The Value of Visibility Improvements in the Southern Appalachian Mountains Region

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Abt Associates' Environmental Research Area provides multi-disciplinary scientific research and environmental policy analysis for the U.S. Environmental Protection Agency, the U.S. Agency for International Development, the Inter-American Development Bank, the World Bank, and directly to foreign, state and local governments. Abt Associates has extensive experience in estimating the potential public health improvements and economic costs and benefits from improving ambient air quality. The Environmental Research Area conducted extensive health analyses for the U.S. EPA in support of the 1997 revisions to both the ozone and the particulate matter National Ambient Air Quality Standards. They also prepared the health and economic analyses for EPA's 1997 Report to Congress *The Benefits and Costs of the Clean Air Act: 1970 to 1990*, and the 1999 Report *The Benefits and Costs of the Clean Air Act: 1990 to 2010*. Abt Associates conducts similar policy, health and economic analyses of regulations on the electric generating industry, automobile exhaust, diesel vehicles, regional haze, and potential policies for climate change mitigation strategies. Abt Associate's Environmental Research Area conducts public health analysis projects worldwide, including air pollution health assessment projects with the environmental and health ministries in Argentina, Brazil, Canada, Chile, Korea, Russia, Thailand, the Ukraine and for the World Health Organization.

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Executive Summary

In 1992, the Southern Appalachian Mountains Initiative (SAMI) was created to "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 I parks and wilderness areas, weighing the environmental and socioeconomic implications of any recommendations" (SAMI, 2001). To do this, SAMI commissioned an "integrated assessment" to estimate the environmental effects and selected socioeconomic costs and benefits of SAMI-designed emission reduction strategies. Four socioeconomic topics were assessed by the integrated assessment, including: 1) fishing; 2) hiking/enjoying scenery (also referred to as visibility); 3) stewardship/sense of place; and 4) lifestyle changes. This report, prepared for SAMI as part of the integrated socioeconomic analysis, presents a quantitative analysis of the economic value of visibility improvements associated with the estimated future air quality improvements from the SAMI emission reduction strategies.

In an area such as the Southern Appalachian Mountains, improved visibility is one of the most tangible results of improving air quality. When the view is obscured there are potentially both aesthetic and economic consequences. Many visitors to our nation's parks and wilderness areas are currently unable to see the spectacular vistas as well as they expected because, at times, a veil of white or brown haze obscures the view. Because poor visibility reduces a person's enjoyment of the views, it may reduce the likelihood of a return visit. There also is evidence that people value visibility at National Parks even when they are at home, whether they visited the area or not. People at home have also shown that they value good visibility within the area they reside. Although difficult to estimate, evidence suggests that people's desire for improved visibility, be it in a recreational or residential area, is genuine.

SAMI examined a series of potential strategies designed to evaluate 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. The strategies' modeling runs generally show visibility improvements throughout most of the SAMI region.

Converting these strategies into the input data for the visibility analysis, SAMI's atmospheric modeling contractor prepared visual air quality profiles for each of three future control strategies. Each strategy represents a series of different assumptions, including different applied control technologies, implementation of regulations and incentives, and demand for goods and services. The first, and least stringent, strategy is referred to as the "A2" scenario, or the reference strategy. This scenario serves as the base level of future-year visual air quality from which changes in air quality conditions 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 (i.e., lower emissions) than A2, and B3 is more stringent than B1. A complete description of the assumptions present within each of these emission reduction strategies can be found in the 2001 SAMI Interim Report.

Because methods to estimate what study subjects are willing to pay for specific environmental improvements may be expensive and time consuming, we instead relied on "benefits transfer" methods to calculate the value of changes in visibility throughout the SAMI region. The benefit transfer approach relies on information from existing studies in which the subjects and the environmental quality improvements are as close as possible to those under consideration. The application of the benefit transfer method for the SAMI analysis consisted of three steps:

Step 1: Choose the Benefit Transfer Studies

Though there have been a number of visibility valuation studies, only two provide monetary estimates of the non-use value of visibility changes in the Southeast. One is a study on residential visibility conducted in 1990 (McClelland et al., 1991) and the other is a 1988 survey on recreational visibility value (Chestnut and Rowe, 1990). Both utilize the contingent valuation (CV) method, which used surveys to ask specific questions about a respondents "willingness to pay" (WTP) for visibility improvements. McClelland et al. (1991) conducted a CV study of residential visibility in Atlanta. Chestnut and Rowe (1990) included a CV study of visibility at National Parks in the Southeast with particular emphasis on Shenandoah National Park.

We chose Chestnut and Rowe (C&R) to serve as the basis for the primary estimate of visibility benefits in the SAMI analysis. A 1999 US EPA Science Advisory Board (SAB) advisory letter to the EPA's Administrator indicated that "although many members of the Council believe that the Chestnut and Rowe study is the best available, we believe that the general principle [of relying on the peer-reviewed literature as the basis for regulatory analyses] should be adhered to," (U.S. EPA, 1999a, p. 13). Though not peer reviewed itself, the Chestnut and Rowe study has been subject to institutional review while also having been cited in numerous peer-reviewed publications. It is also the only study to estimate the value of visibility improvements at parks in the Southeast.

We chose the McClelland et al. residential visibility study as the basis for a supplemental estimate of SAMI visibility benefits. The EPA SAB concluded values based on the McClelland study should be placed in a screening level benefit category because it was only an exploratory study that lacked peer review status (U.S. EPA, 1999a). Despite this uncertainty, the McClelland study has served as the basis for monetary estimates of the benefits of changes in residential visibility for economic analyses conducted by the National Acid Precipitation Assessment Program (NAPAP, 1998) as well as in numerous regulatory analyses conducted by EPA. This report follows the EPA SAB recommendation, presenting residential visibility as a less certain sensitivity analysis.

Step 2: Specify the Benefit Transfer Function

To estimate the value of the different visibility improvements projected to occur under each of the SAMI control scenarios, we estimated a general relationship between the amount of improvement in visibility and the average value households place on that improvement observed in both the C&R and McClelland et al. studies. We expressed this relationship using a constant elasticity of substitution utility function approach consistent with economic theories of utility and budget constraints. This approach served as the basis for economic benefits presented in the Regulatory Impact Analysis for the Final Regional Haze Rule (U.S. EPA, 1999c) and has since been used in a number of regulatory analyses for the EPA.

Step 3: Input SAMI-Specific Data into the Benefit Transfer Function

Using the benefit transfer function, we used the C&R- and McClelland-based WTP parameters, the projected visual air quality for each future year base and control scenario, and the corresponding future year population to estimate each household's WTP for visibility improvements under each of the SAMI emission control scenarios. The sum of household WTP for recreational visibility improvements therefore equaled the total estimate of primary visibility benefits. Similarly, the sum of household WTP for residential visibility improvements equaled the supplemental estimate of total residential visibility benefits.

This analysis considers the value of recreational visibility improvements to be the primary estimate of SAMI-related visibility benefits. Under scenario B1, the value of recreational visibility improvements is \$796 and \$1,474 million (2000\$) for 2010 and 2040, respectively.[1] Under scenario B3, the value of recreational visibility improvements is \$2,502 and \$2,705 million (2000\$) for 2010 and 2040, respectively.

This analysis considers the value of residential visibility improvements to be a supplemental estimate of SAMI-related visibility.[2] Under scenario B1, the value of residential visibility improvements is \$224 and \$791 million (2000\$) for 2010 and 2040, respectively.[3] Under scenario B3, the value of residential visibility improvements is \$1,022 and \$1,463 for 2010 and 2040, respectively.

Estimates of recreational and residential visibility valuation are uncertain and controversial. The report identifies many potential sources of upward and downward bias. We made assumptions using available data to estimate visibility valuation (using techniques from prior federal visibility assessments) associated with improved visual air quality at Class I areas in the SAMI region under SAMI's strategies.

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[1] Benefits in 2010 would be up to 27% higher if an adjustment for income growth were applied. Likewise, in 2040 the total benefits would be up to 82% higher. These values were calculated by EPA for the Heavy Duty Diesel regulatory impact analysis. EPA's Science Advisory Board has concurred with the methodology for the calculation in its review of EPA's health-related analyses, but has been silent regarding the acceptability of these specific values used for assessing visibility benefits. While the concept of an income growth adjustment is reasonable, there are significant uncertainties concerning its value. The issues are discussed more fully in Section 5.

[2] The analysis creates a distinction between primary and supplemental benefits to highlight the uncertainty present within each estimate. Primary benefits, though uncertain, are a better estimate of the magnitude of recreational visibility benefits. Supplemental estimates of the value of improvements in residential visibility are more uncertain than the primary benefits.

[3] See footnote 1.

1 Introduction

In an area such as the Southern Appalachian Mountains, improved visibility is one of the most tangible results of improving air quality. It is also one of the scientifically better-understood impacts of air pollution. Despite this knowledge, the full social costs of impaired visibility are not well understood by policymakers and the public. Some people are not aware that visibility is impaired at all, incorrectly believing that the milky-white haze (as opposed to naturally-occurring blue haze) that often covers the Southern Appalachian Mountains is somehow a natural phenomenon associated with humidity, especially on hot summer days. In fact, visibility impairment is a major problem in the Southern Appalachian Mountains, with both aesthetic and economic consequences.

Although difficult to estimate, evidence suggests the desire for improved visibility is genuine. The challenge to an economic benefits analysis is to reflect this desire in monetary terms. This report presents a quantitative analysis of the demand, measured in dollars, for visibility improvements associated with improved air quality in the Southern Appalachian Mountain region. It also presents a qualitative discussion of the uncertainties associated with the valuation of visibility improvements in general and specifically associated with the results presented in this report.

The Southern Appalachian Mountains Initiative (SAMI) provided Abt Associates a series of air quality profiles that represent emissions levels in two future years, 2010 and 2040. The air quality profiles include, for each year, three scenarios from which we will base our benefit estimates. Each scenario represents a series of different assumptions, including different applied control technologies, implementation of regulations and incentives, and demand for goods and services. The first, and least stringent, scenario is referred to as the "A2" scenario. This scenario serves as the base level of future-year visual air quality from which changes in visibility conditions are calculated.[4] The remaining two scenarios are named the "B1" scenario and the "B3" scenario. These strategies are the control scenarios, where B1 is more stringent (i.e., lower emissions) than A2, and B3 is more stringent than B1. A complete description of the assumptions present within each of these emission reduction strategies can be found in the 2001 SAMI Interim Report.

Before examining the methods used to estimate benefits associated with the emission control scenarios, however, we present a background on the nature and history of visibility valuation. This is presented in Section 2. Section 3 of the report describes the methods Abt Associates applied to value the improvements in Southern Appalachian visibility between the baseline and emission control scenarios. In Section 4 we present the results of the primary benefits analysis. Finally, in Section 5, we discuss many of the limitations and uncertainties associated with the valuation methods. In addition to the main report, there are also three appendices. Appendix A presents the derivation of the valuation functions used in the analysis. Appendix B summarizes the peer review comments that this report did not address and provides a brief explanation why they were not addressed. Finally, in Appendix C, we present maps that overlay the visibility modeling results across the SAMI region.

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[4] Visibility benefits are calculated based on the measured change in visibility between a future-year base-case scenario and a future-year control scenario.

2 Visibility Benefits - A Background

Visibility impairment comes in a variety of forms: intrusive plumes from local smokestacks, a dirty low-lying inversion layer, or a milky or brown regional haze blanketing the view in all directions. Each of these forms of visibility impairment is a function of the nature and source of emissions and the prevailing meteorological conditions (Malm, 1999, p. 20). Plumes, layered haze, and regional haze, however, differ from the clouds and fog that we might see on a rainy day, and instead are human-based impediments to visibility that federal, state, and local governments, as well as multi-stakeholder partnerships such as SAMI, are actively trying to reduce.

Visibility conditions are commonly expressed in terms of three mathematically related metrics: standard visual range (VR), light extinction (ext), and deciviews (dv). Standard visual range is the metric best known by the general public. It is the maximum distance at which one can identify a black object against the horizon, and is typically described in kilometers (or miles). Higher visual range estimates mean better visibility. While the theoretical maximum is 391 kilometers on a perfectly clear day, this is never achieved due to the natural scattering of light by gases in the atmosphere, so-called "Rayleigh scattering" (U.S. EPA, 1996, p. 8-12). While standard visual range is a simple measure that can be easily used to characterize visual conditions, it is somewhat imprecise and cannot be used to effectively determine the relative importance of the contributors to reduced visibility. It is also useless in cloudy conditions near monitors.

Light extinction is a somewhat better alternative than visual range because it allows one to express more objectively the relative contribution of a pollutant to overall visibility impairment. Light extinction is the sum of the light scattering and light absorption by particles and gases in the atmosphere, and is measured in inverse megameters (Mm^{-1}). An inverse megameter is the amount of light scattered or absorbed as it travels over a distance of one million meters. Higher extinction values mean worse visibility, which is the inverse of visual range.

A third measure of visibility is the deciview index, which provides a linear scale for perceived visual changes over a wide range of conditions. On a particle-free, pristine day the deciview index has a value of zero (VR=391 km). On a relatively clear day in the Great Smoky Mountains the deciview index might be about 16 (VR=79 km) and on a relatively hazy day the deciview index might be about 31 (VR=201 km). For each 10 percent increase in light extinction, the deciview index goes up by one. So, higher deciview values mean worse visibility. This logarithmic scaling is analogous to the decibel scale used for the perception of sound. Under many scenic conditions, a change of one deciview is considered to be just perceptible by the average person. However, it is important to understand that the same amount of pollution can have dramatically different effects on visibility depending on existing conditions. Most importantly, visibility in cleaner environments is more sensitive to increases in particle concentrations than visibility in more polluted areas.

No matter how visibility conditions are measured, however, when the view is obscured by pollution, it affects people's enjoyment and sense of "wilderness" experience. Many visitors to our nation's parks and wilderness areas are unable to see the spectacular vistas they had expected, because a veil of white or brown haze hangs in the air blurring the view. Because this reduction can significantly reduce people's enjoyment of the views, and it may reduce the likelihood that they come back to visit, this can have a significant local economic impact. There is also evidence that people value visibility at parks even when they are at home, whether they visited the area or not.

In tackling the problem of how to measure the economic value of preserving or improving visibility, economists have made two important distinctions. The first distinction is between “residential visibility” – the visibility in and around one’s community -- and “recreational visibility” – the visibility at places to which people go for natural scenic beauty and recreation. Economists make this distinction primarily because the values of these two types of visibility are likely to be different from each other. Even within the category of “recreational visibility,” values for visibility improvements may vary substantially from one place to another. People may care much more, for example, about good visibility at well known places like the Great Smoky Mountains and Shenandoah National Parks than they do about good visibility at lesser known places. Another reason economists distinguish between residential and recreational visibility is that, as discussed below, there are different techniques for measuring the two types of visibility benefits. Most public policies that are designed to affect air pollution on a broad geographic basis, such as throughout the Southern Appalachian region, will impact both residential and recreational visibility for many people. The people that demand these two types of visibility improvements, while they may overlap to some degree, may also be different.

Economists distinguish between “use” and “non-use” value. It is easy to understand that people may value things they can use or directly experience. Goods and services that people purchase and use obviously have value. If they did not, people would be unwilling to purchase them at any price. Even though people do not “use” an improvement in visibility in the same way they would use a market product or service, they derive pleasure or satisfaction from directly experiencing it. How much someone is willing to pay for a visibility improvement they would directly experience is their “use value” -- what it is worth to be able to enjoy that improvement in visibility.

In addition, people often want, and are willing to pay for, improvements in visibility that they themselves may not directly experience. They may value such improvements so that other people can enjoy them, or so that future generations can enjoy them. Sometimes, just the knowledge that something exists has value to people, regardless of whether anyone ever directly uses or experiences it. Economists call these types of value “non-use” value, and the evidence suggests that they are indeed real (see Rowe et al., 1980; MacFarland et al., 1983; and Rae, 1983).

Like most environmental quality improvements, improvements in visibility can be enjoyed by many people. One person’s enjoyment of better visibility in no way diminishes or “uses up” another person’s enjoyment of it. Because of this, the economic value of an improvement in visibility is the sum of all individuals’ values – both use and non-use values -- for it. This is important, because, while any individual’s value for a particular improvement in visibility may be relatively small, there may be many people who would derive some value. The total value of the improvement can therefore be substantial.

2.1 Economics: The Non-Market Value of Visibility

A common method for measuring the value people place on environmental quality improvements, such as both residential and recreational visibility improvements, is known as the contingent valuation (CV) method. Although there are various forms of the CV method, they all essentially rely on surveys to elicit from study subjects information about their stated willingness to pay for a specified environmental quality improvement. We do not intend to present a thorough discussion of the CV method here. Instead we note some key issues associated with the valuation methodology. For a comprehensive discussion of contingent valuation see Mitchell and Carson (1989) and Carson (2000).

CV studies of visibility improvements conducted to date typically present study subjects with a series of photographs from actual historical records or model-generated images[5] of the same location at different visibility levels and ask what their household would be willing to pay each year to have average visibility improve from a specified level of lower visibility to a specified level of higher visibility. In a residential visibility valuation study, the pictures would be of a particular urban area – for example, a city skyline – shown with different levels of urban smog. In a recreational visibility study, the picture would be of an important vista in a National Park or scenic area of interest in the study. Researchers try to measure both use and non-use value by including subjects from various locations, both close to and far from the National Park in question and by querying subjects about whether they ever have or ever intend to visit it.

The CV method has several often-noted advantages and disadvantages. The most notable disadvantage is that what people say they would pay for a hypothetical improvement in a hypothetical situation may not be what they would actually pay if the situation were real and they actually were required to pay. There are several possible reasons for this. Subjects in a study may not fully understand what it is they are paying for. They may not take the task entirely seriously if there is no consequence for false answers, or they may give "strategic" answers if they believe that their answers might in some way ultimately affect policy. Or they may simply find it very difficult to assess how much they would be willing to pay for something without being in a situation in which they would actually have to pay it.

Sometimes it is difficult to separate out the value of one "good" from the value of other different but related "goods." In visibility valuation studies, some subjects may not be able to completely separate out the value they place on better visibility from the value they place on other improvements, such as reduced health risks, that they would also enjoy if air pollution were cleaned up. It is also possible that subjects' responses may to some extent reflect a general desire to "clean up the environment," rather than the amount they would be willing to pay specifically for better visibility.

Finally, people's willingness to pay for visibility improvements may depend on what other environmental quality improvements they may be considering paying for as well. Because people do not have unlimited budgets, their willingness to pay for something should depend, to some extent, on how much money they have at their disposal. There is some evidence from studies that people's willingness to pay for an environmental quality improvement does depend on whether it is the only one they are being asked to pay for or one of several.

