Impacts of the SAMI Strategies: An Independent Analysis of the Benefits and Economic Impacts

Conducted by:
U.S. Environmental Protection Agency
U.S. National Park Service
U.S. Forest Service

April, 2002

Abstract

This report was prepared by the U.S. Environmental Protection Agency, U.S. National Park Service, and U.S. Forest Service, to provide an independent analysis of the impacts of control strategies of the Southern Appalachian Mountains Initiative (SAMI) based on state-of-the-art health effects quantification and valuation methods used by the federal government to evaluate air pollution control strategies. Due to the consensus process under which it operated, the SAMI organization chose not to do a full analysis of benefits and costs, but to analyze a few socioeconomic topics[1]. This report uses the air quality analysis and cost analysis conducted by the SAMI organization as inputs to this assessment. As such, we too are not able to present a full analysis of benefits and costs. The benefits reported below are associated with average annual changes in PM2.5, and the economic impacts reported below are associated with the costs to 10 key industries SAMI selected for analysis. Other analyses of air policies conducted by the federal government have included a broader set of functions associated with daily fluctuations in PM, as well as other pollutant impacts. The overall purpose of this report, however, is to augment the findings of the final SAMI report with an assessment of the benefits and distribution of economic impacts to businesses and households in the 8-state region. The conclusions of the analysis include:

- Total benefits of the SAMI control strategy scenarios range from $36 billion to $68 billion.
- North Carolina, Georgia, and Tennessee accrue the largest portion of total benefits in the 8-State region.
- Economic impacts of the SAMI control strategies are spread across numerous industries including the electric power industry, manufacturing industries, and the transportation industry. This reflects the fact that virtually every utility and industrial point source in the SAMI region will be controlled, particularly under the B3 scenario. Across the SAMI strategies, the range of price increases for electricity is from 0.1 percent to 2 percent as a result of the SAMI control scenarios, and the range of price increases for products in other industries is from 0.05 to 0.4 percent.
- Households may spend approximately $12 more per year under the most stringent control requirements of SAMI; typically much less will be spent under other control options.
- Comparing benefits to SAMI's estimated control costs results in net

[1] For more background on SAMI and it's analyses, please refer to their website at *www.SAMInet.org*.

benefits (benefits minus costs) of the B1 strategy ranging from $6 billion to $30 billion, and for the B3 strategy we find net benefits ranging from $19 billion to a net cost (costs exceed benefits) of $30 billion. There are many benefit categories that we are not able to quantify with this analysis, thus the net benefit results presented here would be greater (and net costs would be smaller) if all benefits were monetized.

1.0 Introduction

The Southern Appalachian Mountains Initiative (SAMI) has developed several emission control strategies for improving visibility and air quality, particularly in national parks and monuments, in the eight States that constitute the SAMI region. These emission control strategies may apply to plants and sources in many different industries that are influential in the life and culture of these States. Impacts from SAMI will be broad in scope, including: the potential impacts on the producers of emissions to be controlled, impacts on the households who consume products made by these producers and breathe the air to be cleaned, and impacts on the environment that will be affected by any change in air emissions. Given the potential for effects both positive and negative that may result from implementation of such strategies, an assessment of socioeconomic impacts provides useful information to policymakers seeking to understand what implementing these strategies may entail.

This report provides information on the potential benefits and economic impacts of the alternative pollution control strategies considered by SAMI. This report is independent of the SAMI process and reflects the approach typically employed by the U.S. Environmental Protection Agency to analyze air pollution control strategies and regulations.

As part of the SAMI effort, which included consultations between State and Federal government officials, industry representatives, and members of academia, an extensive integrated assessment of impacts has been conducted to permit an examination of the effects of these control strategies. A full assessment of benefits and costs of SAMI consistent with standard economic practice requires estimation of <u>all</u> benefits and costs, including important public health benefits such as reduced mortality risk, chronic diseases, non-visibility environment impacts, and the total social costs beyond the cost of control equipment. The scope of the analyses sponsored by the SAMI organization was limited, however, such that the final SAMI report will show only a subset of relevant analyses, such as:

- cost estimates of alternative control strategies,
- air quality and certain ecosystem improvements,
- qualitative discussions of how selected costs may impact households and individual's lifestyles,
- benefits of visibility improvements in National Parks and other Class I areas, and
- benefits of brook trout fishing improvements in National Parks.

