 2010 the costs for each strategy were estimated at: A2 =$6 Billion, B1 =$10 to $14 Billion, B2 =$13 to $22 Billion, and B3 =$33 to $61 Billion.

2. In 2040 the costs for each strategy were estimated at: A2 =$12 Billion, B1 =$24 to $43 Billion, B2 =$34 to $60 Billion, and B3 =$61 to $110 Billion.

3. The utility sector costs are more certain than the other sectors; the nonroad engine sector is the least certain. Results for 2010 are more certain than 2040. Costs associated with the strategies are less certain as the strategies get more stringent and the technology or methodology for accomplishing the reductions becomes more speculative.

4. The total cost of reduction in sulfur dioxide is less than the total cost of nitrogen oxides reduction and has more certainty (Figure 20).

5. These costs are valuable as indicators, but should not be relied on solely in policy making. The reader can combine these values with the results from the effects assessment to gain insight into the environmental benefit that can flow from the expenditures on emission reductions.

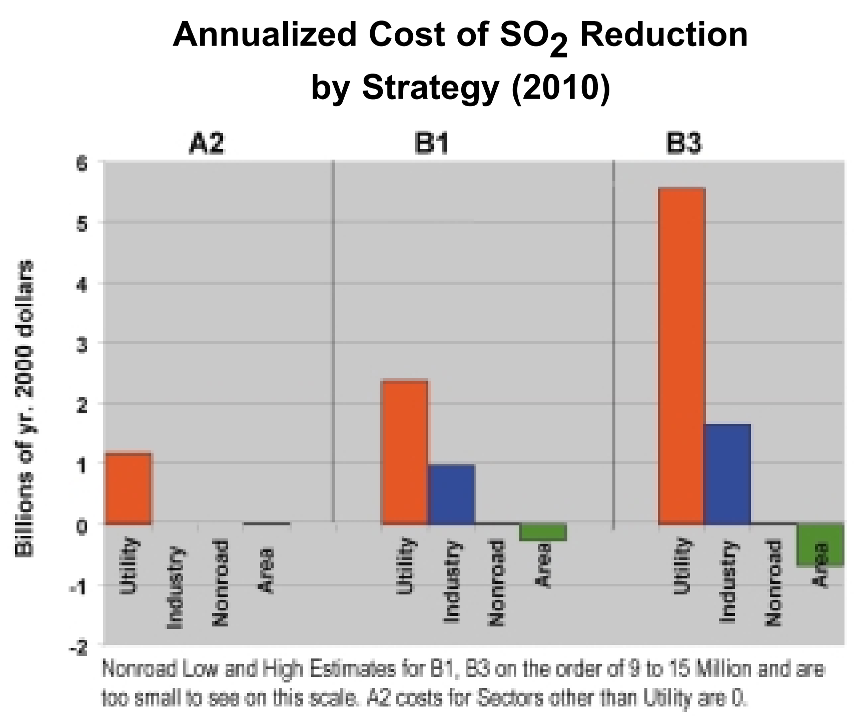


FIGURE 20: Annualized cost of SO_2 reductions by strategy and by source sector.

SOCIOECONOMIC CONSEQUENCES

The socioeconomic component of the Integrated Assessment examined the social and economic implications of the SAMI strategies. Four topics were selected from the numerous possible topic areas. The SAMI socioeconomic analysis was not intended to be a comprehensive cost-benefit analysis but instead focused on four areas: visibility, sense of place/stewardship, lifestyles and fishing. SAMI found that recreational visibility improvements in Class I and tourist areas have value both to individuals living in the SAMI region and throughout the United States. Residential visibility benefits have annual dollar values based on what people are willing to pay (WTP) for visibility improvements (Table 1). Sense of place/stewardship findings showed that residents of the SAMI region are diverse but they are all concerned about both the environment and jobs. They expect the government at one level or another to help them protect the environment for themselves and for future generations. A qualitative analysis of lifestyles effects concluded that emission reductions will require changes in consumer behavior. The larger the emission reductions, the larger will be the impacts on individual lifestyles, both positive and negative. Over time, consumers will adapt and find substitutes for higher priced goods and services and adjust to any job losses. The fishing assessment shows a WTP for water quality improvements in the eight-county area of West Virginia used in the study. The WTP ranged from $500,000 in 2010 to $4.4 million in 2040.

TABLE 1: Supplemental estimate of residential visibility benefits (entire modeling domain).

Year	Strategy	Benefit (Millions 2000$)
2010	A2 to B1	$224
2010	A2 to B3	$1,022
2040	A2 to B1	$791
2040	A2 to B3	$1,463

SOCIOECONOMIC KEY FINDINGS

1. Southern Appalachian residents have a strongly developed sense of place. They hold well-defined opinions from diverse perspectives. Air quality is seen as valuable for tourism and recreation. The cost of living and jobs are also important to residents. They are aware of the importance of a government role in protecting quality of life.