Despite the problems with CV studies, they have some important advantages. One important advantage of the CV method is that it attempts to measure the appropriate economic value concept: individuals' willingness to pay. Another is that it can be used to measure preferences. Perhaps most important, unlike market-based methods, it can be used to measure non-use values. This is an important advantage because in some cases non-use values may be substantial – perhaps more substantial, in aggregate, than use values. This appears to be the case, for instance, for recreational visibility, as discussed below.

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[5] The model typically used to generate such images is WinHaze, a computer-imaging software program that simulates visibility conditions under different air quality conditions (Air Resource Specialists Inc., 1998).

2.2 The Value of Visibility Improvements at National Parks: Evidence from Studies

A number of studies have examined the value of visibility improvement (Exhibit 2-1). One type of study that values improvements in visibility at National Parks may be characterized as an “on-site use value study.” In this type of study, researchers ask visitors to National Parks what they would be willing to pay in additional park entrance fees to have specified visibility improvements during their visits to those parks. This type of study captures direct use value – what people would be willing to pay for visibility improvements that they can enjoy while visiting the park. These types of studies have been conducted at several locations around the United States. MacFarland et al. (1983) elicited on-site visibility values from visitors at Grand Canyon National Park and at Mesa Verde National Park; Rae (1983) surveyed visitors at Great Smoky Mountain National Park and at Mesa Verde National Park; and Rowe et al. (1980) studied the Navajo Reservoir, near Farmington, New Mexico. This last study provides the only estimates of on-site use value for visibility at a recreational area that is not a National Park.

Exhibit 2-1 Economic Valuation Studies for Recreational and Residential Visibility

Study	Location	Valuation Method	Mean WTP (1999$)
Recreational - On-Site			
Rowe et al. (1980)	Navajo Reservoir, NM	Contingent Valuation	$10.94 per visitor party day
MacFarland et al. (1983)	Grand Canyon NP, AZ and Mesa Verde NP, CO	Contingent Valuation	GC - $3.82 per visitor party day MV - $3.24 per visitor party day
Rae (1983)	Mesa Verde NP, CO and Great Smoky Mountain NP, TN	Contingent Valuation	MV - $11.48 per visitor party day GS - $5.81 per visitor party day
Recreational - Off-Site			
Schulze et al. (1983)	Grand Canyon NP, AZ	Contingent Valuation	$7.48 per month per household
Chestnut and Rowe (1990b)	National Parks in the Southwest, California, and the Southeast	Contingent Valuation	CA - $73.93 per year per household for parks in-region and $50.56 for parks out-of-region SW - $62.46 per year per household for parks in-region and $50.56 for parks out-of-region SE - $76.06 per year per household for parks in-region and $46.31 for parks out-of-region
Decision Focus (1991)	Grand Canyon NP, AZ	Contingent Valuation	$0 - $39.12 per year per household
Residential			
Brookshire et al. (1979)	Los Angeles, CA	Contingent Valuation	$146.12 - $374.29 per household per year
Tolley et al. (1986)	Chicago, Atlanta, Boston, Mobile, Washington, DC, Miami, Cincinnati	Contingent Valuation	$97.80 - $522.66 per household per year
McClelland et al. (1993)	Atlanta, Chicago	Contingent Valuation	$49.46 per household per year

The on-site use value studies have generally estimated values on the order of a few dollars to several dollars a day per household for noticeable improvements in visibility (ranging from about twenty miles increase in visual range to well over one hundred miles increase). Because most households do not spend very many days a year at National Parks, however, these studies suggest that the total value of people being able to directly enjoy visibility improvements at National Parks is likely to be small relative to the value of improvements in visibility at and around the communities where people live and spend much more of their time.

Another type of study draws respondents from the general public, rather than from among visitors at National Parks. This "off-site" type of study investigates a broader cross-section of people. In this type of study, respondents are identified in each of several specified locations, some of which are near the National Park(s) in question, and some of which are not. Subjects are asked whether they have ever visited the park in question, and whether they ever intend to. Even people who say they have never visited a particular National Park and never plan to are asked what they would be willing to pay for specified improvements in visibility at the park. This type of visibility valuation study allows researchers greater latitude in investigating both how much value people place on being able to directly enjoy the good visibility at National Parks and how much value they place on just knowing it is there – for others, for themselves, or just in general. Studies using this type of approach have estimated both use and non-use values, as well as the sum of the two – the total value of preserving or improving visibility at National Parks.

Three studies of this second type have estimated the value of preserving or improving visibility at National Parks in different regions of the United States. The National Parks Visibility Values Study (Chestnut and Rowe, 1990) focused on National Parks in California, the Southwest, and the Southeast. A second study (Decision Focus, 1991) focused explicitly on values at Grand Canyon National Park. An earlier study (Schulze et al., 1983) covered National Parks in the Southwest, including the Grand Canyon. These studies provide evidence that people want good visibility preserved at National Parks – even if they do not live anywhere near the parks and even if they have no plans to enjoy that good visibility themselves. People's values for visibility improvements at National Parks in these studies exceeded the values for comparable improvements in visibility at National Parks in the "on-site use value" studies. Although people who had visited or planned to visit the parks were generally willing to pay more, even those who reported that they had never visited the park(s) in question and never planned to generally said they were willing to pay something to preserve the visibility in these parks. These results suggest that a substantial component of the value of good visibility at National Parks derives from knowing that it is there for others to enjoy, knowing that it is there to enjoy if one ever goes to visit the park, and just knowing that it is there, regardless – what economists call "non-use" value.

The studies suggest, moreover, that it is not only people who live close to National Parks who care about preserving the good visibility in them. Although households relatively close to the National Parks in the studies were generally willing to pay more than those far away, even "out of region" households were willing to pay positive amounts per year to preserve the visibility at National Parks. This is important because there are many households in the United States, and even a small amount of demand for out-of-region households can result in a sizable national demand. For example, based on the responses from in-region and out-of-region respondents in the National Parks Visibility Values Study (Chestnut and Rowe, 1990), Chestnut and Dennis (Chestnut and Dennis, 1997, p. 400) calculated that the average out-of-region household was willing to pay about $10 (1999$) a year for a twenty percent improvement in visibility at National Parks in the Southeast. With over 110 million households in the United States, even if all households were "out of region," that adds up to a value of over $1 billion.

It is difficult to compare the results of these studies because different studies asked people to value different amounts of visibility improvement at different National Parks. We cannot say, for example, that households were willing to pay from x dollars a year to y dollars a year for a twenty percent improvement in visibility at National Parks across the country because not all studies asked people to value a twenty percent improvement in visibility. A hypothetical example using values from the National Parks Visibility Values Study (Chestnut and Rowe, 1990), however, gives us an idea of relative magnitudes of the study results.

Because the average household income in the sample of households in the National Parks Visibility Values Study was higher than the national average ($41,000 for the sample versus a national average of $32,000 in 1987), the study authors adjusted the average WTPs for changes in visual range in their sample to better reflect what the average household in the United States would be willing to pay for these changes. Using the estimated income elasticity of WTP (the percent change in WTP corresponding to a one percent increase in income) across the three regions in their study (0.9), the average household WTP in the United States at the time of the study was about 80 percent of the average household WTP in their sample. Using these income-adjusted WTPs, households in the Southeast were, on average, willing to pay $84 (1999$) a year for a two hundred percent visibility improvement (from 25 to 75 kilometers) in National Parks in the Southeast. Households in regions other than the Southeast were willing to pay, on average, $36 (1999$) a year for a one hundred percent visibility improvement (from 25 to 50 kilometers) in National Parks in the Southeast. All other willingness to pay values from that study (for different visibility improvements in National Parks in different regions of the country) fell somewhere in between. If the “out-of-region” households in this study are representative of all households in the United States, then a one hundred percent visibility improvement (from 25 to 50 kilometers) in National Parks in the Southeast would be worth over $3.6 billion.

2.3 The Value of Visibility Improvements in Residential Areas: Evidence from Studies

Residential visibility valuation studies have been carried out in several cities, including Atlanta, Chicago, Boston, Mobile, Washington, D.C., Cincinnati, Miami, Los Angeles and San Francisco. Although different studies considered different visibility changes, the average per household values placed on improvements in residential visibility were generally higher than those for comparable improvements in visibility in the National Park visibility valuation studies. For example, Tolley et al. (1986), who conducted residential visibility studies in several cities, found that the average household in Chicago was willing to pay $389 (1999$) a year for a one hundred percent increase in visibility (from 9 miles to 18 miles); in Washington, D.C. the average household value for a sixty-seven percent improvement (from 15 to 25 miles) was $411 (1999$).

It is again difficult to compare the results of residential visibility valuation studies with one another for the same reason it was difficult to compare the results of different recreational visibility valuation studies – each study considers different visibility improvements. It may also be the case that people in different urban areas do not value visibility in the same way -- even similar visibility improvements across a number of cities may have different values. These studies, however, collectively provide evidence that people value good visibility in their communities. The smallest annual average household value reported was $22 (1999$) for a small visibility improvement of less than fourteen percent (from 17.6 to 20 miles) in both Atlanta and Chicago (McClelland et al., 1993). The largest annual average household value reported in these studies was $523 (1999$) for a visibility improvement of 133 percent (from 15 to 35 miles) in Washington, D.C. (Tolley et al., 1986).

2.4 Applying the Information from Studies to Assess the Visibility Benefits of Reducing Air Pollution

As noted above, each recreational or residential visibility valuation study considers specific visibility changes at specific National Parks (or explicit groups of parks) or urban areas. Any particular willingness to pay estimate is for a particular change in visibility at a particular location. To use the information from these studies to estimate the value of improved visibility that would result from a policy or regulation, we must be able to generalize from the specific visibility improvements and values reported in the studies.

To estimate the value of the many different visibility improvements that would result in different locations from an implemented air pollution policy or regulation, the evidence from these studies can be used to estimate a *general relationship* between the amount of improvement in visibility and the average value households place on that improvement. Chestnut and Dennis (1997) assumed that what matters is the percent change and not the absolute change in visibility. They then estimated household WTP for a change in visual range, from v1 to v2, by multiplying the natural logarithm of (v2/v1) by a coefficient that they estimated from respondent' reported WTP for this visibility change.

Using WTP estimates for visual range improvements in National Parks in the Southeast from the National Parks Visibility Values Study, Chestnut and Dennis (1997) reported estimated coefficients of 85 and 50 for in-region and out-of-region households. Using these fitted relationships, we can estimate household WTP for any percent improvement in visibility at National Parks in the Southeast. For example, a ten percent improvement in visibility would be worth about $8 a year per household for those near the park:

$$\$8 = B * \ln(V2/V1) = 85 * \ln(1.1)$$

Converting this from the 1994 dollars used in the study, we estimate the improvement is worth $9 in 1999 dollars. Similarly, using the out-of-region coefficient of 50, we estimate a ten percent improvement in visibility would be worth about $6 (1999$) a year per household for those far from the park.

We can also assume a general relationship between residential visibility changes and household WTP, such as we did for recreational visibility. Chestnut and Dennis (1997) used the same general form of relationship that was used for National Parks (in which the percent change in visibility, rather than the absolute change, is what matters). Using these city-specific functions, they calculated what a twenty percent improvement in visibility would be worth in each city. There was a broad range. For example, a twenty percent improvement in residential visibility was worth as little as $22 a year per household in Cincinnati and as much as $272 a year per household in San Francisco.

The use of such "benefits transfer" techniques for evaluating the demand for alternative policy scenarios has been a regular component of regulatory impact analyses for years. Exhibit 2-2 presents various recreational and residential visibility benefit totals that have been estimated for significant air quality policies over the last decade. As expected, results are not easily comparable since the geographic coverage and policy emphasis have varied from analysis to analysis. For example, the Section 812 Retrospective and Prospective Analyses measured visibility changes over the entire nation, while the Section 126 and NO_x SIP Call Analyses only estimated visibility changes over a portion of the nation. Benefits for the Navajo Generating Station were estimated for visibility changes at the Grand Canyon National Park alone. In another instance, the Haze Rule was specifically designed to improve visibility and has relatively large visibility benefits, while the Tier 2 Rule is not focused on visibility improvement and the benefits are relatively small.

Valuation methods have also changed over time. Many earlier analyses calculated visibility benefits using a valuation function that gives a constant value for each percent change in visibility. For example, in the NO_x SIP call (Abt Associates Inc., 1998), the percentage change in visual range was multiplied by a given valuation coefficient to estimate annual household willingness to pay. More recent estimates of visibility benefits, such as in the Heavy Duty Diesel Analysis for the EPA (Abt Associates Inc., 2000), use what economists refer to as a utility function approach.

Utility functions capture the basic characteristics of how people (or households) make economic tradeoffs between the possible goods they might consume (buy), given that they have only a finite amount of money to spend in total. The model expresses how much "utility," or satisfaction a person gets from the set of goods he chooses to consume, and is used to calculate what combination of goods will give him the greatest satisfaction, given the prices of the goods and the person's budget. Non-market "goods" like visibility improvements can be included among the goods considered using a utility function. In this case, there is no "price" of the good. Nevertheless, people may value it and be willing to reduce their purchases of other goods to obtain it. A utility function approach balances the tradeoff between people's desire for improvements in visibility and their desire for the other goods on which they normally spend their money. The appeal of this approach is that it is designed to avoid benefits estimates that suggest people would spend an unrealistic amount of their income for improved visibility.

As research continues, our knowledge about how much people value visibility improvements of different amounts in different urban areas and at different National Parks and wilderness areas will increase. At any point in the research process, analysts must rely on the information that is available at that time, and draw tentative conclusions about the *general relationship* between the amount of improvement in visibility and the average value households place on that improvement. Analysts can then use this general relationship to estimate the value of improved in urban areas and National Parks that might result from an air pollution policy or regulation.

Exhibit 2-2 Visibility Benefits from Different Policy Analyses

Analysis[a]	National Coverage	Year of Analysis	Benefits (millions 1999$)	
			Recreational	Residential
Navajo - EPA Analysis	Partial	1991	268	n/a[b]
Navajo - Salt River Project Analysis	Partial	1991	3	n/a
NAPAP	Partial	1994	1,451	2,559
Ozone/PM NAAQS	National	1997	5,983	3,906
812 Retrospective	National	1997	n/a	4,311
NOx SIP Call	Partial	1998	13	75
Haze Rule	National	1999	1,816	149
812 Prospective	National	1999	3,697	n/a
Section 126	Partial	1999	43	31
Tier 2	National	1999	385	578
Heavy Duty Diesel	National	2000	1,789	1,188

[a] The following describes the policy scenarios considered in each of the analyses:
Navajo: Benefits due to a 90% reduction in sulfur emissions from the Navajo Generating Station near the Grand Canyon in 1995 National Acid Precipitation Assessment Program (NAPAP): Benefits due to improvements in 2010 visibility conditions in the Eastern U.S., relative to what would have been expected to occur without Title IV.
812 Retrospective: Visibility benefits associated with the Clean Air Act between 1970 and 1990.
Ozone/PM National Ambient Air Quality Standards: Benefits associated with changes from the PM NAAQS 10/65 incremental to the current PM10 standard assuming partial attainment.
NOx SIP Call: 0.15 trading alternative incremental to baseline 2007 using a threshold of background.
Haze Rule: 1.0 dv/10 years incremental to baseline 2015, fugitive dust controls included, threshold of background, wilderness area benefits not additional to total regional values.
812 Prospective: Visibility benefits due to criteria pollutants in 2010 post-1990 CAA Amendments.
Section 126: Visibility benefits associated with changes from the 2007 representative year scenario.
Tier 2: Benefits due to changes from the final Tier 2 2030 control scenario.
Heavy Duty Diesel: Benefits due to changes from the final Heavy Duty Diesel 2030 control scenario.

[b] n/a: benefits were not calculated for this visibility category in the analysis.

3 Visibility Valuation Method and Application

Methods, such as those described in the previous section, have been devised and applied to estimate what study subjects would be willing to pay for specific environmental quality improvements. However, such studies are time consuming and expensive. Because commissioned studies on the specific populations that would be affected by a particular regulatory program are usually not available, practitioners of benefit-cost analysis have typically relied on "benefit transfer" methods. Rather than collecting primary data on individuals who benefit from a particular policy scenario, the benefit transfer approach relies on information from existing studies in which the subjects and the environmental quality improvements are as close as possible to those under consideration. We then assume that the WTP estimated in the study for some unit of environmental quality improvement can be transferred from the study location and study subjects to the location and individuals in the policy scenario. Overall, benefits transfer reduces both the time and financial resources needed to develop benefit estimates of a particular policy. The SAMI analysis is based on benefits transfer methods.

Specifically, our benefits transfer employs a utility function approach that values the direct change in visibility. This approach has been used in a number of benefits analyses, both for the EPA and for other interested stakeholders, and has undergone institutional review within the Federal Government by the EPA's Science Advisory Board (SAB) and the Office of Management and Budget (OMB). This method forms the basis for the calculation of a best estimate of visibility benefits associated with the SAMI policy scenarios.

3.1 The Valuation Studies

Though there have been a number of visibility valuation studies, only two provide monetary estimates of the non-use value of visibility changes in the Southeast. One is a study on residential visibility conducted in 1990 (McClelland, et al., 1991) and the other is a 1988 survey on recreational visibility value (Chestnut and Rowe, 1990). Both utilize the contingent valuation method. McClelland et al. (1991) conducted a CV study of visibility in Atlanta. Chestnut and Rowe (1990) included a CV study of visibility at National Parks in the Southeast with particular emphasis on Shenandoah National Park.

A 1999 SAB advisory letter to the EPA's Administrator indicated that "although many members of the Council believe that the Chestnut and Rowe study is the best available, we believe that the general principle [of relying on the peer-reviewed literature as the basis for regulatory analyses] should be adhered to," (U.S. EPA, 1999a, p. 13). Though not peer reviewed itself, the Chestnut and Rowe study has been subject to institutional review while also having been cited in numerous peer-reviewed publications. It is also the only study to estimate the value of visibility improvements at parks in the Southeast. When presented with an adequate discussion of the uncertainty inherent in the valuation, the Chestnut and Rowe study can serve as an acceptable basis for monetary estimates of the benefits of visibility changes in recreational areas. We therefore use the Chestnut and Rowe study as the basis for the SAMI visibility project.

Also consistent with SAB advice, we believe that using the McClelland, et al. study provides useful estimates on the order of magnitude of residential visibility benefits. However, the SAB concluded values based on the McClelland study should be placed in a screening level benefit category because it was only an exploratory study that lacked peer review status (U.S. EPA, 1999a). Despite this uncertainty, the McClelland study has served as the basis for monetary estimates of the benefits of changes in residential visibility for economic analyses conducted by the National Acid Precipitation Assessment Program (NAPAP, 1998) as well as in numerous regulatory analyses conducted by EPA's Office of Air Quality Planning and Standards. We therefore include residential visibility benefits, based on values derived from McClelland et al., only as a supplemental calculation of the potential magnitude of residential visibility benefits in the SAMI region.