Evaluating these and other impacts of air quality policies is a very complex process that requires multiple disciplines to estimate several outputs, including: emission inventory assessments, air quality predictions, pollution control technology selection, cost estimation, and assessment of health risks and ecological effects.

Each component of the SAMI assessment will provide information to decision-makers, such as the total tons of SO_2 reduced, or the change in acidification of rivers and streams, but comparing the whole set of outputs across different control strategies is difficult. In this report, we strive to put this information into monetary terms using economic theory to allow for better comparison of alternative control strategies and their impact on society.

The purpose of this report is to augment the findings of the final SAMI report with an assessment of producers response to control costs, consumers response to increased prices of electricity and other goods in the region, and additional benefits from avoided premature deaths, avoided cases of bronchitis, and other respiratory illnesses that result from elevated levels of air pollution.

Below we briefly describe the results of the Independent Analysis. A detailed description of how the analysis is conducted is provided in two documents: *Benefit Analyses of Alternative SAMI Strategies: Selected Health and Welfare Methods and Analysis Results* (Abt Associates, 2002), and *Competitiveness Analysis of Alternative SAMI Strategies* (RTI, 2002).

1.1 Results in Brief - Economic Impact Analysis

One of our Independent Analyses is an analysis of the effects to producers and consumers (i.e., households) from application of two of the SAMI control strategies, B1 and B3, with an emphasis on the effect of these strategies on the ability of firms to compete after these controls are applied. This analysis provides the following information:

- changes in prices to consumers and levels of production by producers after these control strategies are applied in the benchmark years for the analyses, 2010 and 2040.

The model employed in this analysis examined the changes in prices and outputs for affected products using a framework that looks at changes in supply and demand, a framework not employed in the SAMI draft competitiveness analysis. The framework employed in the SAMI draft competitiveness analysis focused on the direct effect to producers, and the estimated impacts did not consider the responsiveness of consumers and producers to pollution control costs in accord with standard economic practice. Changes in supply and demand in the independent analysis are estimated using the results from the official SAMI Cost Report. The modeling in this analysis is a straightforward use of microeconomics, though it is complex due to the many industries and markets affected.

Industries included in this analysis are the ten that are the focus of the SAMI draft competitiveness analysis, with the electric power industry being the major industry included and impacted. The effect on the competitiveness of firms in the SAMI is also assessed by this model and presented in this report.

Also, this report includes the effect on economic impacts due to improvements in how firms use control equipment (or "learning curve" effects), and how much stimulation of environmental goods and services occurs. Included in the report is demonstrations of the sensitivity of the reports' results to changes in key model parameters such as how consumer demand will change with a change in price, among other parameters.

This analysis does not include impacts associated with the area and mobile source control costs included in the SAMI Cost Report, nor the costs to point sources other than those for the ten industries focused on in the SAMI draft competitiveness analysis. Hence, the impacts calculated in this Independent Analysis should not be regarded as reflecting the complete set of costs associated with the SAMI control strategies.

Key Findings:

C Results from this analysis show that the price of electricity increases nationwide in 2010 by 0.6 percent under B1 and 1.9 percent under B3. This represents an increase in 2010 of less than 0.03 cents per kilowatt-hour in 2010 for B1 and 0.11 cents per kilowatt-hour for B3. In 2040, these price increases are 0.1 and 1.2 percent, or less than 0.01 cents/kilowatt-hour or 0.06 cents per kilowatt-hour, respectively. Effects on other energy markets are of smaller magnitude.

C Demand for coal will fall slightly both regionally and nationally in response to reduced electricity demand due to the higher electricity prices.

C For all other industries covered in the analysis, changes in price and output for all other products nationwide are well below 0.5 percent in 2010 and 2040.