2. Over time the impact of SAMI strategy emissions reductions on lifestyles will decrease as consumers have time to make adjustments. Employment impacts also tend to be temporary as the economy absorbs available labor resources. Uncertainties exist with regard to technology mitigating lifestyle impacts, the participation of surrounding states in similar emissions controls, international competition, and industry expansion capacity.

3. Fishing benefits increase as air quality improves. The estimated economic value of fishery improvement in the SAMI region under strategy B3 is $4.4 million in 2040.

4. Residential visibility benefits are projected to be from $224 million to $1.46 billion annually in the SAMI modeling domain. National recreational visibility benefits range from $796 million to $2.7 billion annually depending on the year and strategy of interest (Table 2).

TABLE 2: Primary recreational visibility benefits* in the SAMI region and non-SAMI region (millions of 2000$)

Year	Strategy	Region	Benefits
2010	A2 to B1	National	$796
		SAMI 8 State Region	$155
		Non-SAMI Region	$641
	A2 to B3	National	$2,502
		SAMI 8 State Region	$482
		Non-SAMI Region	$2,021

Year	Strategy	Region	Benefits
2040	A2 to B1	National	$1,474
		SAMI 8 State Region	$301
		Non-SAMI Region	$1,173
	A2 to B3	National	$2,705
		SAMI 8 State Region	$555
		Non-SAMI Region	$2,150

* SAMI Region value represents the WTP for visibility improvements from populations within the SAMI 8 State region
** Non-SAMI region value represents the WTP for visibility improvements in Class I areas of the SAMI region that is valued by populations outside the SAMI region.
*** SAMI Region plus non-SAMI region equals National.

INCENTIVES

SAMI examined a range of incentive systems as a possible means of carrying out air quality management recommendations. For example, employers can provide cash to employees that choose to ride by transit or in car pools and do not use the "free" parking benefit at work. That incentive rewards people who reduce mobile sources emissions. For incentives that are likely to affect consumer behavior, the SAMI analysis focused on transportation and building energy efficiency. SAMI also examined incentives to affect the behavior of organizations such as companies and institutions. Tax credits for pollution control devices are an example of this type of "organizational" incentive that may benefit private sector organizations. Another example of an organizational incentive is the North Carolina Clean Smokestacks Law that requires approximately 75% reductions in both sulfur dioxide and nitrogen oxide emissions from coal-burning power plants in that state. By the State agreeing to postpone a regulatory proceeding, they provided the two North Carolina electric utilities an adequate incentive to make emissions reductions in the same order of magnitude as the SAMI strategy B2. SAMI found that while incentives appear capable of generating significant reductions, incentives alone are not likely to produce the full emission reductions described in B1 or B3. Regulatory approaches are also likely to be required. The magnitude of incentive-based emission reductions depends on the specific nature of the incentive program employed.

TABLE 3. Potential emissions reductions from selected consumer incentives

	NO_x reductions (tons/yr)		SO_2 reductions (tons/yr)	
	2010	2040	2010	2040
Transportation Incentives (top two)				
Aggressive alternative fuel vehicle program	61,736	408,048	n/a	n/a
Vehicle miles traveled based pricing	192,925	510,060	n/a	n/a
Building incentives (active strategy)				
Residential	70,000	170,000	170,000	440,000
Commercial	30.000	100.000	80.000	250.000
Total emissions reductions	354,661	1,188,108	250,000	690,000
Reductions as % of baseline emissions (approximate)	**8.4%**	**28.3%**	**4.2%**	**11.7%**

Source: ICF Consulting, Demand Management Incentive Strategy Evaluation. Final Report, September 6, 2001.

INCENTIVES KEY FINDINGS

1. An aggressive alternative fuel vehicle (AFV) program has the best potential for long-term, substantial mobile sources emission reductions (potential 20% reduction in estimated 2040 NOx emissions). Auto mileage-based pricing shows the second highest potential for short and long-term emissions reductions. Clean diesel and an increased gas tax show the next highest potential to increase reductions (Table 3).

2. For building technology incentives, the greatest nitrogen dioxide and sulfur dioxide emissions reductions are likely to occur under aggressive strategies, although potential for significant reductions exists with just the employment of passive strategies. Active and aggressive strategies for building technology incentives offer more potential emission reductions but are not more cost-effective than the passive strategies.

3. To implement organizational incentives, the majority of the alternatives are likely to be most effective if implemented region-wide (Table 4). While administrative implementation is easier, most of the alternatives may require passage of state legislation in order to be implemented.

4. New taxes may be difficult to implement in the current political climate.

5. SAMI looked at incentives that might reduce emissions of sulfur dioxide and nitrogen dioxide and focused on larger industries. Similar incentives may work to reduce other pollutants, especially ones that have not been so heavily regulated. They may also be effective in working with smaller sources.

TABLE 4: Potential emissions reductions from organizational incentives.