Though we present residential visibility benefits separately from recreational benefits, the same utility function approach to valuation that we use to calculate recreational visibility benefits is used to calculate residential visibility benefits. The methodology discussion therefore includes references to both recreational and residential visibility estimation, though residential visibility benefits are only considered a supplemental calculation to the primary estimate of recreational visibility benefits.

3.1.1 The Preservation Values Study, Chestnut and Rowe (1990)

Chestnut and Rowe's (1990) Preservation Values study examined the demand for visibility in Class I-area National Parks in three broad regions of the country: California, Southwest, and Southeast. Because the SAMI analysis only includes parks located in the Southeast, we do not consider parks located in the other two regions. For the Southeast region, the Preservation Values study asked respondents in Arizona, California, Missouri, New York and Virginia for their willingness to pay to protect visibility at National Parks in that region. Exhibit 3-1 lists the parks included in the study.

Exhibit 3-1 Class I Areas Included in Original Visibility Study By Region

Region	National Parks
Southeast	**Shenandoah**, Great Smoky Mountains, Mammoth Cave, Everglades

Note: The “indicator” park is shown in bold. The indicator park is a well-known park in that region, and the respondents were shown photos from the indicator park in each region. Source: Chestnut (1997)

Photos depicting a range of visibility conditions at Shenandoah National Park, considered the region's “indicator park” for it's prominence in the Southeast region, were provided as part of the survey instrument. After a number of preparatory questions, respondents reached the WTP section of the survey. Respondents were first instructed that their answer to the WTP question applied only to the region in their survey, and that they did not have to worry about other regions of the country. It was also made clear that other individuals were being asked about visibility, human health, and vegetation protection in urban areas and at National Parks in other regions. After furnishing their WTP, respondents were asked what portion of their stated total value was for visibility at the indicator park alone. The reported answers were then appropriately adjusted to avoid including these “extraneous” benefits not meant for inclusion in the elicited WTP. These safeguards were designed to make it less likely that there would be overlap between residential and recreational visibility benefits.[6]

Because the regional distribution of National Parks throughout the U.S. is so varied, the household WTP estimated in the study changed in value depending upon the location of the Class I area. Household WTP was originally estimated for three primary visibility regions: California, Southwest, and Southeast.

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[6] There are a number of Class I areas in the Southeast region that are *not* National Parks (e.g., Florida’s Okefenokee Wilderness Area), and are thus not included in the estimated value for visibility. We do not attempt to estimate WTP for these other areas, and simply note that they are omitted.

For the SAMI benefits transfer however, we use only the values associated with parks located in the Southeast visibility region. Exhibit 3-2 lists the states in the Chestnut and Rowe defined Southeast visibility region.

Exhibit 3-2 States in the Southeast Visibility Region

Visibility Region	States
Southeast	**Alabama**[*], Delaware, Florida, **Georgia**, **Kentucky**, Maryland, Mississippi, **North Carolina**, **South Carolina**, **Tennessee**, **Virginia**, **West Virginia**, Washington DC

[*] States in bold are located within the SAMI region.

3.1.2 The Residential Visibility Study, McClelland et al. (1991)

For the supplemental residential visibility analysis, the values associated with the McClelland et al. study are used in the benefits transfer. A mail survey was conducted in 1990 for this study, also called the Two Cities Study, in Chicago and Atlanta. Respondents were shown photographs illustrating three different air quality levels in their area and were told how many days per year each level currently occurs on average. Respondents were asked what their household would be willing to pay per year to have air quality on 25 of the poor days improve to the best air quality level shown. This amounted to about a 14 percent improvement in average annual visual range. Respondents were asked to say what percentage of their response was attributable to concern about health effects, soiling, visibility, or other air quality impact. On average, respondents attributed about 18% of their total WTP for changes in air quality to visibility.

3.2 The Benefits Transfer Method

In 1999, EPA proposed regulations to address the visibility degradation and impairment that occurs at Class I areas throughout the United States.[7] Collectively titled the Regional Haze Rule, the proposed regulations were intended to reduce levels of visibility impairing pollutants to benefit the public health and welfare. As part of the Regulatory Impact Analysis (RIA) for the Final Regional Haze Rule (U.S. EPA, 1999c), Abt Associates applied a method based on the approach developed by Smith et al. (1999) to estimate the monetary benefits of visibility improvements that are predicted to result, both in residential areas and in Class I recreational areas, as a result of that rule. This approach has been used to value policy-related changes in visibility in subsequent regulatory impact analyses for both the EPA and other interested stakeholders, as well.

The evolution of the visibility valuation methodology was a result of the move to a more economically sophisticated model. Below we present the utility model on which these analyses were based, and describe its specific application to the SAMI policy scenario.

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[7] The Clean Air Act defines Class I Federal areas as certain National Parks (over 6000 acres), wilderness areas (over 5000 acres), national memorial parks (over 5000 acres), and International Parks that were in existence as of August 1977. There are 156 of these areas protected under the existing visibility protection program established under the Clean Air Act.

3.2.1 The Basic Utility Model

To model the choice between consumption and environmental quality, we use a constant elasticity of substitution (CES) utility function, whose basic form is:

$$U(X,Q) = (aX^{r} + gQ^{r})^{1/r} \; , a > 0, g > 0, r \leq 1,$$

where X is “all consumption goods” and Q is a level of environmental quality that is exogenous to the household. The household budget constraint is

$$m - pX \geq 0 \; ,$$

where m is income, and p is the price of X. Without loss of generality, we set a = 1 and p =1. The only choice variable is X. The household maximizes utility by choosing X = m. The indirect utility function, V(m, Q; g , r), is therefore:

$$V(m,Q;g\,,r\,) = (m^{r} + gQ^{r})^{1/r} \; .$$

Evaluated at an initial level of environmental quality, Q_0, the (indirect) utility is therefore

$$V_0 = (m^{r} + gQ_0^{\,r})^{1/r} \; .$$

The amount the household would be willing to pay, WTP, for an increase of environmental quality from Q_0 to Q_1 satisfies:

$$V_1 = ((m - WTP)^{r} + gQ_1^{\,r})^{1/r} = V_0$$

so that

$$WTP = m - [m^{r} + g\,(Q_0^{\,r} - Q_1^{\,r})]^{1/r} \; .$$

The above treats environmental quality as if it were undifferentiated -- a measurable index of the “quality of the environment.” If, however, there are n “environmental goods,” Q=(Q_1, …, Q_n) , a CES utility function that is weakly separable in the partition {X, Q} would be

$$U(X,Q_1,\ldots,Q_n) = (X^{r} + f(Q)^{r})^{1/r} \; ,$$

where f(Q) is some function of Q_1, …, Q_n. WTP for an improvement in the quality of the jth environmental good would be

$$-\,[m^{r} + f(Q_{0,1},..,Q_{0,n})^{r} - f(Q_{0,1},..,Q_{0,j-1},Q_{1,j},Q_{0,j+1},..,Q_{0,n})^{r}\,]^{1/r} \; .$$

While this may be a reasonable way to model the tradeoffs people make between income and environmental quality, it is not a feasible approach for benefits analyses. To estimate the parameters of this model would require that each study that supplies an estimate of WTP for a particular environmental quality change and an estimate of income would also have to supply estimates of the levels of all the other environmental quality variables in the model. Such information is generally not available. We therefore use a simpler but more restrictive model in which the utility function is strongly separable in all its arguments. In this model, WTP for one environmental quality change is independent of the levels of the other components of environmental quality. With two environmental quality-related factors, Q and Z, the utility function is:

$$U(X,Q,Z) = (X^r + gQ^r + dZ^r)^{1/r}$$

$$WTP(\Delta Q) = m - [m^r + g(Q_0{}^r - Q_1{}^r)]^{1/r}$$

and

$$WTP(\Delta Z) = m - [m^r + d(Z_0{}^r - Z_1{}^r)]^{1/r} .$$

Because the recreational and residential WTP equations each consider environmental quality change as if it occurs before the other environmental quality change (for which the household may have a positive WTP), they are consistent with the estimates of WTP for environmental quality changes that are typically obtained from contingent valuation (CV) surveys. CV surveys tend to consider environmental quality improvements in isolation. When respondents are asked what they would be willing to pay for a given environmental quality improvement, they are generally not queried about or reminded of what they may already have paid (or what they may still be required to pay) for other environmental quality improvements. The WTP estimates derived from such studies are therefore likely to correspond to what people would be willing to pay for the environmental quality change of interest *if they have not already paid for other environmental quality changes.* Therefore, although there are now three parameters -- g, d, and r -- that must be estimated, if we have (or have estimated) a value for r, then the value of g can be estimated using a study of WTP for improvements in Q, and the value for d can be estimated using a study of WTP for improvements in Z.

3.2.2 An Adaptation of The Basic CES Utility Function to Value Improvements in Visibility in Residential Areas and in National Parks and Wilderness Areas

As we have noted before, the SAMI policy scenarios will produce two different broad categories of visibility changes: (1) changes in "residential" visibility – i.e., the visibility in and around the locations where people live; and (2) changes in "recreational" visibility at Class I areas. Recall that there is evidence that a household's WTP for improvements in visibility at a Class I area is influenced by whether or not it is in the same region as the household (Chestnut and Rowe, 1990). In general people appear to be willing to pay more for visibility improvements at parks and wilderness areas that are "in-region" than at those that are "out-of-region." This is plausible, because people are more likely to visit, be familiar with, and care about parks and wilderness areas in their own part of the country. We therefore model three categories of visibility change predicted to result from the SAMI policy scenarios: residential, "in-region" recreational, and "out-of-region" recreational. Only parks within the SAMI region (Southeast) will be considered. All households located within the eight SAMI states are considered "in-region," while all others are "out-of-region." The CES utility function of an in-region household in the nth residential area is:

$$U_{n,in} = (X^{r} + qZ_n^r + \sum_{k=1}^{N} g_k Q_k^r)^{1/r} \quad ,$$

The CES utility function of an out-of-region household in the jth residential area is:

$$U_{j,out} = (X^{r} + qZ_j^r + \sum_{k=1}^{N} d_k Q_k^r)^{1/r} \quad ,$$

$$q > 0, g_k > 0, \forall k, d_k > 0, \forall k, \;\; r \leq 1.$$

where

Z_n = the level of visibility in the nth in-region residential area;
Z_j = the level of visibility in the jth out-of-region residential area;
Q_k = the level of visibility at the kth Southeastern park;
N = the number of Class I areas in the Southeast region; and

q , the g 's and d 's are parameters of the utility function corresponding to the visibility levels at residential areas, and at in-region and out-of-region Class I areas, respectively. We assumed that the relationship between residential visibility and utility is the same everywhere, so there is only one residential visibility parameter, q . The household's WTP for any set of changes in the levels of visibility at in-region Class I areas and the household's residential area is:

$$WTP_n(\Delta Z, \Delta Q) = m - [m^r + q\,(Z_{0n}^r - Z_{1n}^r) + \sum_{k=1}^{N} g_k (Q_{0k}^r - Q_{1k}^r)]^{1/r} \quad .$$

The household's WTP for any set of changes in the levels of visibility at out-of-region Class I areas, and the household's residential area is:

$$WTP_j(\Delta Z, \Delta Q) = m - [m^r + q\,(Z_{0j}^r - Z_{1j}^r) + \sum_{k=1}^{N} d_k (Q_{0k}^r - Q_{1k}^r)]^{1/r} \quad .$$

The household's WTP for a single visibility improvement will depend on its order in the series of visibility improvements the household is valuing.[8] If it is the first visibility improvement to be valued, the household's WTP for it follows directly from the equations above. For example, an in-region household's WTP for an improvement in visibility at the first Southeastern park, from $Q_1 = Q_{01}$ to $Q_1 = Q_{11}$, is

$$WTP(\Delta Q_1) = m - [m^r + g_1(Q_{01}^r - Q_{11}^r)]^{1/r}$$

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[8] In general, WTP for an environmental quality change will decrease as disposable income decreases (unless rho = 1); therefore, if several environmental quality changes are to be valued, the WTP for a given change will be greater, the closer it is to being the first in the series.

if this is the first (or only) visibility change the household values.

3.2.3 The Measure of Visibility Improvement

In the above model, Q and Z are environmental “goods.” As the level of visibility increases, utility increases. The measure of visibility that is currently preferred by air quality scientists is the deciview (DV), which increases as visibility *decreases*. Deciview, in effect, is a measure of the *lack* of visibility. As deciviews increase, visibility, and therefore utility, decreases. The deciview, then, is a measure of an environmental “bad.”[9] One way to value decreases in environmental bads is to consider the “goods” with which they are associated, and to incorporate those goods into the utility function. If B denotes an environmental “bad,” and the environmental “good,” Q, is a function of B, F(B), then the environmental “bad” can be related to utility via the corresponding environmental “good”:

$$V = V(m, Q) = V(m, F(B))$$

The relationship between Q and B, F(B), is an empirical relationship that must be estimated.

In order to translate DV, a “bad,” into visual range (VR, in kilometers), a “good,” we used a relationship derived by Pitchford and Malm (1994) in which:

$$VR = 391 * e^{-0.1DV} .$$

This conversion is based on specific assumptions characterizing the “average” conditions of those factors, such as light angle, that affect visual range. To the extent that specific locations depart from the average conditions, the relationship will be an imperfect approximation.[10]

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[9] There are many examples of environmental “bads” – all types of pollution are environmental “bads.” Utility decreases, for example, as the concentration of particulate matter in the atmosphere increases.

[10] A potential problem with this approach arises if the function relating B and Q is not the same everywhere (i.e., if for a given value of B, the value of Q depends on other factors as well). Then there can be more than one value of the environmental good corresponding to any given value of the environmental bad, and it is not clear which value to use. This has been identified as a problem with translating deciviews into visual range. For a given deciview value, there can be many different visual ranges, depending on the other factors that affect visual range – such as light angle and altitude. We note here, however, that this problem is not unique to visibility, but is a general problem when trying to translate environmental “bads” into “goods.” For example, the relationship between survival probability (Q) and the ambient particulate matter air pollution (PM), an environmental “bad,” is generally taken to be of the form

$$Q = 1 - \alpha e^{\beta PM} .$$

where α denotes the mortality rate (or level) when there is no ambient PM (i.e., when PM=0). However, a is implicitly a function of all the factors other than PM that affect mortality. As these factors change (e.g., from one location to another), a will change (just as visual range changes as light angle changes). It is therefore possible to have many values of Q corresponding to a given value of PM, as the values of a vary.

3.2.4 Calibrating Model Parameters

The empirical evidence to date suggests that the income elasticity of WTP for visibility improvements is about 0.9 (Chestnut and Rowe, 1990). We found that, if m is much greater than WTP, the income elasticity of WTP derived from a CES utility function can be well approximated by (1- r). We therefore set r =0.1.

Our estimate of the parameter associated with residential visibility, q , is based on McClelland et al. (1991) where household WTP for improvements in residential visibility was elicited from respondents in Chicago and Atlanta. Mean household income in the study was $44,355 (1990$) and mean household WTP for a visibility improvement from a visual range of 28.3 km (Z_0) to a visual range of 32.2 km (Z_1) was $18.15. Solving for q in the WTP function, assuming that residential visibility is the first or only environmental quality change being valued,

$$\theta = \frac{(m - WTP)^{\rho} - m^{\rho}}{(Z_0^{\rho} - Z_1^{\rho})} .$$

Using r =0.1 and the values for m, WTP, and Z_0 and Z_1 from McClelland et al. (1993), q = 0.006638.

The parameters associated with in-region and out-of-region visibility improvements at National Parks and wilderness areas (the g 's and d 's) were calibrated to information collected in the Chestnut and Rowe study (1990), which estimated WTP (per household) for specific visibility changes at National Parks in three regions of the United States – both for households that are in-region (in the same region as the park) and for households that are out-of-region. Recall that the Chestnut and Rowe study asked study subjects what they would be willing to pay for each of three visibility improvements in the National Parks in a given region. Subjects were shown a map of the region, with dots indicating the locations of the parks in question. The WTP questions referred to the three visibility improvements in all the parks collectively; the survey did not ask subjects' WTP for these improvements in specific parks individually. Responses were categorized according to whether the respondents lived in the same region as the parks in question ("in-region" respondents) or in a different region ("out-of-region" respondents). The study estimated in-region and out-of-region WTP estimates for three regions, however, this analysis only uses the estimates associated with the Southeast.

While the Chestnut and Rowe study (1990) provides estimates of households' WTP for visibility improvements in National Parks, there are two significant gaps remaining between the information provided in that study and the information necessary for the benefits analysis. First, as noted above, the WTP responses were not park-specific, but only region-specific. Because visibility improvements vary from one park in a region to another, we needed to estimate the values of park-specific visibility changes. Second, not all Class I areas in each of the three regions considered in the study were included on the maps shown to study subjects. Because the focus of the study was primarily National Parks, most Class I wilderness areas were not included.

We will use Southeast region-specific parameters calibrated to the WTP estimates calculated by Chestnut and Rowe (1990) and presented in Exhibit 3-3.

Exhibit 3-3 Average Annual Household WTP for Visibility Changes at National Parks in The Southeast

Region	Change in Annual Average Visual Range	Mean Annual WTP ($2000) in-region	Mean Annual WTP ($2000) out-of-region
Southeast	25 km to 50 km	$87	$46
	25 km to 75 km	$109	$71
	25 km to 10 km	$99	$63

Source: Chestnut and Rowe (1990). The original WTP values given in Chestnut and Rowe (1990) were adjusted to average household income. To get the unadjusted values, shown here, we divided the adjusted WTP values by 0.7981. This is 1 - ((sample mean income - national mean income)/(sample mean income))*(income elasticity of WTP). Sample mean income = $41,441 ($1987); national mean income = $32,144 ($1987); income elasticity of WTP = 0.9. Sample mean income in $2000 = $62,818. Results above have been inflated to $2000 from $1990 using a CPI-U All factor of 1.3175.