C In terms of impact to households, the total change in yearly electricity expenses for residential consumers in 2010 is $4.90 per U.S. household under B1, and $15.80 per U.S. household under B3. For 2040, the change in yearly electricity expenses are $1.60 per U.S. household under B1, and $12 per U.S. household under B3.

C Since this analysis assumes competitive national energy markets, these results may overstate the losses to SAMI power producers and gains to power producers outside the SAMI region. This is true because limits on the ability of producers to sell power across regions, such as spatial transmission limits and state government regulation of power, are not taken into account.

1.2 Results in Brief – Benefit Assessment

The emission reductions expected from the SAMI strategies will result in many benefits to the SAMI region and the nation as a whole. Visibility will improve in this mountainous region that contains many National Parks and National Forests where the vista is an important component of the park experience. Reducing pollution in the area will also result in reducing many health complications of excessive pollution. For instance, studies show that there may be an association between concentrations of fine particles in the air we breath and mortality rates. There is also evidence that fine particles contribute to incidences of bronchitis (i.e. coughing, chest tightness, cold symptoms), exacerbation of other respiratory illnesses such as asthma, and reduced worker productivity. Air pollution has also been found to impact agricultural crops and ecosystems. It can reduce the growth of particular trees, or acidify streams and rivers such that fish and other aquatic life are impacted. While several categories of impacts can be estimated in a benefit analysis, the Independent Analysis of the SAMI strategies only quantifies benefits for premature deaths, chronic bronchitis, and acute bronchitis. In addition, we add to our total benefit value the results provided by SAMI for improved visibility and improved fishing in the region. The limited scope of the analysis is due to the air quality data available for our analysis.

In our analysis, we use the SAMI organization's data on emissions inventories, and projected air quality changes in 2010 and 2040 for the B1 and B3 control scenarios. All benefits are calculated incremental to SAMI's baseline scenario of A2 (i.e., what would happen in the absence of SAMI controls). Changes in concentrations of fine particles (PM2.5) in the 8-State region serve as inputs to the Criteria Air Pollutant Modeling System (CAPMS), a model used by the U.S. EPA to estimate changes in incidences and monetary value of health effects associated with air pollution. While it is expected that SAMI will also reduce PM10, ozone, SO2, NOx, and CO, the efforts by the SAMI organization to model air quality changes were limited to PM2.5 alone to conform to the scope, budget, and priorities of the SAMI organization. Therefore, the benefits of these other pollutants are not included in our analysis, and thus, our estimate of total benefits is below the actual value.

Our analysis of PM2.5 alone, however, shows that the benefits of SAMI will be substantial. Some key findings of the benefit analysis are presented below.

Key Findings:

- Total benefits of the B1 scenario are approximately $12 billion in 2010 and grows to $36 billion by 2040.
- The benefits of the B3 scenario are 2 to 3 times greater than the B1 scenario – $45 billion in 2010 and $68 billion by 2040.
- North Carolina, Georgia, and Tennessee accrue the largest portion of total benefits in the 8-State region.
- By 2040, SAMI may result in as many as 8,000 fewer premature deaths, 6,000 fewer cases of chronic bronchitis, and over 16,000 fewer cases of acute bronchitis in children in each year if the B3 strategy were implemented.
- Visibility improvements in National Parks and National Forests are $1.7 billion of the total benefits under the B1 scenario and $3.2 billion under the B3 scenario in 2040.
- A supplemental estimate of residential visibility improvements totals $0.9 billion for B1 and $1.7 billion for B3 in 2040.
- Total benefits are understated because several other benefit categories are not quantified, including: hospital admissions for respiratory and cardiovascular causes, upper and lower respiratory symptoms in children (i.e., cold and flu-like symptoms), asthma

attacks, decreased worker productivity and lost work days, household soiling damage, and agricultural crop and forest damage.

2.0 Summary of Methodology and Analysis

In this section, we provide a summary of the methodologies used and the analysis findings for the economic impact analysis (also referred to as Competitiveness Analysis) and the benefit assessment. A detailed description of the methodologies, data utilized, and results are contained in the technical support documents, titled *Benefit Analyses of Alternative SAMI Strategies: Selected Health and Welfare Methods and Analysis Results* (Abt Associates, 2002), and *Competitiveness Analysis of Alternative SAMI Strategies* (RTI, 2002).