	2010 NOx and SO_2 reduction (tons/yr)			Reductions as % of total 1990 emissions
	Utilities	Other Industries	Total	
Organizational Incentives Approaches				
Alt. A - Sector-Based Voluntary Program	212,000	55,000	267,000	2.6%
Alt. B - Targeted Emitter Voluntary Program	489,000	44,000	583,000	5.2%
Alt. C - Utility Cost Recovery	1,556,000	0	1,566,000	15.2%
Alt. D - Sector Tax and Rebate	3,770,000	565,000	4,335,000 *	42.1%
Alt. E - Cross-Sector Tax and Rebate	511,000	175,000	686,000	6.7%
Alt. F - Cap and Trade Program	3,770,000	565,000	4,335,000 *	42.1%
Alt. G - Cross-Sector Trading Program	n/a	n/a	4,335,000*	42.1%

*These reductions are equivalent to reductions for the B1 strategy.
Alt. G requires Alt. F and just shifts the reductions between industrial sectors.

Source: BBC Research & Consulting, Air Emission Reduction Incentives Program Development. Final Report, April 17, 2002

CONCLUSIONS

SAMI used a systematic process (Figure 21) to move from the results of each phase of the Integrated Assessment to observations and then to conclusions that were presented to the SAMI Governing Body. Based on these conclusions the SAMI recommendations described in the next section were agreed upon and adopted. Summary conclusions and recommendations are listed below:

1. To improve visibility, it is most important to reduce sulfur dioxide emissions.

2. To improve visibility, it could become necessary, under certain future sulfur dioxide control strategies, to reduce ammonia emissions.

3. To reduce acid deposition affecting streams in the central and northern part of the SAMI region, it is important to reduce sulfur dioxide emissions.

4. To reduce acid deposition affecting streams in geographically limited areas, it is important to reduce nitrogen oxide and ammonia emissions.

5. For high-elevation spruce-fir forests, it is important to reduce nitrogen oxide and ammonia emissions.

6. Ozone exposure does not produce a region-wide effect on forest basal area, so nitrogen oxide or volatile organic compound reductions are not needed for this purpose. However, site-specific ozone effects to certain forest species are a concern for Federal Land Managers and other stakeholders. Nitrogen oxides emission reductions are important to address that concern.

7. For SAMI to accomplish its mission, emissions reductions are essential both inside and outside the SAMI region.

FIGURE 21: Recommendation development process

SAMI RECOMMENDATIONS

Upon consideration of the conclusions presented above, the SAMI Governing Body adopted the recommendations listed below on April 18, 2002 by consensus among the state representatives.

The SAMI states support and will promote strong national multi-pollutant legislation for electric utility plants to assure significant sulfur dioxide and nitrogen oxides reductions both in and outside the SAMI region. This national multi-pollutant legislation should result in no less than the reductions for sulfur dioxide and for nitrogen oxides represented by the Administration's Clear Skies Initiative. Reductions from other source categories should also be considered in national legislation, and such national legislation should contain sufficient measures to protect Class I areas. Should the national legislation fail to materialize, the states that participated in SAMI will work together to consider regulatory alternatives and to encourage non-SAMI states to participate. Leadership by states ahead of national legislation is encouraged.

Each SAMI State should seek ways to reduce ammonia emissions from animal feeding operations. Also, support should be given in future work such as VISTAS to improve the understanding of the sources of ammonia, to develop better inventories, and to seek more effective control approaches.

Where States have control strategy option choices in their eight hour ozone and fine particle State Implementation Plans, that also have co-benefit for the environmentally sensitive Class I areas, they should choose them. Ambient ozone monitoring should be conducted near all Class I areas in the future.

Each SAMI state should encourage energy efficiency, conservation, and use of renewable energy to reduce the emissions from stationary and mobile sources.

Through this report and its recommendations, SAMI has completed its mission and has officially closed its operations. By adoption of the final technical report, the SAMI states recognize the value and importance of our Class I areas and agree to work towards the implementation of SAMI recommendations. Each SAMI state will determine the most appropriate strategy for its own unique circumstances that will lead to successful achievement of SAMI's final recommendations.

LESSONS LEARNED FROM THE SAMI EXPERIENCE

SAMI participants representing a variety of perspectives such as industry representatives and environmentalists developed a series of suggestions for others undertaking a similar environmental decision making process and also for those undertaking air quality modeling in the future. In general, all participants value the opportunity to understand the perspective of other stakeholders and generally they recommend a participatory process for environmental decisions. If a smaller set of participants or a single organization were given authority to hear a variety of perspectives but to then make decisions without needing to rely on full consensus, the process would probably move more quickly than the process that SAMI used.

ADDITIONAL DATA AND RESOURCES

SAMI generated a large volume of results, reports and computer files. These supporting materials will be available electronically to the SAMI participants and to other interested parties as described at www.saminet.org and later at www.vistas-sesarm.org. SAMI will close its doors in the fall of 2002. Please direct inquiries about the SAMI report to your state air quality agency.

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