Given a value of rho and estimates of m and the in-region WTP for a change from Q_0 to Q_1 in the Southeastern in-region area (SE):

$$g_{SE} = \frac{(m - WTP_{SE}^{in})^{r} - m^{r}}{(Q_{0SE}^{r} - Q_{1SE}^{r})}$$

and given a value of r and estimates of m and the out-of-region WTP for a change from Q_0 to Q_1 in the jth out-of-region area:

$$\delta_j = \frac{(m - WTP_j^{out})^{\rho} - m^{\rho}}{(Q_{0j}^{\rho} - Q_{1j}^{\rho})} \quad .$$

The Chestnut and Rowe study, however, considered *three* visibility changes in the Southeast region rather than just one. Although in theory all three visibility changes and the corresponding WTPs should be consistent with the same parameter value, in practice, of course, they are not. To derive a single g and a single d for the Southeast, we therefore chose those parameter estimates that minimized the sum of the squared percentage differences between our predicted WTPs (based on our parameter estimate) and the three Southeast-specific WTPs observed in the study. Denoting $\hat{g}$ as our estimate of g for the Southeast region based on all three visibility changes, we selected $\hat{g}$ to minimize:

$$\sum_{i=1}^{3}\left[\frac{WTP_i(\hat{g}) - WTP_i}{WTP_i}\right]^2$$

where WTP_i and $WTP_i(\hat{g})$ are the observed and the predicted WTPs for a change in visibility in the Southeast from $Q_0 = Q_{0i}$ to $Q_1 = Q_{1i}$, i=1, ..., 3. An analogous procedure was used to select an optimal d, for the Southeast region in the Chestnut and Rowe study.

The final step was to derive park- and wilderness area-specific parameter values from the corresponding Southeastern region values. First, to estimate Southeastern park- and wilderness area-specific WTPs, we apportioned the Southeastern WTP parameters (the g's and d's) between what Chestnut and Rowe referred to as the indicator park (in this case, Shenandoah) and the remaining Class I areas within the Southeastern region. Recall that the indicator park was the park that Chestnut and Rowe used to illustrate the hypothetical change in visibility conditions throughout the entire Southeastern region in the survey instrument. Because survey respondents may have attached a significant portion of their WTP response to the indicator park presented in the survey, Chestnut and Rowe asked a follow-up question to determine what share of a respondent's WTP was for the indicator park. For the Southeast, in-region respondents stated that, on average, 54% of their WTP was for the indicator park. Out-of-region respondents said that 38% of their WTP was for the indicator park. With these percentages in mind, we assigned Shenandoah 54% of the in-region WTP parameter (the g) and 38% of the out-of-region WTP parameter (the d).

The remaining portion of each of the WTP parameters was then allocated between the remaining Class I areas in the SAMI region based on a method that incorporates each area's share of the Southeast region's visitor-days (not including Shenandoah visitation).[11] This approach apportions the non-indicator park WTP parameter for Southeast visibility changes between the remaining Class I areas for which there was visitation rate information. Because we derived the Southeastern-specific parameter as a function of rho, m, and the Southeastern-specific WTP (based on the corresponding C&R visual ranges), we can similarly derive the Class I area in-region parameters using the following:[12]

$$g_{SE,k} = \left[\frac{(m - (\%Vis_k * WTP_{SE}^{in})^r - m^r}{(m - WTP_{SE}{}^{in})^r - m^r} \right] * \hat{g}_{SE}$$

where $\%Vis_k$ is equal to the percent distribution of visitation at each non-indicator Class I area, k. The calculations were repeated for apportioning the out-of-region WTP parameter. Exhibit 3-4 lists the Class I areas, their level of visitation, and their percent distribution of visitation at each area.

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[11] This allocation scheme implicitly assumes that the relative frequencies of visits to the remaining parks in the SAMI region *from everyone in the world* is a reasonable index of the relative WTP of an average household in or out of the Southeast region, despite the fact that only U.S. citizens are valuing visibility improvements at these parks. A possible problem with this allocation scheme is that the relative frequency of visits is an indicator of use value but not necessarily of nonuse value, which may be a substantial component of the household's total WTP for a visibility improvement at Class I areas.

[12] Because three different changes in visual range were considered in Chestnut and Rowe (1990), the selected value for gamma is only approximately equal to the right-hand side of its equation on page 19 because, although it is the optimal value designed to reproduce as closely as possible all three of the WTPs corresponding to the three visibility changes in the Chestnut and Rowe study, it will not exactly reproduce any of these WTPs. Analogously, the selected value for d_j is only approximately equal to the right-hand side of its equation also on page 19.

An alternative approach to allocating the WTP parameter amongst Class I areas located in the Southeast is to rely on the distribution of recreational visitation at all of the areas instead of first allocating the indicator park portion of WTP (identified in the Chestnut and Rowe study). We did not use this approach in the SAMI analysis, though it has been used in a number of regulatory analyses conducted by the EPA's Office of Air Quality Planning and Standards and reviewed by the Science Advisory Board. The issue of WTP apportionment is discussed more fully in Section 5.

Since the SAMI region is smaller in size than the Southeastern visibility region considered in the Chestnut and Rowe study, we do not include the value assigned to parks located outside of the SAMI region in the calculation of recreational visibility benefits. In other words, the portion of household WTP for visibility changes in the Southeast assigned to Mammoth Cave (KY) and Everglades (FL) National Parks is removed from the analysis. The remaining is allocated between the other 9 Class I areas.

3.2.5 Estimating Total Benefits for Policy-Specific Recreational and Residential Visibility Changes

Once the calibrated Class I area-specific WTP equation is specified, we can input the corresponding policy-specific visual ranges to calculate the total amount households, both in-region and out, are willing to pay for a given visibility change at Class I areas. Similarly, once the calibrated residential visibility WTP equation is specified, we can input the corresponding policy-specific visual ranges to calculate the total amount households are willing to pay for a given visibility change in the area where they live.

Exhibit 3-4 Distribution of Recreational Visitation at Southeastern Class I Areas (source: National Park Service 1997 Statistical Abstract)

Class I Area	Visitor Days (millions)	Percent Distribution
Everglades NP [a]	0.44	6.12%
Great Smoky NP	6.29	86.96%
Mammoth Cave NP	0.43	5.94%
Cohutta W [a]	0.03	0.40%
Dolly Sods W	0.01	0.10%
James River Face W	0.002	0.02%
Joyce Kilmer-Slickrock W	0.01	0.16%
Linville Gorge W	0.004	0.06%
Otter Creek W	0.003	0.05%
Shining Rock W	0.01	0.10%
Sipsey W	0.01	0.08%
Total	**7.24**	**100%**

[a] NP = National Park, W = Wilderness Area

3.3 Input Air Quality

The SAMI Socioeconomic Workgroup provided Abt Associates with the annual average visual air quality data necessary for the recreational visibility benefits analysis. The data, based on adjusted IMPROVE monitor data, was provided for the 10 Class I areas located within the SAMI region. We input this data directly into the valuation procedure. The Class I area-specific visual air quality used in the analysis is presented in Exhibit 3-5. Note that the changes in average visual ranges here are smaller than those evaluated in the Chestnut and Rowe study. This is discussed further in Section 5.

Exhibit 3-5 Visual Air Quality of Class I Areas by Year and Scenario

Year	Extinction (1/Mm)			Visual Range (miles)			Deciviews (dv)		
	A2	B1	B3	A2	B1	B3	A2	B1	B3
Great Smoky Mountains									
2010	100.3	86.9	63.6	24.2	28.0	38.2	23.1	21.6	18.5
2040	83.0	68.4	58.7	29.3	35.5	41.4	21.2	19.2	17.7
Shenandoah									
2010	105.7	98.2	85.4	23.0	24.7	28.4	23.6	22.8	21.4
2040	90.2	79.2	70.9	27.0	30.7	34.3	22.0	20.7	19.6
Cohutta									
2010	127.6	107.8	76.0	19.0	22.5	32.0	25.5	23.8	20.3
2040	103.1	81.0	66.4	23.6	30.0	36.6	23.3	20.9	18.9
Dolly Sods									
2010	239.0	217.7	183.3	10.2	11.2	13.3	31.7	30.8	29.1
2040	181.1	162.9	138.2	13.4	14.9	17.6	29.0	27.9	26.3
James River Face									
2010	174.7	158.1	121.2	13.9	15.4	20.0	28.6	27.6	25.0
2040	149.0	118.5	98.8	16.3	20.5	24.6	27.0	24.7	22.9
Joyce Kilmer-Slickrock									
2010	104.6	87.7	64.6	23.2	27.7	37.6	23.5	21.7	18.7
2040	87.0	70.7	59.6	27.9	34.4	40.8	21.6	19.6	17.8
Linville Gorge									
2010	190.8	158.2	111.6	12.7	15.4	21.8	29.5	27.6	24.1
2040	147.7	117.5	98.8	16.5	20.7	24.6	26.9	24.6	22.9
Otter Creek									
2010	241.4	220.2	184.0	10.1	11.0	13.2	31.8	30.9	29.1
2040	186.1	163.8	138.1	13.1	14.8	17.6	29.2	28.0	26.3
Shining Rock									
2010	126.2	108.0	77.3	19.3	22.5	31.4	25.3	23.8	20.4

Exhibit 3-5 Visual Air Quality of Class I Areas by Year and Scenario

Year	Extinction (1/Mm)			Visual Range (miles)			Deciviews (dv)		
	A2	B1	B3	A2	B1	B3	A2	B1	B3
2040	99.7	82.1	70.0	24.4	29.6	34.7	23.0	21.1	19.5
Sipsey									
2010	139.9	128.6	103.1	17.4	18.9	23.6	26.4	25.5	23.3
2040	118.9	100.8	91.3	20.4	24.1	26.6	24.8	23.1	22.1

For the supplemental residential visibility analysis, we were again provided data by the SAMI Socioeconomic Workgroup. We received URM model-based annual average extinction data for each of the three scenarios. Data was provided at the URM grid cell level; a nested grid structure comprised of an inner set of 12x12 km grid cell and an outer set of coarser 24x24 km grid cells. Because we value residential visibility based on visibility changes that occur where people live, we assigned grid cells to counties located within the SAMI region. A grid cell was assigned to a county if its centroid fell within a given county's boundary. The extinction values associated with the resulting set of grid cells within a county were then averaged to calculate a representative estimate of annual average extinction for that county.

3.4 Population Projections

Integral to the estimation of visibility benefits is an accurate estimate of future population projections. This section describes the method used to estimate county-level 2010 and 2040 populations.

The underlying data used to create county-level population projections is based on: (1) 1990 county-level population statistics for all U.S. counties collected by the U.S. Census (Wessex, 1994), and (2) future-year state and metropolitan area population estimates calculated by the Bureau of Economic Analysis and provided to Abt Associates by Maureen Mullen of E.H. Pechan and Associates. Growth factors are calculated using the BEA data and are applied to the 1990 county-level populations.

We calculate growth factors by taking the ratio of an estimated region's future population divided by the1990 population for that same area. Population estimates for the years 1990-93, 2000, 2005, 2010, 2015, 2025 and 2045 were collected by the BEA. A 2040 population estimate was not provided. Instead, 2040 state and metropolitan area populations were interpolated linearly using estimates from the years 2025 and 2045.

Growth factors are calculated for both urban areas and rural areas. An urban area is defined as a county that falls within a metropolitan area. This includes metropolitan statistical areas (MSAs), primary metropolitan statistical areas (PMSAs), consolidated metropolitan statistical areas (CMSAs), and New England county metropolitan areas (NECMAs), as defined by U.S. Census Bureau.[13] In this

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[13] The Census Bureau definitions are available at: http://www.census.gov/population/www/estimates/aboutmetro.html .

section, however, all metropolitan areas are referred to as MAs. A rural area is defined as a county that falls outside the defined metropolitan areas.

Urban areas grow according to the growth rate calculated for the particular metropolitan area within which they are located. This adjustment is very straightforward, simply taking the ratio of future year to base year metropolitan area population and multiplying that factor by the base year county population. The equation is:

$$FutureCountyPop_i = 1990CountyPop_i \cdot \frac{FutureMAPop_i}{1990\,MAPop_i}$$

where:

FutureCountyPop$_i$ = projected 2010 or 2040 population in urban county i
1990CountyPop$_i$ = actual 1990 population for county i
FutureMAPop$_i$ = projected 2010 or 2040 population in metropolitan area for county i
1990MAPop$_i$ = actual 1990 population for metropolitan area for county i.

Rural areas grow according to the growth rate calculated for the particular state within which they are located, adjusted to subtract out metropolitan area populations. Before the ratio of future year to base year state population is calculated, the population attributed to all metropolitan areas located within that state is subtracted from the future year and base year population totals. Once this metropolitan area adjustment has been made, the rural growth factor is multiplied by the base-year population in all non-MA counties to get future-year population projections.

To calculate the future year population, we use the following equaiton:

$$FutureCountyPop_i = 1990CountyPop_i \cdot \frac{(FutureStatePop_i - \sum FutureMAPop_i)}{(1990StatePop_i - \sum 1990\,MAPop_i)}$$

where:

FutureCountyPop$_i$ = projected 2010 or 2040 population in rural county i
1990CountyPop$_i$ = actual 1990 population for county i
FutureStatePop$_i$ = projected 2010 or 2040 population in state where county i is located
1990State Pop$_i$ = actual 1990 population for state where county i is located
ΣFutureMAPop$_i$ = projected 2010 or 2040 population in metropolitan areas located in state with county i
Σ1990MAPop$_i$ = actual 1990 population for metropolitan areas located in state with county i .

One problem that exists with this method is that many metropolitan areas cross state boundaries. To accurately subtract urban populations from state populations, we need to know the urban county populations for both 1990 and the future year. Using the county populations for 1990, we can estimate the portion of a particular metropolitan area's population that belongs to a given state. However, we do not have future year county population projections with which to apportion future year metropolitan area populations. To remedy this, we apply the same percent of the population a given county contributes to a metropolitan area in 1990 to 2010 and 2040 metropolitan areas when apportioning populations between states. Exhibits 3-6 and 3-7 present a summary of the projected future populations at the national, SAMI-region, and individual state level.

Exhibit 3-6 Population Forecasts

	2010	2040
Total U.S. Population [a]	297,628,851	367,499,681
SAMI Region Population	45,546,999	57,012,171

[a] 48 contiguous states and the District of Columbia.

Exhibit 3-7 Population Forecasts by SAMI Region State

	2010	2040
Alabama	4,659,277	5,716,195
Georgia	8,426,612	10,788,846
Kentucky	4,211,218	5,069,862
North Carolina	8,376,571	10,669,923
South Carolina	4,298,664	5,384,658
Tennessee	6,009,761	7,440,500
Virginia	7,638,744	9,670,311
West Virginia	1,926,151	2.271,876

4 Results

Results from the primary recreational visibility benefits analysis are presented in Exhibits 4-1 and 4-2. Exhibit 4-1 presents the national benefits for each control scenario in 2010 and 2040, as well as the portion of national benefits attributable to residents both within and outside of the SAMI region. Recreational visibility benefits, however, are based on the visibility change at each of the Class I areas, and therefore accrue at the park itself. Exhibit 4-2 presents the share of benefits associated with each park in the SAMI region.

As expected, the more stringent control scenario, B3, yields larger benefits. In 2010, benefits associated with the B3 scenario are over three times as large as those associated with the B1 scenario. In 2040, however, B3 is less than twice as large. Looking at the same control scenario across years we see that the B1 result in 2040 is almost twice as big as in 2010. The B3 results, on the other hand, are nearly equal between 2010 and 2040, with the 2040 result slightly higher. These observations suggest two trends: 1) visibility changes associated with the B1 scenario are increasing between 2010 and 2040, and 2) visibility changes associated with the B3 scenario are decreasing between 2010 and 2040 (keeping in mind that population, which is key to the valuation, increases over the same time period). For all parks except James River Face, Shenandoah, Dolly Sods and Otter Creek, this is the case.

Looking at the per-park recreational visibility benefits, we see that, across the scenarios, Great Smoky Mountains National Park (GSM) dominates the benefit totals. This is not surprising for two reasons: 1) GSM receives approximately 40% of the in-region WTP coefficient (used within the valuation procedure) and 54% of the out-of-region WTP coefficient; and 2) some of the largest visual air quality changes across all of the SAMI region Class I areas occur at GSM. Shenandoah National Park, the park generating the next-largest amount of benefits, has smaller visibility changes while receiving 54% and 38% of the in- and out-of-region WTP coefficients, respectively.

Results of the supplemental analysis of residential visibility benefits for the SAMI analysis are presented in Exhibit 4-3. Because the URM model, upon which the residential visibility data was based, has a nested grid structure, we present benefits associated with residential visibility throughout the entire modeling domain, as well as for only the 12x12km region.

To place estimated residential visibility benefits into context with modeled air quality, we have included in Appendix C maps of the baseline extinction, as well as the changes in extinction between each of the control scenarios and the baseline. Exhibit C-1 presents 2010 A2 scenario annual average extinction at the URM grid cell level. Exhibits C-2 and C-3 present the change in annual average extinction for the 2010 B1 and B3 scenarios, respectively. Exhibits C-4 through C-6 present the same information for the 2040 scenarios. Exhibits C-7 through C-12 present the same suite of maps in terms of annual average visual range.

Exhibit 4-1 Primary Analysis: Recreational Visibility Benefits [a]			
Year	**Control Scenario [a]**	**Region**	**Benefits [b] (Millions 2000$)**
2010	B1	National	$796
		SAMI Region	$155
		Non-SAMI Region	$641
	B3	National	$2,502
		SAMI Region	$482
		Non-SAMI Region	$2,021
2040	B1	National	$1,474
		SAMI Region	$301
		Non-SAMI Region	$1,173
	B3	National	$2,705
		SAMI Region	$555
		Non-SAMI Region	$2,150

[a] Total benefits in 2010 would be up to 27% higher than the totals reported in this table if an adjustment for income growth were applied. Likewise, in 2040 the total benefits would be up to 82% higher. These values were calculated by EPA for the Heavy Duty Diesel regulatory impact analysis, based in part on Chestnut and Rowe's income elasticity estimate of 0.9. The Science Advisory Board has concurred with the methodology for the calculation in its review of EPA's health-related analyses, but has been silent regarding the acceptability of these specific values used for assessing visibility benefits. While the concept of an income growth adjustment is reasonable, there are significant uncertainties concerning its value. The issues are discussed more fully in Section 5.

[b] Benefits are calculated based on the changes in visibility from future base-case to future control. For both control scenarios, benefits are based on visibility changes from the A2 scenario.

[c] Benefits may not sum to total due to rounding.

Exhibit 4-2 Primary Analysis: Recreational Visibility Benefits by Class I Area (Millions 2000$) [a]

Class I Area	2010		2040	
	B1	**B3**	**B1**	**B3**
Great Smoky Mountains	$561	$1,810	$952	$1,724
Shenandoah	$229	$673	$511	$961
Cohutta	$3.0	$9.3	$5.4	$9.9
Dolly Sods	$0.4	$1.1	$0.6	$1.4
James River Face	$0.1	$0.4	$0.3	$0.5
Joyce Kilmer-Slickrock	$1.3	$3.5	$1.9	$3.4
Linville Gorge	$0.5	$1.3	$0.7	$1.3
Otter Creek	$0.2	$0.5	$0.3	$0.8
Shining Rock	$0.7	$2.3	$1.1	$2.0
Sipsey	$0.3	$1.1	$0.7	$1.1

[a] Total benefits in 2010 would be up to 27% higher than the totals reported in this table if an adjustment for income growth were applied. Likewise, in 2040 the total benefits would be up to 82% higher. These values were calculated by EPA for the Heavy Duty Diesel regulatory impact analysis, based in part on Chestnut and Rowe's income elasticity estimate of 0.9. The Science Advisory Board has concurred with the methodology for the calculation in its review of EPA's health-related analyses, but has been silent regarding the acceptability of these specific values used for assessing visibility benefits. While the concept of an income growth adjustment is reasonable, there are significant uncertainties concerning its value. The issues are discussed more fully in Section 5.