2.1 Economic Impact Analysis

The SAMI commissioned an "integrated assessment" of the environmental effects and selected socioeconomic costs and benefits of SAMI-designed emission reduction strategies. Part of this assessment was an analysis of the effects of these strategies on the competitiveness of firms operating in the SAMI region. This analysis estimated impacts based only on the direct impact to affected producers, and did not fully take into account the behavioral response of consumers to potential increases in product prices. In addition, the analysis focused only on impacts to a sample of industries having to install pollution control equipment. The analysis summarized here is meant to provide an alternative evaluation of the same SAMI emission reduction strategies through the estimation of economic impacts including the effects on competitiveness of firms within the SAMI region.

The SAMI-designed emission reduction strategies proposed progressively more stringent emission reduction controls in each of five major source categories (utility, industrial, highway vehicle, non-road engines, and area sources) for 2010 and 2040. Because the SAMI did not examine the effect of these control strategies on consumers in a complete way, the SAMI analysis did not estimate the full economic impacts of these strategies. The first, and least stringent, of these strategies is referred to as the "A2" scenario, which serves as the baseline of future year economic conditions from which changes in economic impacts are calculated. The remaining two scenarios are named the "B1" scenario and the "B3" scenario. These strategies serve as the control scenarios, where B1 is more stringent than A2, and B3 is more stringent than B1.

We base our economic analysis on a model currently employed in several U.S. Environmental Protection Agency rulemakings affecting manufacturing industries. The model uses techniques that are typically utilized by the Agency in its rulemakings. This model is explained in detail in Appendix A of the analysis report. Besides the effect on competitiveness of firms, the analysis also examines price and output changes for a variety of manufactured products, impacts on energy markets including electricity, and the impact of the control strategies on production of environmental goods and services. We also consider qualitatively the effects of the control strategies on tourism.

We estimated the economic impacts of these strategies with the Economic Model for Policy Analysis of Control Techniques (EMPACT). This model was developed to support analyses by EPA of the economic impacts of regulations on combustion turbines, industrial, commerical, and institutional boilers, reciprocating internal combustion engines, and process heaters. The EMPACT model includes linkages between energy-using sectors such as the industrial and residential sectors and petroleum, natural gas, electricity, and coal markets.

We used the plant-level data generated for the official SAMI Cost Report as inputs to this analysis. The SAMI Cost Report is based on application of a least-control cost model that mimics pollutant emissions trading within the 8 State region. The trading of emissions credits is presumed to be the lowest cost method for achieving a given emissions target as based on economic theory. This theory is the rationale for the Acid Rain Program and NOx SIP Call Trading Program developed by the EPA. Results from the Cost Report are presented in a range, with low-end and high-end estimates presented for each control strategy to reflect uncertainties in the data for area and mobile source controls. The data included both capital and annual costs for control equipment at the plant-level for each plant affected by these strategies. We selected a midpoint of this cost range as the cost input to the model for each strategy. Extensive data on the industries covered in the modeled was also employed and consumers of their products. This data was then matched to the firms that own these plants, and was also inserted as appropriate to generate industry-level supply curves that are at the core of the model. Once these industry-level supply curves were generated, these curves are then shifted by the change in cost associated with these control strategies. From this point, changes in price and output for affected products are calculated through the interplay of the supply and demand curves. Changes in price and output in energy markets are also calculated in a similar fashion, with a reliance on data prepared by the U.S. Department of Energy's Energy Information Administration. These changes in price and output are estimated nationally, but this analysis does provide some information on effects on producers in several individual SAMI States. Also, estimates on the burden of impacts to producers in the SAMI region compared to their competitors outside the region are made. The data and the equations that make up the model are shown in Appendix A of the report.

Impacts to producers and consumers can be measured in terms of "social costs," which are the costs after the behavioral response to an action, such as applying a control strategy. These social costs are the sum of the effects on both producers and consumers. Since producers and consumers are the categories in which those in our society participate in the economy, these impacts are said to be "social" costs. Table 1 shows the social costs to consumers and producers for control strategies B1 and B3 incremental to A2 for 2010 and 2040. The costs are broken down by types of consumers and producers (stakeholders in the SAMI process), and show these costs to producers in and outside the SAMI region).

Table 1. Distribution of Incremental Social Costs, 2010 and 2040

Stakeholder	B1 Incremental to A2, Loss/Gain (million $2000) in 2010	B1 Incremental to A2, Loss/Gain (million $2000) in 2040	B3 Incremental to A2, Loss/Gain (million $2000) in 2010	B3 Incremental to A2, Loss/Gain (million $2000) in 2040
Consumers - Total	-$1,260	-$700	-$3,900	-$4,200
Agricultural, Mining, Manufacturing[2]	-400	-300	-1,100	-1,200
Commercial	-200	-100	-800	-1,000
Residential	-600	-200	-1,800	-1,900
Transportation	-60	-30	-200	-200
Producers - Total	- $1,100	-$700	-$3,200	-$4,300
Energy - Rest of U.S. - South Atlantic/East South Central	 -300 1,200 -1,500	 -200 500 -700	 -1,000 3,800 -4,800	 -1,600 3,800 -5,400
Agriculture, Mining Manufacturing - Rest of U.S. - SAMI Region	 -500 -40 -400	 -300 80 -400	 -1,200 -300 -800	 -1,400 -200 -1,200
Commercial	-300	-200	-1,000	-1,300
Transportation - Rest of U.S. - SAMI Region	-9 -7 -2	-5 -5 -0.1	-30 -20 -5	-40 -40 -1
Total Social Cost	-$2,200	-$1,400	-$7,100	-$8,500

[2] The South Atlantic/East South Central Census region is a proxy for the SAMI region, since energy data was not available for the SAMI region as a distinct body.

Limitations

As with any model of an extremely complicated process, there are uncertainties and limitations associated with the results presented in this report. These limitations should be kept in mind when reviewing and interpreting the economic impact estimates. The results presented in this report are dependent on a number of assumptions and projections of baseline conditions into the distant future, which introduces a great deal of uncertainty concerning the exact magnitude of the impacts. Some of the key limitations of the analysis include the following:

- Results are dependent on the annualized costs estimated in the SAMI Cost Analysis report. However, there is uncertainty concerning these costs because, for example, pollution control technology has advanced considerably in recent years, but it is difficult to predict future changes in technology that may change the costs of compliance, especially looking forward to 2040. Other limitations are the following:

- Only a portion (about half) of the total incremental costs to point sources associated with SAMI strategies B1 and B3 are used to drive the model results. In addition, control costs to area and mobile sources are not included as inputs to the model and can be substantial. This is due to the fact that only the costs for the ten industries analyzed in SAMI's draft Competitiveness Analysis were suitable for inclusion in our economic model;

- No linkages between sectors other than linkages with the energy sectors,

- Results are dependent on the assumed growth rates in each industry as projected EIA for the energy markets and the BEA for other goods and services, growth rates that can vary considerably, and

- Assumption of perfectly competitive national markets has a large impact on the distribution of impacts between consumers and producers and between the SAMI region and the rest of the U.S.

The economic impacts listed above are considered as the best estimates of impacts based on the best available methods and data. Where possible, we attempt to provide estimates of the effects of uncertainty about key analytical parameters. Appendix B of the analysis presents sensitivity analyses that provide estimates of economic impacts based on changes in price elasticities of demand and supply for each control strategy. These sensitivity analyses provide information on how effects to producers and consumers vary as a results of changes in the responsiveness of demand and supply to changes in price. Also, economic impacts based on incorporation of "learning curve effects," which are effects from more efficient use of pollution control equipment over time, are calculated. This calculation is based on a reduction in control costs in 2040 due to such effects.