Exhibit 4-3 Supplemental Analysis: Residential Visibility Benefits[a]

Year	**Control Scenario** [b]	**Benefits (Millions 2000$)**
Entire Modeling Domain [c]		
2010	B1	$224
	B3	$1,022
2040	B1	$791
	B3	$1,463
Inner Grid Cells Only (12x12)		
2010	B1	$137
	B3	$627
2040	B1	$492
	B3	$913

[a] Total benefits in 2010 would be up to 27% higher than the totals reported in this table if an adjustment for income growth were applied. Likewise, in 2040 the total benefits would be up to 82% higher. These values were calculated by EPA for the Heavy Duty Diesel regulatory impact analysis, based in part on Chestnut and Rowe's income elasticity estimate of 0.9. The Science Advisory Board has concurred with the methodology for the calculation in its review of EPA's health-related analyses, but has been silent regarding the acceptability of these specific values used for assessing visibility benefits. While the concept of an income growth adjustment is reasonable, there are significant uncertainties concerning its value. The issues are discussed more fully in Section 5.

[b] Benefits are calculated based on the changes in visibility from a future-year base case to future-year control. For both control scenarios, benefits are based on visibility changes from the future-year A2 scenario.

[c] The entire modeling domain consists of both 24x24 km grid cells and an inner grid of 12x12 km grid cells.

5 Qualitative Discussion of Uncertainty

The valuation methodology we use in this analysis yields the best available estimate of the magnitude of potential visibility benefits associated with the SAMI pollution control scenarios. There are, however, many issues associated with visibility valuation, both in general and specifically related to the visibility valuation studies used as the basis of the SAMI analysis, that contribute to the uncertainty of such an estimate. Specific issues may bias the results upward or downward leading to an overestimate or underestimate of the benefits. Often, however, the direction of bias arising from a specific issue can not be determined. This section attempts to identify and explain the most significant sources of uncertainty and, where possible, identify the likely direction of bias such uncertainties have on the estimate.

5.1 Uncertainty Associated With the Preservation Values Study (Chestnut and Rowe, 1990)

Though we use the WTP values estimated by Chestnut and Rowe (C&R) in the benefits transfer approach, a number of assumptions present within the study itself add to the uncertainty that surrounds our estimate of recreational visibility benefits. Unfortunately, the C&R study is also the only available study of general household demand for visibility improvements at national parks in the southeast; there are no additional studies available to investigate and/or reduce the uncertainty of relying on only one study.

Many of the uncertain characteristics associated with the C&R study are summarized in a draft report prepared by Decision Focus (DF) titled "A Review and Critique of the Applicability of Visibility Valuation Studies to a Navajo Power Plant BART Decision," (Decision Focus, Inc., 1990). In the DF report, however, many of the criticisms leveled at the study were in specific regard to its use in a regulatory decision about a power plant in Arizona. Some of the issues raised by DF are directly relevant to valuing visibility in the SAMI region, while others are not. We review the key issues raised by DF that are applicable to the SAMI analysis below.

"Pristine Premium"

The DF report criticized the Preservation Values Study because C&R, they believed, did not inform their respondents about the natural weather conditions that often affect visibility in each of the visibility regions. DF believed that this omission may have led respondents to overestimate their WTP amounts because they were not taking into account naturally occurring reductions in visibility due to the weather. In other words, DF believed that respondents were adding an additional "pristine premium" to their WTP responses. However, C&R presented the survey to respondents with photos that represented events that occur with different frequencies "on days without rain or natural fog," (Chestnut and Rowe, 1990, p. 3-6). To what extent this corrected for the "pristine premium," however, is unknown, though C&R report that pretests of the survey responses indicated that respondents understood this caveat.

Photograph Issues

The photographs that C&R used in the survey also raise issues regarding the uncertainty of the elicited WTP estimates. All of the photos in the C&R survey show noticeable (to a lay observer) differences in visibility conditions and depict the entire change in visibility considered in the survey. Differences between the photos, however, not only arise from the pollutant concentration present in the air, but also arise from the photos being taken at different times of the year (between June and

September), with different sun angles present (though all photos were taken at 3:00pm) and the coloration of the clear sky. Photo clarity is also obscured due to the inherent flaws associated with the reproduction process and the size of the images actually presented to the survey participants. These are all examples of the challenge that contingent valuation (CV) practitioners face in accurately depicting the environmental good in question to the respondents. Problems such as these increase the uncertainty of the results, though there is no way to know whether the photograph-induced uncertainty leads to an over- or underestimate of the benefits.

Another issue associated with the photographs is the critical dependence of the valuation function on the representation of the visibility conditions. The valuation function used for the SAMI analysis is derived from the C&R survey results of the WTP for a series of changes from one visibility condition to another. The survey participants were not provided with specific measurements of the air quality or visibility conditions of the photos; the alternative visibility conditions were entirely described by what was shown in the photos. The visibility valuation function was subsequently estimated using the visibility measurements (visual range) of the days shown in the photos. Any difference between the visibility conditions perceived by the respondents and the actual visibility conditions will introduce uncertainty into the estimation procedure. There is no perfect way to reproduce actual visibility conditions in any photographic medium. Color slides, projected under optimal conditions, are the most accurate method. Photographic prints, even with the best photographic duplication conditions, are inherently less accurate in depicting visibility conditions. The size of the photos presented to the respondents in the C&R survey were relatively small to accurately depict visibility changes in a scene with broad vistas. In particular, differences between visibility conditions are more difficult to detect when viewing photographic prints than with slides (personal communication, John Molenar, Air Resource Specialists). The apparent change in visibility conditions in the photographs presented in the C&R study were likely to be smaller than the actual differences used to estimate the valuation function. This will lead to a valuation function that underestimates the value of a change in visibility.

Non-Response Bias

The DF report also argues that C&R's elicited mean WTP values ignored the possibility of sample selection bias caused by non-responses to the survey. By assuming that non-respondents valued visibility the same as those people that did respond, DF claims that benefits would be overestimated. DF pointed out that by ignoring the characteristics of those people that did not respond to the survey, C&R implicitly assumed that those who did not respond to their questionnaire had an identical (or at least similar) WTP distribution to those that did respond. DF suggested that those survey participants that did not respond could likely have been people who were not interested in the survey topic and not likely to value improved visibility highly, if at all.

Potential non-response bias is a fundamental concern in any survey design, and was not ignored in the C&R analysis. A telephone follow-up survey of non-respondents was undertaken to examine the existence, direction and general magnitude of any potential bias affecting the WTP estimates. The results of the survey indicated that non-respondents contacted by telephone were similar to the original survey respondents in their importance rating for improving or preventing degradation in visibility at national parks, but were somewhat less likely to visit national parks in the selected regions and had lower household income than did the mail respondents (Chestnut and Rowe, 1990, p. 4-11). C&R concluded that the dollar WTP for the telephone respondents might be somewhat, though not dramatically, lower than for the mail respondents and the impact of non-response bias upon the sample-wide WTP estimate would be relatively small (Chestnut and Rowe, 1990, p. 4-11). C&R also warned that the results of the telephone follow-up survey should be interpreted cautiously, due to the much smaller sample size compared to the mail survey, unlisted numbers causing sampling problems, failure to contact all targeted names, refusals to participate, and necessary differences in the survey instrument (Chestnut and Rowe, 1990, p. 4-5). In the end, no adjustment for non-response bias was incorporated in the final estimates of WTP in the C&R study, nor in the SAMI visibility analysis. This leads to the conclusion that non-response bias may be inflating the WTP estimates used in the analysis, though C&R believe this bias to be very small.

Single Focus and Part-Whole Bias

Some concern has been raised as to the effect that part-whole bias, and the related concept of a single focus study, has on the magnitude of the WTP estimates elicited in the survey. Part-whole bias occurs when a respondent has difficulty separating the valuation for something that is a part of a larger issue. Separating the visibility component from the broader desire to protect National Parks may have a part-whole bias problem. In such a case, the respondents may be valuing a larger or smaller entity than the researcher intended (Mitchell and Carson, 1989). A single focus study is one that centers exclusively on a single issue, without reminding the respondents to place that issue in a larger context of potentially relevant issues. The C&R study has been criticized for being a “single focus” contingent valuation study, which could lead to upwardly biased estimates of the WTP estimates elicited in the survey.

The potential seriousness of a single focus bias in contingent valuation was explored by Kemp and Maxwell (1993). Kemp and Maxwell describe a CV survey conducted to estimate the public's WTP to avoid oil spills off the Alaska coast. In the single focus version of the study, the average WTP per household was $85. Under an alternative version of the survey, which asked respondents how much they would contribute to eight separate environmental programs, one of which was environmental protection from oil spills, the average WTP declined to $.29 per household.

The results of this study suggest that a part-whole bias could be significant in some CV applications, inflating estimates of WTP by over 250 times. We note, however, that the environmental resource in question in the Kemp and Maxwell study, the prevention of environmental damages due to oil spills, is a different resource than that considered in the C&R study, the future improvement in visibility from current conditions. The valuation of such different resources (environmental damages vs. improvements) in a CV survey context requires different considerations from respondents when estimating their WTP. This does not mean that part-whole bias does not exist in the C& R study, however, care should be taken when extrapolating the magnitude of the effect of part-whole bias from the Kemp and Maxwell study to the C&R study. In fact, because the C&R did not address the broader context of National Park protection as one specific issue among a range of environmental issues, nor did they address environmental protection as a choice among a range of other desirable social programs, the Kemp and Maxwell results suggest that an upward bias in the C&R estimates does exist.

For their part, C&R acknowledged that part-whole bias could enter into a respondent's WTP estimate in at least three ways:

1. Respondents fail to isolate visibility effects from other effects of air pollution, such as damage to vegetation and risks to human health;
2. Respondents fail to isolate visibility effects from other concerns about national parks, such as preservation of natural geologic features and prevention of water pollution;
3. Respondents fail to isolate visibility effects at the identified park(s) from similar effects at other park(s) or in other geographic areas (Chestnut and Rowe, 1990).

To minimize the potential impact in the survey design, C&R took a number of steps to test for the ability to control part-whole bias related to other air pollution impacts and other national park natural resource protection issues, and to correct for any such bias. They did this through a survey design that attempted to mitigate such impacts before the WTP question, paired with a follow-up question addressing the existence and significance of the problem (Chestnut and Rowe, 1990). For example, an introductory survey question asked respondents to consider several different types of potential pollution impacts to national park resources from human activities outside the parks, and whether they consider the prevention of each a low, medium, or high priority. One of the impacts listed was visibility degradation. The authors asked this question to get respondents to think about the range of potential threats to park resources before considering one specific threat, visibility degradation, in more detail (Chestnut and Rowe, 1990, p. 3-5).

In the WTP elicitation question itself, C&R included the following wording to account for part-whole bias:

> These questions concern only visibility at national parks in the [region in question] and assume there will be no change in visibility at national parks in other regions. Other households are being asked about visibility, human health and vegetation protection in urban areas and at national parks in other regions (Chestnut and Rowe, 1990, p. 3-7).

These comments, according to C&R, were designed to reduce the tendency to include values for other air pollution impacts and at other locations into the visibility value responses.

A follow-up question to the WTP elicitation questions asked respondents to consider their WTP responses and to say whether they were basically for the stated changes in visibility at national parks or whether the responses also reflected values for other needs. This was done to separate the respondent's value of other needs at national parks from their value of visibility protection at national parks in the region in question. The second part of the question asked respondents who stated that other concerns were also reflected in their WTP to then estimate what percentage of their WTP responses was really for visibility. According to C&R,

> Because the early sections in the questionnaire separated visibility from other issues, and clearly indicated that the WTP responses were to be only for the stated visibility changes at national parks, this question provides information to address whether extensive scenario development can, on its own, overcome potential part-whole bias for related resource protection issues, and provides data to correct for any such bias in the value calculations.

When C&R corrected for this part-whole bias in their study, it reduced the WTP values for the Grand Canyon by about 35% (Chestnut and Rowe, 1990, p. 4-106). Their part-whole correction for the south east region WTP values is included in the estimation of SAMI visibility values. Despite these precautions, the existence of part-whole bias within the stated C&R WTP estimates is possible, especially because C&R limited their consideration of the whole to only park issues. This could certainly lead to an overestimate of the benefits.

5.2 Uncertainty Associated With the Residential Visibility Study (McClelland et al., 1991)

Many of the same sources of uncertainty associated with the Chestnut and Rowe study exist within the McClelland study. These include issues with the quality of the photographs used, non-response, single focus, and part-whole bias. The authors took a number of steps to account for some of the biases, including corrections for both selection and part-whole bias. However, the WTP estimates derived from the McClelland study likely contain some degree of bias.

The EPA's Science Advisory Board recognized the uncertainty associated with the McClelland study, recommending that residential visibility benefits based on the McClelland study be placed in a "screening level" benefit category. To retain this distinction in the analysis, we consider estimates of residential visibility benefits associated with the SAMI emission control scenarios supplemental to the primary estimate of recreational visibility benefits. Furthermore, the SAB reported that since the study was completed, the authors recognized that the values found in the study likely contained a "warm glow" effect (U.S. EPA, 1999a). The authors also stated that they would have treated non-responses differently. Adjusting for both, the authors estimated that these corrections would reduce the WTP derived from the study by approximately 57%.

5.3 Uncertainty Associated with the Benefits Transfer

Benefits transfer is a benefits estimation technique that is, itself, inherently uncertain. Rather than discuss the many potential theoretical uncertainties with benefits transfer techniques in general, we highlight several key uncertainties and assumptions associated with the benefit transfer technique applied to the specific SAMI policy scenarios.

The Preference Calibration/CES Utility Function Approach

Recall from the methodology chapter that benefits for this analysis are based on a derived WTP function calibrated to parameters observed in the C&R study. This approach addresses two problems often associated with benefits transfer. The first problem stems from the fact that, as Smith et al. (1999) point out, "the procedures [used in benefit transfer] are not consistently linked to the concept we wish to measure. These procedures are not derived from a framework that establishes the connections between the [environmental] quality change to be valued, the quantity of use associated with the new and the old quality, and the economic values (total and marginal) people would place on the change" (pp. 10-11). Instead, "unit values" (values associated with each measurable unit of environmental quality change) are typically derived from a given study and applied to another benefit analysis.[14]

The second problem is that benefit transfer methods do not necessarily ensure that WTP will be related to household income in a way that is consistent with microeconomic theory. As a result, benefits analyses sometimes report monetary benefits that are implausibly large.

The "preference calibration" approach proposed by Smith et al. (1999) addresses both of these problems by assuming a "representative" preference (utility) function which incorporates the environmental quality measure. Recall that utility is the satisfaction a person receives from the set of goods they choose to consume. The representative preference function therefore calculates what combination of goods will give a person the greatest satisfaction, given the prices of the goods and the person's budget. Non-market "goods" like visibility improvements are included among the goods considered in the function. Using the characteristics of the input variables taken from the C&R study (mean survey respondent income, the elasticity of that income, and WTP values for the visibility changes

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[14] When applying C&R unit values to a simple point estimate of recreational visibility benefits, total benefits will be slightly larger than those estimated using the preference calibration approach.

in the pictures shown to respondents), WTP for any specified improvement in visibility can be derived from the utility function and is directly dependent on the relationship between WTP and the environmental quality changes observed in the original study.

This approach makes two critical assumptions that, if incorrect, introduces uncertainty to our estimate of visibility benefits. The first is that the preference (utility) function, and corresponding WTP function, is correct; that utility is maximized with some combination of income and level of environmental quality. The second assumption is that the value of the WTP parameters derived from the C&R study are applicable to the SAMI policy scenario. Once we make these two assumptions, the difference between the environmental quality change observed in the study and in the policy scenario is no longer relevant. The WTP function can accept the policy-related change in visibility, and is consistent with economic theories of utility and budget constraints. If either or both of these assumptions are wrong, it will certainly bias the resulting estimate of benefits. The magnitude and direction of bias, however, is impossible to estimate in the SAMI analysis.

Geographic/Demographic Comparisons

One reason why the assumptions above are plausible is that the geographical coverage is equivalent in both the study and the SAMI policy application. In this case, both the location and context of the environmental change match reasonably well between the original study and the policy application in the SAMI analysis. The southeastern visibility region used in the C&R study encompasses the SAMI region, including Shenandoah and Great Smoky Mountains National Parks; a better geographical match than many benefit transfers used in other policy analyses. In fact, the photos used to represent the Southeastern visibility region were taken from Shenandoah National Park.

Though the geographical coverage is equivalent, another potential source of uncertainty associated with the transfer is whether the sample population and the applied population are the same. C&R provided a number of demographic characteristics of their study sample, which we compare with similar statistics from each of the 8 SAMI states (Exhibit 5-1). It is important to note that, when comparing the demographic characteristics of C&R's study sample to those of the SAMI region states, C&R collected survey data from five states located throughout the country: Arizona, California, Missouri, New York, and Virginia. Unfortunately, C&R did not present the demographic characteristics of the Virginia sample population alone, which would have facilitated a more meaningful comparison with the SAMI states. However, it is useful to note that discrepancies between the sample and applied populations may lead to biases in the estimation of WTP, though the magnitude and direction are unknown.

In-Region and Out-of-Region Residents

The C&R study distinguished between the WTP value of respondents that lived in the same region as the indicator park used in the survey (Shenandoah National Park for Virginia residents, Yosemite National Park for California Residents and Grand Canyon National Park for Arizona residents) and the WTP value of respondents that lived outside of each region. We have taken this in-region and out-of-region distinction and applied it to the transfer of benefits based on the C&R visibility region classification; residents that live within the eight SAMI states value changes at SAMI Class I areas using an in-region WTP and all other residents of the United States value changes at those same areas using an out-of-region WTP. This approach ignores the possibility that it is a household's proximity to a park, and not the visibility region a household is located within, that drives the magnitude of a person's WTP for visibility improvements at a Class I area. For example, the residents of border states, such as households in Pennsylvania, may actually value changes at a Southeastern park, such as Shenandoah, more than residents of Georgia or Alabama. Alternatively, the approach does not take into account that households in Maryland and Virginia may care more about parks in Pennsylvania than parks in Georgia. To the extent that these considerations are true, the SAMI valuation approach may be biased, though in what direction is uncertain.