2.2 Benefit Assessment

As part of the integrated assessment, SAMI also strived to assess the environmental effects and benefits of SAMI-designed reduction strategies. Though four socioeconomic topics overall were considered in the assessment,[3] the topics were very narrow in scope in terms of the possible set of benefits achievable under each control strategy. The final SAMI report provides benefit estimates for improved visibility in National Parks and other Class I areas, and for improved fishing in selected Class I areas. This analysis provides an estimation of the benefits associated improved health from the SAMI-related pollution reductions.

The SAMI strategies are expected to reduce emissions of many pollutants, including: NOx, SO2, ozone, PM10, and others. The SAMI organization only estimated changes in air quality associated with annual average PM2.5 for the alternative control strategies. Thus, our analysis relies on this air quality data and only estimates monetary benefits for changes in annual average PM2.5.

We base our analysis on the assumptions and models that have been approved by the EPA Science Advisory Board (SAB) and are typically utilized by EPA to assess national regulatory programs. Specifically, this analysis relies upon the methods used in the analysis of EPA's Heavy Duty Engine/Diesel Fuel Rule and described in detail in the Heavy Duty Diesel Technical Support Document (Abt Associates, 2000). We estimate not only premature human mortality, but other health effects associated with exposures to annual measures of PM2.5. We also include in our results the outcome of SAMI's analyses of visibility and fishing benefits. To account for unquantifiable benefits associated with the range of potential SAMI-related air quality improvements, we consider, qualitatively, the benefits associated with exposures to daily measures of PM2.5, PM10 and particulate matter between 2.5 and 10 microns (coarse PM10), NOx, SO2, ozone, and others.

Estimation of Health Effects

We estimated PM2.5-related health effects using the Criteria Air Pollutant Modeling System (CAPMS). CAPMS is a population-based system for modeling exposures of populations to ambient levels of criteria pollutants that we use to estimate health benefits. CAPMS divides the United States into eight kilometer by eight kilometer grid cells and estimates the changes in incidence of adverse health effects associated with given changes in air quality in each grid cell. Total incidence changes are the sum of grid cell-specific changes.

The SAMI annual average PM2.5 data came to Abt Associates at the modeled grid cell level; a nested grid structure comprised of an inner set of 12x12 km grid cells and an outer set of coarser 24x24 km grid cells. The data represented predicted annual average values at the center point of each grid cell. The SAMI modeling domain covered a geographical range that extended beyond the eight state SAMI region while not entirely covering the extent of the eight SAMI

---

[3] The topics covered by the assessment include fishing, hiking/enjoying scenery and visibility, stewardship/sense of place, and lifestyle changes.

states. Coverage of the 8 state SAMI region was about 85%. This analysis limited the consideration of annual PM2.5 data to those grid cells whose centers fell within the eight state region. We then assigned each 8x8 km CAPMS grid cell to the nearest SAMI grid cell by calculating the shortest distance between the center of the CAPMS grid cell to the center of a SAMI grid cell.

Using the suite of health effect studies considered in the Heavy Duty Diesel analysis as our guide, we identified three annual average PM2.5-related endpoints for inclusion in the analysis; mortality associated with long-term PM2.5 exposures, chronic bronchitis, and acute bronchitis. Table 2 contains details about each health effect, the study upon which the concentration-response function is based, and its associated valuation.

Table 2. Annual Average PM2.5-Related Health Endpoints

Endpoint	Population	Study	Mean Estimate [a]	Uncertainty Distribution [a]
Mortality				
Associated with long-term exposure	Ages 30+	Krewski et al. (2000), reanalysis of Pope et al. (1995) using the annual mean and all-cause mortality	$6.324 million per statistical life	Weibull distribution, mean = $6.324 million; std. dev. = 4.27 million.
Chronic Illness				
Chronic Bronchitis	>26	Abbey et al. (1995b)	$340,568 per case	A Monte Carlo-generated distribution, based on three underlying distributions.
Respiratory Symptoms/Illnesses Not Requiring Hospitalization				
Acute bronchitis	Ages 8-12	Dockery et al. (1989)	$59.29 per case	Continuous uniform distribution over [$17.13, $101.45].

[a] The derivation of each of the estimates is discussed in the main text. All WTP-based dollar values were obtained by multiplying rounded 1990 $ values used in the §812 Prospective Analysis by 1.318 to adjust to 2000 $.

Health Effect Results: Incidence and Valuation

The total dollar benefit associated with a given endpoint depends on how much the endpoint will change (e.g., how many premature deaths will be avoided) and how much each unit of change is worth (e.g., how much a premature death avoided is worth). Table 3 summarizes the mean changes in incidence associated with each SAMI control scenario in each future year. Table 4 summarizes the mean valuation (in 2000$) associated with the changes in incidence across all endpoints (mortality, chronic bronchitis, and acute bronchitis) for each SAMI control scenario in each future year. Table 5 provides a break down of total benefits by State. Finally, Table 6 presents a supplemental calculation of benefits associated with residential visibility improvements.

We note that the benefits presented in the tables below include an adjustment for the impact of expected growth in real income on future year benefit estimates. The factors were calculated by EPA for use in the Heavy Duty Standards RIA (U.S. EPA, 2000), and are discussed fully in the main text.

Table 3. Estimated Annual Average PM2.5-Related Health Effects Associated with Air Quality Changes Resulting from the SAMI Control Scenarios

Endpoint	Mean Avoided Incidence (cases/year)			
	2010 B1	2040 B1	2010 B3	2040 B3
Premature Mortality	1,662	4,273	6,155	8,007
Chronic Bronchitis	1,258	3,303	4,531	6,051
Acute Bronchitis	3,464	8,952	12,192	16,177
Unquantified Benefits[a]	U_1	U_2	U_3	U_4

[a] Several benefit categories are not quantified. Thus, the change in incidence for unquantified benefits are represented by "U".

Table 4. Estimated Annual Average PM2.5-Related Benefits Associated with Air Quality Changes Resulting from the SAMI Control Scenarios

Endpoint	Mean Monetary Benefits (millions 2000$)			
	2010 B1	2040 B1	2010 B3	2040 B3
Premature Mortality[a]	$11,114	$33,332	$41,163	$62,457
Chronic Bronchitis	$483	$1,508	$1,740	$2,763
Acute Bronchitis	$0.2	$0.6	$0.8	$1.1
Recreational Visibility[b]	$948	$1,755	$2,979	$3,221
Fishing Improvements[b]	$0.5	$1	$1	$4
Unquantified Benefits[c]	B_1	B_2	B_3	B_4
Total	$12,546 + B	$36,597 + B	$45,884 + B	$68,446 + B

[a] Calculated using a 3% discount rate and a 5-year lag structure for the onset of effects. See the technical report (Abt, 2002) for the discussion on estimate of premature mortality benefits.
[b] Visibility and fishing benefits are obtained from the final SAMI report. For visibility, SAMI did not apply an adjustment to reflect increases willingness to pay for environmental improvements as real incomes grow. Because EPA typically adjusts benefit values to reflect growth in real income, a factor of 1.1908 is applied to SAMIs total visibility benefits and reported here.
[c] Several benefit categories are not quantified in this analysis and are, thus, represented by "B" for the monetary value that would accrue.

Table 5. Total Benefits in 2040 By State
(Excluding Visibility and Fishing Benefits)
(Millions of $2000)

State	**B1 Control Strategy**	**B3 Control Strategy**
Alabama	$4,149	$7,209
Georgia	$7,285	$13,948
Kentucky	$1,196	$3,555
North Carolina	$8,404	$14,992
South Carolina	$2,827	$5,986
Tennessee	$5,772	$10,251
Virginia	$4,345	$7,469
West Virginia	$863	$1,811
Total Benefits (excluding Visibility and Fishing)	$34,841	$65,221

Table 6. Supplemental Benefit Assessment of
Residential Visibility Improvements

Year	**Control Scenario**	**Benefits ($Millions)**[a]
2010	B1	$267
	B3	$1,217
2040	B1	$942
	B3	$1,742

a Visibility benefits are obtained from the final SAMI report. SAMI did not apply an adjustment to reflect increases willingness to pay for environmental improvements as real incomes grow. Because EPA typically adjusts benefit values to reflect growth in real income, a factor of 1.1908 is applied to SAMIs total visibility benefits and reported here.