Exhibit 5-1 Comparison of C&R Respondents and SAMI Population Characteristics

	Persons Per [a] Household	Female Persons [a]	Median Age [a,b]	Mean Income (2000$) [c]
C&R Sample	2.77	41%	44	$62,818
Alabama	2.49	51.7%	35.8	$44,283
Georgia	2.65	50.8%	33.4	$53,293
Kentucky	2.47	51.1%	35.9	$42,879
North Carolina	2.49	51.0%	35.3	$49,346
South Carolina	2.53	51.4%	35.4	$47,336
Tennessee	2.48	51.3%	35.9	$47,555
Virginia	2.54	51.0%	35.7	$60,611
West Virginia	2.40	51.4%	38.9	$37,368

[a] SAMI state population data based on 2000 Census Data, U.S. Census Bureau, http://quickfacts.census.gov/qfd/.

[b] C&R presented median age for survey respondents aged 18+. Median age for the SAMI states is calculated based on all ages.

[c] C&R mean income adjusted to 2000$ from 1987$ using a CPI-U "All Items" factor of 1.516. SAMI state income data based on the U.S. Census Bureau's 2000 supplementary survey, http://www.census.gov/c2ss/www/Products/Profiles/2000/index.htm.

With that said, the survey sought to measure the WTP for an improvement in visibility across a class of parks, organized by region. Respondents that lived in each of the three visibility regions gave consistently higher WTP responses. Though the visibility boundaries may have been somewhat arbitrary, they did group populations around the set of parks under consideration in the survey. For the resource the survey was attempting to value, it does not seem unreasonable to transfer the in- and out-of-region values from the survey based on the C&R visibility regions.

Single Study Bias

Another concern about the recreational visibility benefits transfer used in the SAMI analysis is the methodology's reliance on a single study, C&R. In meta-analysis, it is common to use studies from different geographic regions to construct a "benefit transfer function" that can then be used to value benefits in a particular location. For the SAMI analysis, it would have been preferable to take advantage of information from a variety of studies to estimate WTP parameter values in the CES utility function approach. However, such studies do not exist. This obviously leads to uncertainties regarding the choice of inputs such as income elasticity (used to calculate rho and integral in the estimation of the WTP parameters). It also affects the calculation of the WTP parameters, gamma and delta, that are transferred from the study to the SAMI analysis, since rho is integral to the calculation. If, for instance, 0.9 is not the correct elasticity for valuing visibility improvements in the SAMI region, the results will be biased for two reasons: 1) the WTP parameters will have been estimated based on the incorrect rho, and 2) the use of the incorrect rho will persist into the WTP functions used to value the SAMI visual air quality changes. If the elasticity taken from the C&R study is incorrect, it is impossible to say what the magnitude or the direction of the bias might be.

Accuracy of Population Projections

Not necessarily related to the benefits transfer procedure itself, but integral to the estimation of benefits, is the accuracy of the population projections used in the analysis. For the SAMI analysis, we based our 2010 and 2040 population forecasts on Bureau of Economic Analysis projections. These projections were used to calculate growth factors that were then applied to 1990 Census Data. Now that 2000 Census Data is available, we can compare actual Census data against BEA-based 2000 projections as a check on the robustness of the population forecasts used in the analysis. Exhibit 5-2 presents 2000 Census data and projected 2000 data for each of the SAMI states. When compared side by side, the BEA-based projections are quite close to the 2000 Census figures; the state with the largest discrepancy, Georgia, is 93% of the Census number. Interestingly, all of the BEA-based populations, except West Virginia, underestimate the 2000 Census populations by a few percent (the BEA-based West Virginia estimate over-predicts population by about three percent). If this trend persisted into the 2010 and 2040 estimates, it is likely that there would be a downward bias in the benefits estimate; benefits would be underestimated. However, it is impossible to know if the future year projections are underestimates of the future population, and if they were, what the magnitude of such an underestimate would be.

Exhibit 5-2 2000 SAMI State Population Comparison

State	2000 Population - U.S. Census Bureau [a]	2000 Population - BEA Projections [b]	Ratio of BEA to U.S. Census
Alabama	4,447,100	4,383,000	0.99
Georgia	8,186,453	7,602,000	0.93
Kentucky	4,041,769	3,967,000	0.98
North Carolina	8,049,313	7,610,000	0.95
South Carolina	4,012,012	3,919,000	0.98
Tennessee	5,689,283	5,521,000	0.97
Virginia	7,078,515	6,953,000	0.98
West Virginia	1,808,344	1,858,344	1.03

[a] Source: U.S. Census Bureau, 2000 Census Data, http://quickfacts.census.gov/qfd/.

[b] Source: Maureen Mullen, E.H. Pechan and Associates, 2001.

Apportionment

The apportionment of the C&R-derived Southeastern WTP parameter amongst SAMI-region Class I areas was based on an approach that combined information gathered from the C&R study with visitation rates to the Southeastern Class I areas. C&R asked survey respondents to state how much of their WTP for Southeastern visibility improvements was meant for the indicator park shown in the survey (Shenandoah). Using this percentage, we assigned Shenandoah its portion of the WTP parameter and allocated the rest between the remaining SAMI Class I areas based on their share of visitation in the region. We chose this approach because of its geographic "fit" to the benefits transfer; the C&R study specifically considered visibility in an area that encompasses the SAMI region, and emphasized visibility at a key SAMI region Class I area, Shenandoah. We did not want to ignore this additional piece of region-specific information within the benefits transfer. However, this is not the only apportionment method we could have used.

Many other national visibility benefits analyses, conducted both for the U.S. EPA and other interested organizations, have used only Class I area visitation rates, instead of directly using the C&R survey's indicator park apportionment rate, to allocate a region's WTP among the Class I areas. As it turns out, the two approaches are often similar. Recall that C&R considered three broad visibility regions in their survey: California, the Southwest, and the Southeast. In California and the Southwest, the portion of survey respondents' WTP that they allocated to the indicator park (Yosemite and the Grand Canyon) turned out to be very close to the share of visitation at each of those parks (compared to total visitation at parks within a visibility region). This was not the case in the Southeast visibility region. In the survey, respondent's allocated from 38% to 54% of their stated WTP to the indicator park, Shenandoah. However, Shenandoah makes up only 11% of total visitation among Class I areas located within the Southeastern visibility region. It has been suggested that since the survey response for Virginian residents[15] do not match the visitation rates for Shenandoah, while visitation rates and survey responses do match in the other two visibility regions, that there is a problem with using this estimate. If the SAMI analysis had used the visitation-only approach to apportionment, benefits would be up to 16% larger.

The Measure of Visibility

Another potential source of uncertainty is the difference between the magnitude of annual mean visibility changes used in the C&R study and the magnitude of the anticipated annual mean changes in each of the SAMI control scenarios. The C&R study asked respondents to consider shifts in a 120-day distribution of summer visibility days. These distributions were translated into an annual mean measurement of visibility and presented to survey respondents in four representative photos. Respondents were asked what they would be willing to pay for a shift from one distribution of days to another. The smallest annual mean change considered in the Southeast was a 9 mile change in VR, the largest a 31 mile change. The mean changes in the SAMI analysis ranged from a 1 mile change in VR to a 14 mile change in VR.

Though the annual mean changes are smaller, the method used to estimate benefits for the SAMI analysis is able to estimate the value for any size visibility change. Smaller changes than those observed in the C&R survey clearly produce smaller benefits. Yet, because the changes in the C&R study and the changes in the SAMI analysis are not the same, there is uncertainty inherent in the scaling of WTP for visual air quality changes smaller than those observed in the original study.

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[15] Only residents in Arizona, Virginia, California, New York, and Missouri were included in the survey.

There is also uncertainty surrounding the use of an annual mean measure of visibility as a proxy for a shift in the distribution of visibility across days in a given year. Like the annual mean visibility C&R used in their study, the annual mean visibility values we use as the basis for the SAMI analysis are also built off of a distribution of days, each with a weight signifying that day's representative frequency in a year. Each annual average measure of visibility captures the implied distribution of visibility on days throughout the year of the given scenario (2010 and 2040 A2, B1, and B3). A change in annual average visibility (from the A2 scenario to either B1 or B3) therefore captures an implied shift in the annual distribution of visibility days.

Unlike the C&R study, however, the SAMI annual averages are calculated from a series of visibility event days that take place between February and August, instead of a summer season of 120 days. By comparing the nature of the SAMI visibility distributions to the implied distribution presented in the C&R study, we can get an idea of biases that are present when using annual mean visibility in the WTP function.

Though all 10 Class I areas each had a distribution of days from which an annual mean was built, we only look at the distributions for Great Smoky Mountains and Shenandoah National Parks, since these parks generated the majority of recreational visibility benefits. In both cases, the most noticeable trend is that, in terms of extinction, the largest changes in visual air quality occur on the summer days. However, the C&R study measured its visibility changes in terms of visual range. Converting the extinction data to visual range dampens this trend; visual range changes are not linear with respect to changes in extinction. An equal change in extinction when the starting visual air quality is good versus when it is bad does not equal a similar change in visual range; the visual range change is larger when the starting air quality is better. Because, in general, the starting air quality on the summer event days was much worse than on the remaining event days, the resulting summer air quality changes in visual range terms were, on average, smaller than those occurring on other event days.

Looking at the distribution of visual range changes for each park, we see that, for both parks, there are some large daily changes that occur outside of the summer season (considered between May and August for the purpose of comparability to the EPA's 120 day summer season). In the annual average weighting procedure, these non-summer changes increase the annual average effects more than if only the summer days were used. Because the annual averages used in the SAMI analysis are measuring a somewhat different distribution of days than the C&R analysis measured, there is likely to be an upward bias in the benefit estimates.

Thresholds

Significant concern also exists regarding whether or not it is appropriate to impose visibility thresholds on the value of visibility improvements. A threshold is the point below which a mental or physical stimulus cannot be perceived. A visibility threshold is therefore the point at which a person can no longer distinguish between a change from one visibility condition to another. Sisler (1996) characterized a change in light extinction of one deciview as "a small but perceptible scenic change under many circumstances." Deciviews are standardized for a reference distance in such a way that one deciview corresponds to a change of about 10 percent in available light. It is generally regarded that a change of less than 10 percent in the light extinction budget represents a measurable improvement in visibility, but may not be perceptible to the eye in many cases. Many of the annual average regional changes in visibility are less than one deciview (i.e. less than 10 percent of the light extinction budget), which some argue means the changes are less than perceptible. However, if many sources each contribute an imperceptible impact, the sum of individual changes should not be assumed to be zero because the sum of the impacts may be perceptible (and even significant). Instead, we assume 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.

At the Class I areas considered in this analysis, annual average visual air quality changes between the baseline and control scenarios for 2010 and 2040 rarely dip below 1dv. They do so only at Sipsey (0.8dv for the 2010 B1 scenario), Shenandoah (0.7dv for the 2010 B1 scenario), Otter Creek (0.9dv for the 2010 B1 scenario), and Dolly Sods (0.9dv for the 2010 B1 scenario). The rest of the annual average visibility changes fall above the accepted threshold of perceptibility, from a 1.0dv change (James River Face, 2010 B1 scenario) to a maximum change of 5.4dv (Linville Gorge, 2010 B3 scenario). The fact that most of the observed changes in visibility for this analysis are over 1dv is notable since these changes are in annual average terms; both smaller and larger changes in visibility are implied in the underlying distribution associated with the annual average.

The SAMI policy scenarios will likely not characterize all potential sources of air pollution reduction and, therefore, not characterize the total reduction in visibility that will occur in the SAMI region out to the years 2010 or 2040. If, alternatively, we assumed that the SAMI control scenarios captured all sources of pollution control in the SAMI out to the years 2010 or 2040, the cases where the annual change in visibility fell below the perceptibility threshold, or where the days in the underlying distribution fell below the perceptibility threshold, could bias the benefits estimate upward. Yet, the control scenarios are not meant to, and do not, capture all sources of pollution control. Therefore, we value these changes.

There is also contention regarding thresholds in terms of where visual air quality is or is not considered acceptable, the ramification being that even if a change is perceptible, it may not be worth valuing. Some contend that, in the SAMI region, we may need to value visibility changes when the visibility range improves beyond about 30 miles or the deciview becomes less than 24.5, based on the results of a recent pilot focus group. This would necessitate a closer examination of the daily distribution of air quality values that were used to calculate the annual mean SAMI estimates. The pilot focus group, conducted in a joint effort between EPA and Abt Associates, was undertaken to test both the session design and the survey questions in a larger effort to ascertain public opinion regarding the discernability and acceptability of differing levels of urban and residential visibility impairment (Abt Associates, 2001). Conducted in Washington, D.C., nine metro-area residents were chosen to view slides of the downtown Washington, D.C. mall area with the view obscured by varying levels of air pollution. The slides prominently displayed the Washington Monument in the foreground, with other familiar landmarks, including the Capitol Dome, in the background. The sight path to the furthest landmark in the scene (the Anacostia neighborhood) was fairly short - approximately 5 miles. We believe that because the nature of the resources in question are not the same, a close view of an urban landscape dotted with prominent landmarks versus Class I area landscape views with sight paths of hundreds of kilometers, any conclusion drawn from the pilot focus group and applied to the SAMI scenarios is not valid. However, as we stated above, when the daily distribution of visibility values that underlie each of the annual mean averages is examined, a number of changes between scenarios fall below the perceptibility threshold of 1 dv. Yet, because the air quality improvements measured by the SAMI scenarios are not meant to capture all sources of pollution control out to the years 2010 and 2040, and because air quality improvements are cumulative with other pollution control efforts, we believe that all improvements in visual air quality should be valued.

Income Growth Adjustment

Recent benefit analyses have included the impact of expected growth in real income on future year WTP-based benefit estimates. In fact, EPA's most recent regulatory impact analysis of the Heavy Duty Standards/Diesel Fuel Rule applied an income growth adjustment factor to its benefit estimates. The SAMI visibility analysis does not account for expected growth in real income in its primary calculation of recreational visibility, though the implications and uncertainties of doing so are addressed here.

Economic theory argues that WTP for most goods (such as environmental protection) will increase if real incomes increase. There is substantial empirical evidence that the income elasticity[16] of WTP for health risk reductions is positive, although there is uncertainty about its exact value (see Kleckner and Neumann, 1999, who present as examples Alberini et al., 1994; Mitchell and Carson, 1986; Loehman and Vo Hu De, 1982; Gerking et al., 1988; and Jones-Lee et al., 1985). We also expect that the WTP for improved visibility in Class I areas would increase with growth in income.

The effects of income changes on WTP estimates can influence benefit estimates in two different ways: 1) as changes that reflect estimates of income change in the affected population over time; and 2) as cross-sectional changes based on differences in income between study populations and the affected populations at a given point in time. Empirical evidence of the effect of income on WTP gathered to date is based on studies examining cross-sectional data, including the income elasticity of demand found in the C&R study. Income elasticity adjustments to better account for changes over time, therefore, will necessarily be based on potentially inappropriate data. However, these longitudinal adjustments based on cross-sectional income elasticities are meant as a proxy for how preferences and utility may change as projected overall average income increases.

Based on the income elasticity reported in the Chestnut and Rowe study of 0.9, the valuation of visibility improvements could be adjusted upward to account for projected growth in real U.S. income. The factors, as calculated by EPA and described in the Heavy Duty Diesel Standards RIA (U.S. EPA, 2000), would increase total benefits in 2010 up to 27% higher than the primary calculation of residential visibility benefits. Likewise, in 2040 the total benefits would be up to 82% higher.

Benefits At Recreational Areas Not Classified as Class I

There are a number of recreational areas that were not included in this analysis, but are located within the SAMI region, that will benefit from improved visibility associated with the SAMI emission control scenarios. These areas include federally managed lands not considered Class I areas, state and local parks, scenic parkways, and other areas where the scenic vista is important to the recreational area. Because we did not consider the value of visibility improvements at these other areas, the estimate of recreational visibility is likely to include a downward bias, leading to an underestimate of the total benefit associated with improved visibility throughout the SAMI region.

It is possible that Chestnut and Rowe captured some of this value, even though that study specifically asked respondents to only consider visibility at National Parks within a given visibility region. For this to have happened, however, survey respondents would have had to consider all parks within the

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[16] Income elasticity is a common economic measure equal to the percentage change in WTP for a one percent change in income.

visibility region, irrespective of their class designation, when providing their WTP for improvements in visibility. Similarly, the McClelland et al. study of residential visibility valuation may have captured a portion of the value residents place on visibility improvements at parks and other recreational areas enjoyed on a day-to-day basis in a residential setting. To the extent that the CR and McClelland studies captured survey respondents' WTP for improvements at non-Class I recreational areas, the underestimate of recreational visibility benefits may be small. However, because there are no studies relevant to the SAMI region that have looked at the value of visibility improvements at areas beyond National Parks or in a residential context, we are unable to know the magnitude of the potential underestimate of benefits.

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7 Appendix A: Example of Recreational and Residential Visibility WTP Calculations

Recreational Visibility Based on Chestnut and Rowe, 1990

Calculation of Park-Specific Gammas and Deltas

Exhibit A-1 Average Annual Household WTP for Visibility Changes at Southeastern Class I Areas

Change in Annual Average Visual Range	Mean Annual WTP (2000$) In-Region	Mean Annual WTP (2000$) Out-of-Region
25 km to 50 km	$87.49	$46.22
25 km to 75 km	$108.96	$70.99
25 km to 10 km	$99.05	$62.73

Source: Chestnut and Rowe, 1990. The original WTP values given in C&R, presented in 1990$, were adjusted to average household income. To get the unadjusted values, shown here, we divided the adjusted WTP values by 0.7981. This is 1 - ((sample mean income - national mean income)/(sample mean income))*(income elasticity of WTP). Sample mean income = $41,441 ($1987); national mean income = $32,144 ($1987); income elasticity of WTP = 0.9. A CPI-U "All Items" factor of 1.317521 was then applied to bring the WTP values to 2000$. Sample Mean income in 2000$ = $62,818.

For each visibility change, we calculate the in- and out-of-region WTP parameter. For the first visual range change:

$$g_{Southeast,In\,Region} = \frac{(\$62{,}818 - \$87.49)^{0.10} - \$62{,}818^{0.10}}{(25^{0.10} - 50^{0.10})} = 0.004248$$

and,

$$d_{Southeast,Outof\,Region} = \frac{(\$62{,}818 - \$46.22)^{0.10} - \$62{,}818^{0.10}}{(25^{0.10} - 50^{0.10})} = 0.002244$$

Recall that if income is much greater than WTP, the income elasticity of WTP derived from a CES utility function can be well approximated by (1-rho). C&R found income elasticity of WTP to be 0.9, therefore rho = 0.10. Repeat this calculation for the other two visual range changes.