Uncertainty

As with any complex analysis such as this one, there are a wide variety of sources for uncertainty. Some key sources of uncertainty in each stage of the benefits include:

- gaps in scientific data and inquiry;
- variability in estimated relationships, such as C-R functions introduced through differences in study design and statistical modeling;
- errors in measurement and projections for variables such as population growth rates;
- errors due to misspecification of model structures, excluded variables, and simplification of complex functions;
- biases due to omissions or other research limitations.

The above benefits are considered primary estimates for this analysis, based on the best available scientific literature and methods. Where possible, we attempt to provide estimates of the effects of uncertainty about key analytical assumptions. In the technical report (Abt, 2002), we address uncertainty by presenting alternative calculations, sensitivity analyses, and probabilistic assessments associated with the annual average PM2.5-related health effects. They include:

- Alternative Calculations - Estimates of mortality based on alternative studies; Valuation of avoided premature mortality incidence based on statistical life years; Age-based adjustments to the value of a statistical life lost; Estimation and valuation of reversals in chronic bronchitis.
- Sensitivity Analyses - Calculation of the impact varying threshold assumptions have on the estimation of mortality incidence; Calculation of the impact different lag structures have on the estimation of benefits associated with avoided mortality incidence.
- Statistical Uncertainty Bounds - The total dollar benefit associated with a given endpoint depends on how much the endpoint will change due to the assumptions in the control scenarios (e.g., how many premature deaths will be avoided) and how much each unit of change is worth (e.g., how much a premature death avoided is worth). Based on these distributions, we use Monte Carlo methods to provide estimates of the 5^{th} and 95^{th} percentile values of the distribution of estimated health effect endpoint incidence and valuation.

Unquantified Benefits From Other Pollutant Reductions

One significant limitation of the SAMI health benefits analyses is the inability to quantify many of the adverse effects associated with exposures to pollutants other than annual average PM2.5. Though estimates of PM2.5-related mortality and chronic and acute bronchitis may have captured the bulk of the economic benefits associated with reducing emissions in the SAMI region, we still miss a variety of potential benefits because there are a limited number of epidemiological studies based on annual PM2.5. Benefits missed in the SAMI analysis likely include:

• **Other PM Effects (daily PM2.5, PM10 and coarse PM10)** - In analyses conducted for the EPA, benefit estimates related to hospital admissions, emergency room visits, lower and upper respiratory symptoms, work loss days, MRADs, and recreational visibility improvements have equaled between 3 to 5% of benefits related to annual average PM2.5 effects. Residential visibility improvements are considered a supplemental calculation and not included in the total benefits due to limitations of the study used in our assessment. Residential visibility benefits may be substantial based on our supplemental calculation.
• **Ozone Effects** - Across the same EPA analyses, benefits of ozone related hospital admissions, emergency room visits, MRADs, decreased worker productivity and agricultural crop losses have equaled between 2 to 24% of benefits related to annual average PM2.5 effects.
• **NO2, SO2, and CO Effects** - These pollutants are generally related to a small subset of effects; the most serious of which is perhaps hospitalization for heart-related problems.There have been studies finding some evidence that NO2 and CO are linked to mortality but it is difficult to determine if these effects are in addition to effects associated with PM and ozone.
• **Effects of Air Toxics** - Air toxics encompass a broad range of harmful chemical compounds that are either released directly into the air or formed in secondary reactions in the air, water, and soil. Exposure to air toxics can result in cancer, noncancer health effects, and ecological damage. The large number of air toxics, and the difficulties associated with estimating the impact of changes in emissions of air toxics, make these effects extremely hard to quantify.
• **Nitrogen Deposition Effects** - Excess nutrient loads, especially that of nitrogen, are responsible for a variety of adverse consequences to the health of estuarine and coastal waters. These effects include: toxic and/or noxious algal blooms such as brown and red tides; low (hypoxic) or zero (anoxic) concentrations of dissolved oxygen in bottom waters; the loss of submerged aquatic vegetation due to the light-filtering effect of thick algal mats; and fundamental shifts in phytoplankton community structure.