To derive a single gamma and delta for the Southeast, we chose a WTP parameter estimate that minimizes the sum of the squared percentage differences (SSPD) between predicted WTPs (based on a single parameter estimate) and the three Southeast-specific WTPs observed in the study. The parameter estimates that minimized the SSPD were 0.003726 and 0.002270 for gamma and delta, respectively. The minimum SSPD was based on the following:

$$SSPD_{\min,gamma} = \left(\frac{(\$87.49 - \$76.73)}{\$87.49} \right)^2 + \left(\frac{(\$108.96 - \$124.10)}{\$108.96} \right)^2 + \left(\frac{(\$99.05 - \$93.60)}{\$99.05} \right)^2$$

and,

$$SSPD_{\min,delta} = \left(\frac{(\$46.22 - \$46.77)}{\$46.22} \right)^2 + \left(\frac{(\$70.99 - \$75.65)}{\$70.99} \right)^2 + \left(\frac{(\$62.73 - \$57.05)}{\$62.73} \right)^2$$

Once the optimal gamma and delta are calculated, we apportion them based on the apportionment method discussed in the text. The indicator park, Shenandoah, is allocated a percentage of each WTP parameter based on the percentage survey respondents said their stated WTP for the Southeast region was meant for the indicator park. This means that Shenandoah is allocated 54% of the in-region WTP parameter (the gamma) and 38% of the out-of-region WTP paramter (the delta). The Shenandoah WTP parameters are:

$$g_{Shenandoah} = 0.003726 * 0.54 = 0.002012$$

and,

$$d_{Shenandoah} = 0.002270 * 0.38 = 0.000863.$$

The rest of each WTP parameter is apportioned between the remaining Class I areas located within the Southeast region based on a method that incorporates each area's rate of visitation. Using Great Smoky Mountains National Park as an example, the amount of each WTP parameter allotted to the park is calculated as follows:

$$g_{GreatSmokyMountains} = \frac{(\$62{,}818 - (0.87 * \$87.49))^{0.10} - \$62{,}818^{0.10}}{(\$62{,}818 - \$87.49)^{0.10} - \$62{,}818^{0.10}} * 0.001714 = 0.001490$$

and,

$$d_{GreatSmokyMountains} = \frac{(\$62{,}818 - (0.87 * \$46.22)^{0.10} - \$62{,}818^{0.10}}{(\$62{,}818 - \$46.22)^{0.10} - \$62{,}818^{0.10}} * 0.001407 = 0.001224$$

where,

0.87 = percent of total visitation among Class I areas located in the Southeast (excluding Shenandoah) that is attributable to Great Smoky Mountains National Park,
0.001714 = remaining portion of the in-region WTP parameter, and
0.001407 = remaining portion of the out-of-region WTP parameter.

Note that in the adjustment equations above, the WTP values associated with a visual range change from 25 to 50 are used. The adjustment factors would be approximately the same if the other WTP values were used.

Calculation of WTP

Now that the WTP parameters are calculated, they can be entered into the household WTP equation for SAMI-specific changes in visual air quality at each of the Southeastern Class I areas. To do this, we must first calculate the portion of the WTP equation that is specific to each Class I area and their corresponding changes in air quality. Recall that the WTP equation for changes in recreational visibility is specified as

$$WTP_n(\Delta Q) = m - [m^r + \sum_{k=1}^{N} g_k (Q_{0k}^r - Q_{1k}^r)]^{1/r}$$

for residents whose households are located within the SAMI region, and

$$WTP_j(\Delta Q) = m - [m^r + \sum_{k=1}^{N} d_k (Q_{0k}^r - Q_{1k}^r)]^{1/r}$$

for households located outside of the SAMI region.

Again, using Great Smoky Mountains National Park as an example, we can plug in the visual air quality changes to calculate the WTP component of the equation. Using the air quality changes from the 2040 A2 to B3 scenario, we get:

$$g_{GreatSmokyMountains}(Q_{A2,2040}^r - Q_{B3,2040}^r) = 0.001490 * (47.11_{km}^{0.10} - 66.61_{km}^{0.10}) = -7.72E-05$$

for in-region residents and,

$$d_{GreatSmokyMountains}(Q_{A2,2040}^r - Q_{B3,2040}^r) = 0.001224 * (47.11_{km}^{0.10} - 66.61_{km}^{0.10}) = -6.34E-05$$

for out-of-region residents. These calculations are repeated for each of the Class I areas located within the SAMI region.

To calculate county-specific WTP for changes in air quality at each of the Class I areas within the SAMI region, we input county-specific income into the equation and multiply the resulting WTP by the county-specific household population. Future year population estimates are based on projections provided by the Bureau of Economic Analysis. The method is described in the main text of this report. Household size is assumed to be 2.68 for all counties. County specific income is calculated from national mean income (in 2000, $57,045) by taking the ratio of national mean income from 1990 to county-level income (measured by the Census) in 1990 and applying that ratio to the 2000 mean income. The WTP calculation below uses information for Autauga County, AL as an example.

Because Autauga, AL is located within the SAMI region, we use the in-region equation to calculate WTP. Plugging in the county-specific household population, income, and the Great Smoky Mountain component of the WTP equation (calculated above), we get the following:

$$WTP_{Autauga,AL}(\Delta Q_{GreatSmoky,2040\,A2-B3}) = (\$47{,}764 - [\$47{,}764^{0.10} - 7.72^{E-05}]^{1/0.10}) = \$12.55$$

$$HHWTP_{Autauga\,,AL}(\Delta Q_{GreatSmoky,2040\,A2-B3}) = \$12.55 * 19{,}265 = \$241{,}870.$$

National-level benefits related to visual air quality changes at Great Smoky Mountains would then be the sum of WTP values across all in- and out-of-region counties in the United States (48 states and D.C.). To calculate national-level benefits attributed to visibility changes at all SAMI-region parks, we would add the park-specific WTP components to the above equation and sum across counties.

Residential Visibility Based on McClelland et al., 1991

Calculation of Theta

Our estimate of the parameter associated with residential visibility, q , is based on McClelland et al. (1991) where household WTP for improvements in residential visibility was elicited from respondents in Chicago and Atlanta. Mean household income in the study was $44,355 (1990$) and mean household WTP for a visibility improvement from a visual range of 28.3 km (Z_0) to a visual range of 32.2 km (Z_1) was $18.15. Solving for q in the WTP function, assuming that residential visibility is the first or only environmental quality change being valued,

$$q = \frac{(\$44{,}355 - \$18.15)^{0.10} - \$44{,}355^{0.10}}{(28.3_{km}^{0.10} - 32.2_{km}^{0.10})} = 0.006638.$$

Calculation of WTP

We can now enter the residential visibility WTP parameter into the household WTP equation. Similar to the equation for recreational visibility, the residential WTP equation is specified as:

$$WTP(\Delta Z) = m - [m^r + q(Z_0^r - Z_1^r)]^{1/r} \quad .$$

Using residential visibility changes in Autauga County, AL as an example, we can calculate the WTP of residents for changes in residential visibility from the 2040 SAMI scenario A2 to B3. County-specific inputs, such as population, household size, and income are the same as those used in the recreational visibility WTP calculation. Plugging in each of these variables, as well as the residential visibility WTP parameter, we get:

$$WTP_{Autauga\,,AL}(\Delta Z_{2040\,A2\,to\,B3}) = \$47{,}764 - [\$47{,}764^{0.10} + 0.006638(37.81_{km}^{0.10} - 50.67_{km}^{0.10})]^{1/0.10} = \$46.09$$

$$HHWTP_{Autauga\,,AL}(\Delta Z_{2040\,A2-B3}) = \$46.09 * 19{,}265 = \$887{,}889.$$

8 Appendix B: Unaddressed Peer Review Comments

Where possible, we have addressed all of the comments made by the peer reviewers. However, we were unable to address a number of specific requests to quantify uncertainties, adjust the primary estimate of benefits, and provide a range of estimates due to the directives given to us by the SAMI Operations Committee/Governing committee. The directive stated,

> Comments dealing with uncertainties in the visibility analysis will be discussed in a separate chapter on uncertainty. In general, uncertainties will be discussed in qualitative terms. The discussion will indicate the nature of any change in the outcome of the analysis suggested by the uncertainty topic. Where numbers are useful in describing the nature of the uncertainties, practical under the existing scope of the contract, numbers will be furnished, provided such action is consistent with the Operations Committee/Governing Body directive that no SEWG work should be redone. It is understood that uncertainty numbers will not be used to modify the central method...

Instead, we have attempted to provide an idea of the nature and scope of the uncertainties present in the analysis, and have used numbers when possible. Below is a list of comments, by peer reviewer, that were not addressed in the main text.

Carol Mansfield, RTI International

Comment - "Provide a diagram or other discussion of the expected difference between the utility function approach and just transferring a point estimate," and similarly, "Estimate the visibility benefits using a simple point estimate to provide some sense of how much larger or smaller this number is than the benefits derived from the utility function approach."

Abt Response - Unfortunately, there is no simple comparison between the utility function approach and a point estimate approach because all of the divergent input variables including regional differences in air quality, income, population location, etc. The finer points of such a comparison, and for that matter the process of calculating a point estimate of SAMI visibility benefits, would have required a discussion and presentation of what we referred to as "Methodology 1" in the methods document. We were directed not to calculate benefits based on this method by the SEWG. Also, the calculation of point estimates would have gone against the response to comments directive. We did mention in the uncertainty discussion that a point estimate would yield a higher estimate of benefits, however.

Comment - "Provide some sensitivity analysis for other values of gamma and rho."

Abt Response - We commented on the direction of the effect of other gamma and rho values on the central estimate, though calculating them outright would contradict the above directive.

Ronald E. Wyzga, EPRI

Comment - "Methods and assumptions to address this problem [of the use of annual averages versus the number of days with meaningful visibility changes] would provide range estimates."

Abt Response - The provision of range estimates is not allowed by the above directive, but we have addressed the issue in the uncertainty section.

Comment - “Given that the differences could be as great as 250-fold this issue [of part-whole bias] deserves more attention than inclusion in a list of uncertainties. I would urge the Contractors to derive some quantitative estimates that address this issue.”

Abt Response - Again, according to the directive, we included discussion of the magnitude of the potential bias, but did not go as far as to recalculate WTP.

Comment - “I would like to see some of the uncertainties present incorporated into these tables.”

Abt Response - This is not in the scope of the directive.

9 Appendix C: Visibility Modeling Maps

Exhibit C-1
Annual Average Extinction
2010 Scenario A2

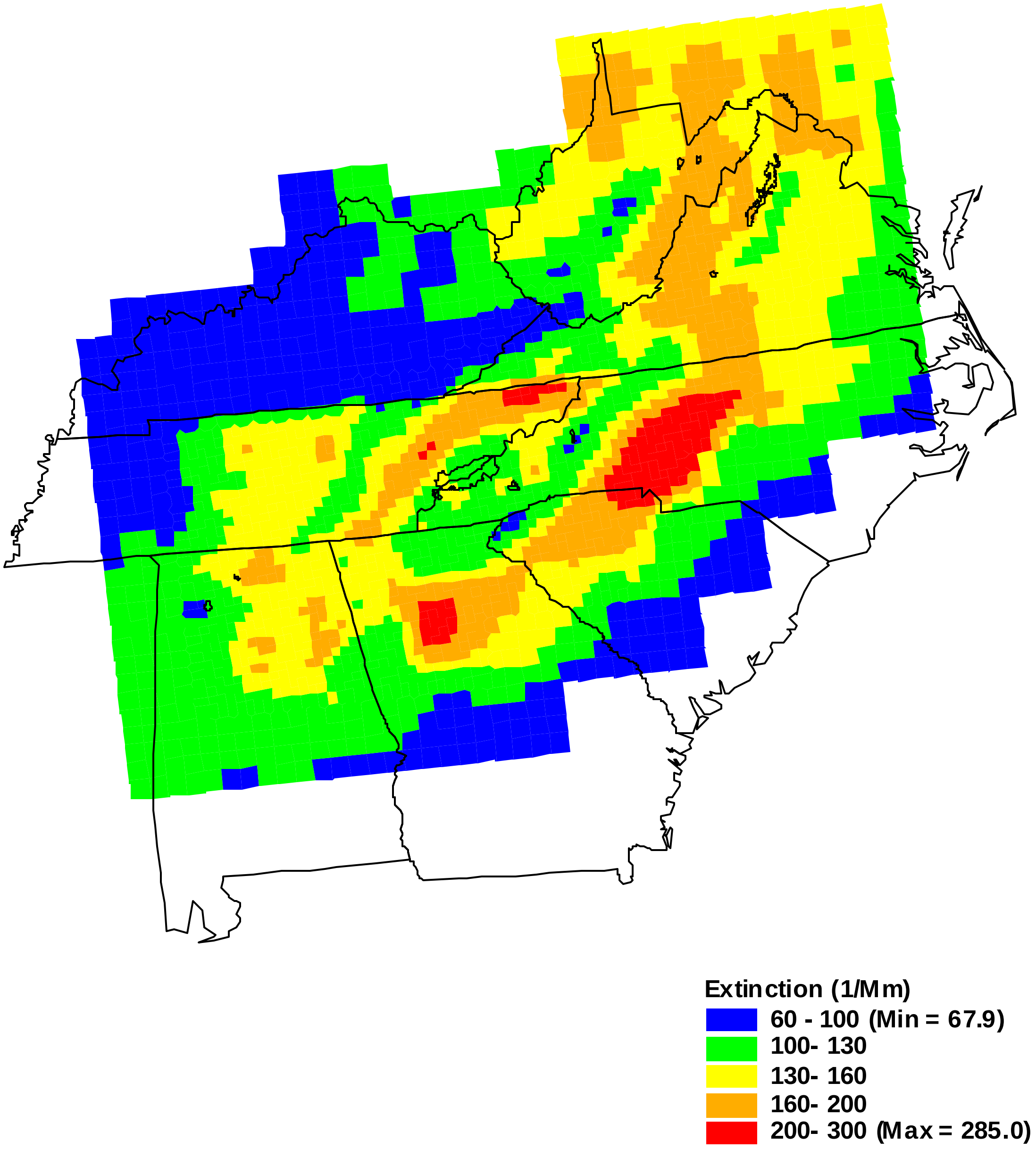

Exhibit C-2
Change in Annual Average Extinction
2010 Scenario A2 Minus Scenario B1

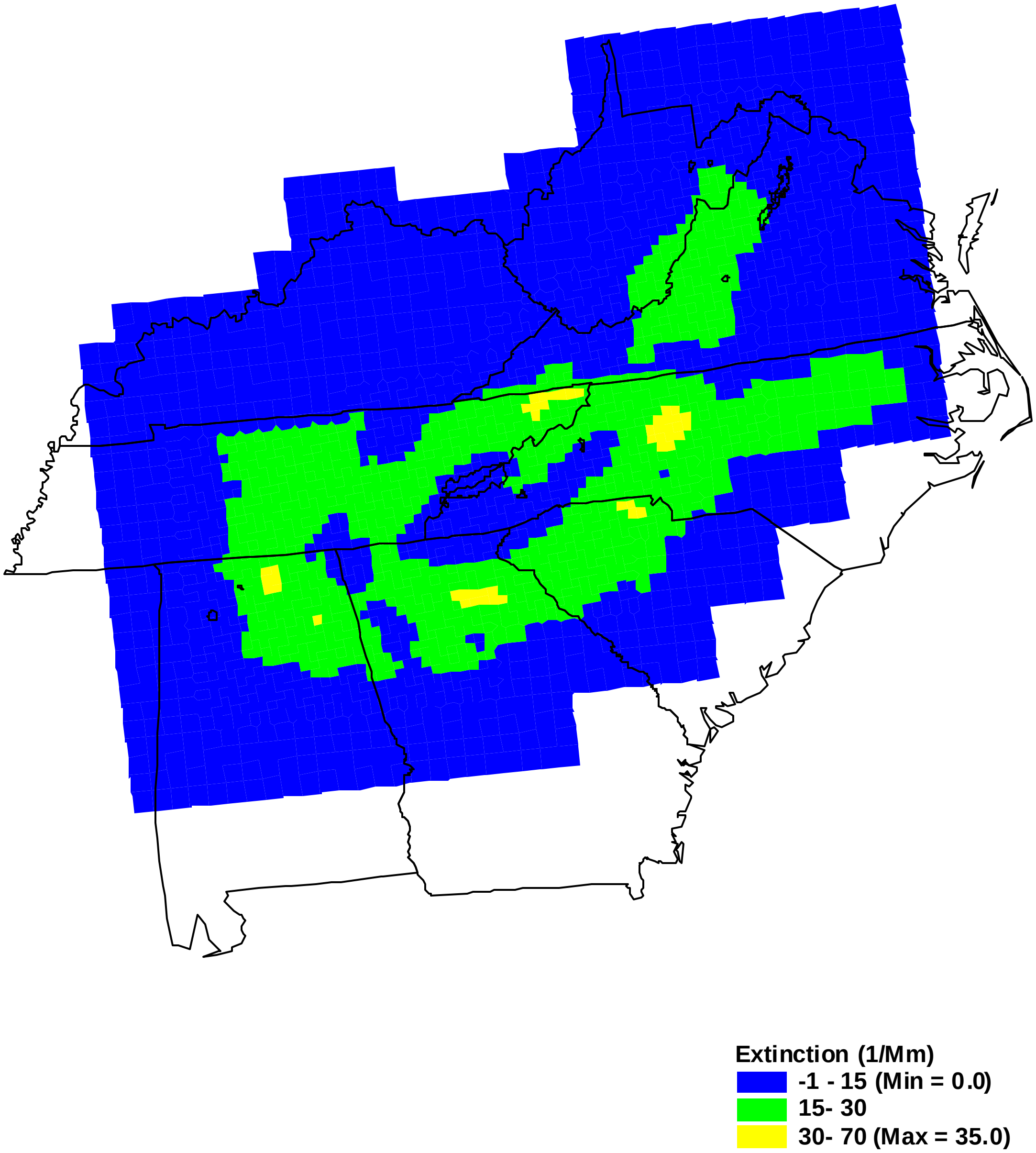

Exhibit C-3

Change in Annual Average Extinction
2010 Scenario A2 Minus Scenario B3

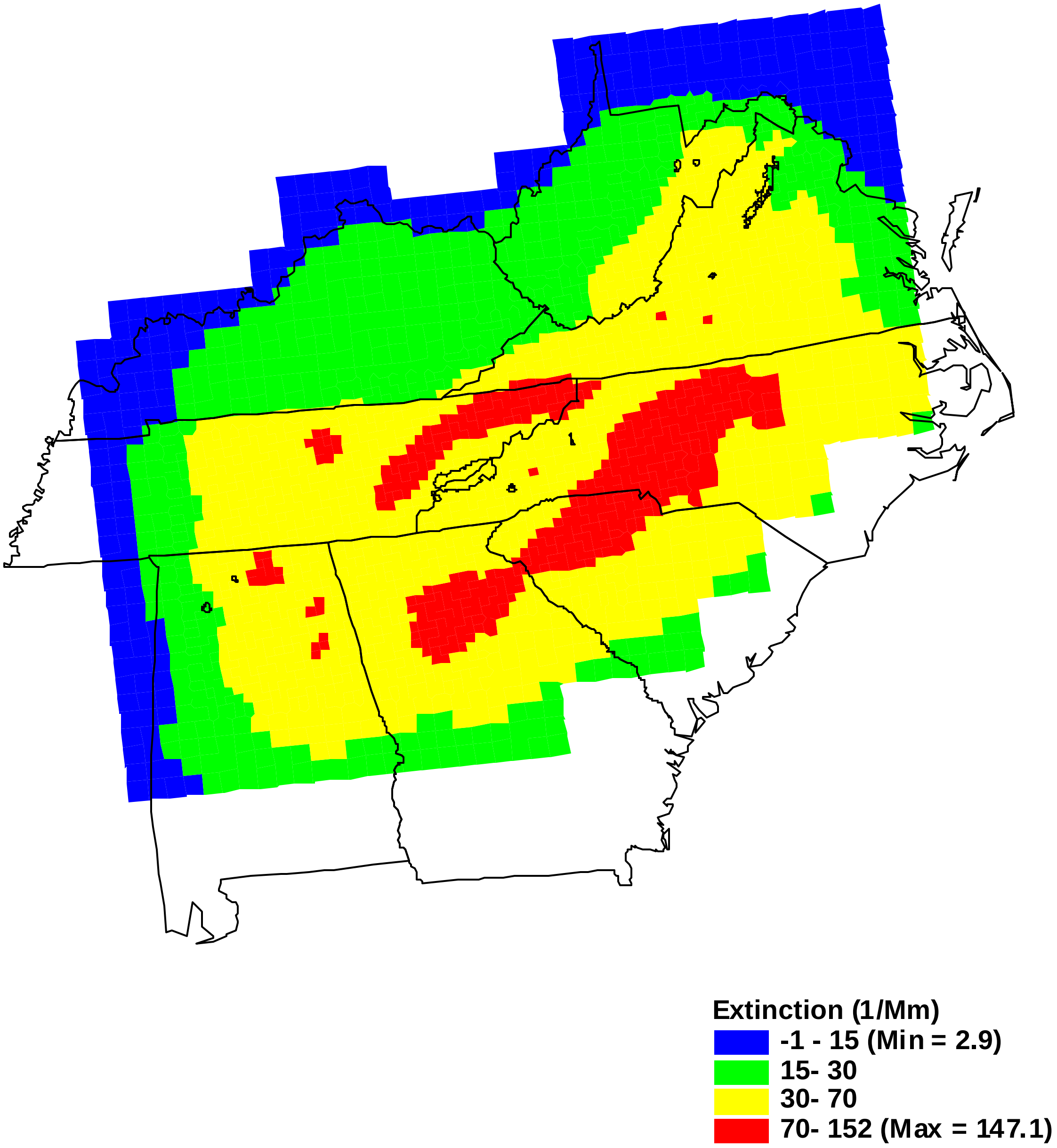

Exhibit C-4
Annual Average Extinction
2040 Scenario A2

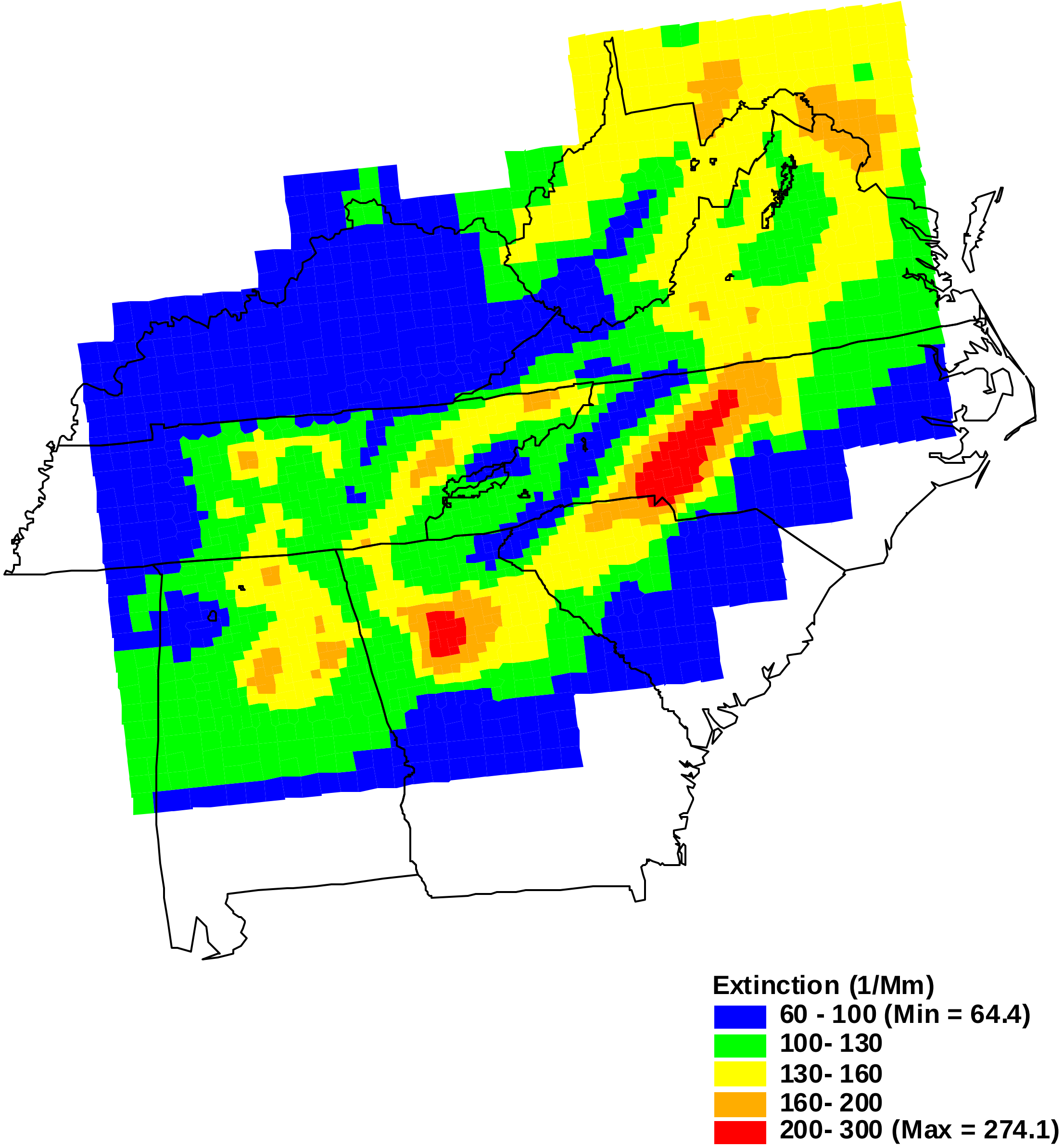

Exhibit C-5
Change in Annual Average Extinction
2040 Scenario A2 Minus Scenario B1

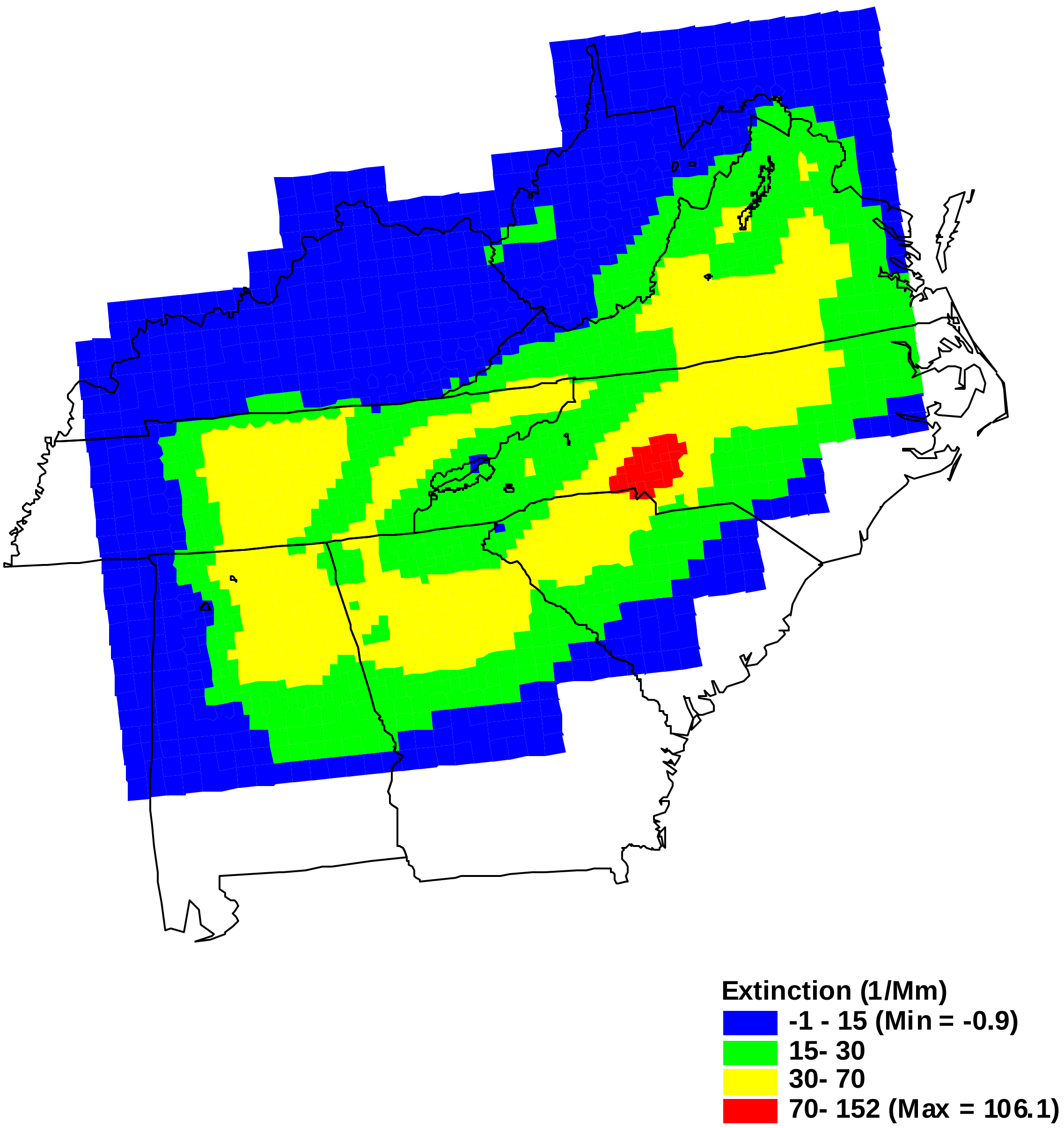

Exhibit C-6
Change in Annual Average Extinction
2040 Scenario A2 Minus Scenario B3

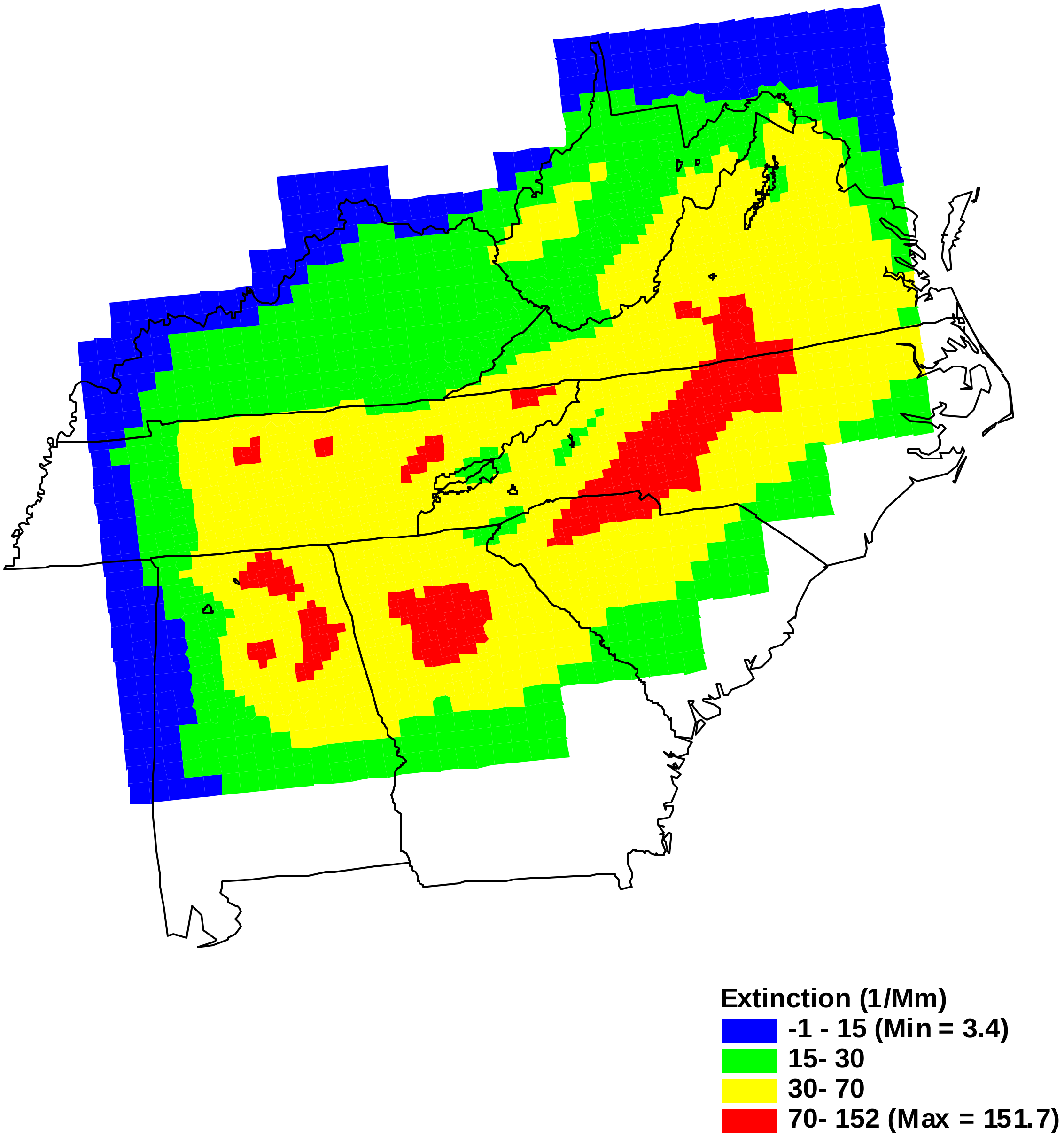

Exhibit C-7
Annual Average Visual Range
2010 Scenario A2

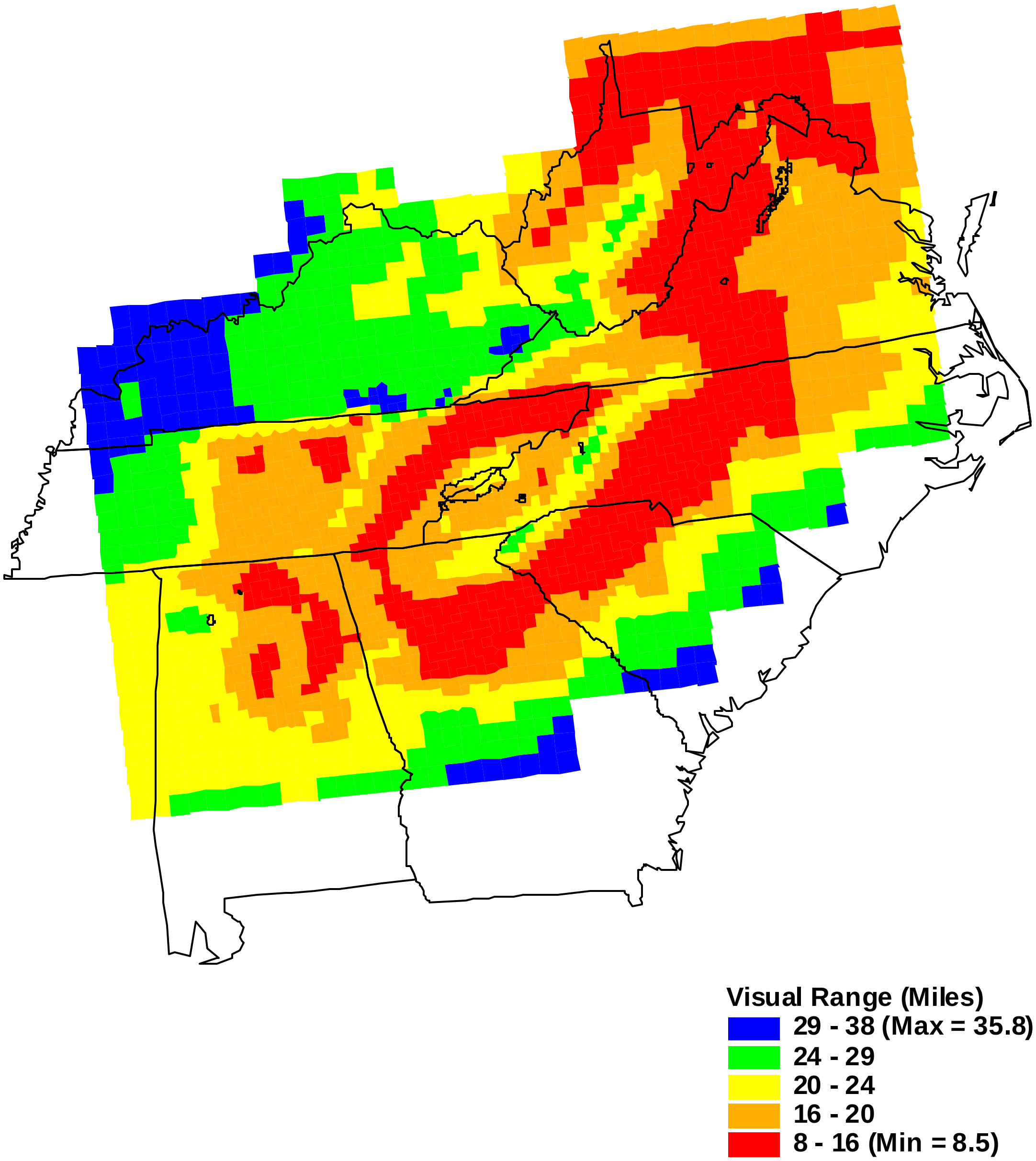

Exhibit C-8
Change in Annual Average Visual Range
2010 Scenario B1 Minus Scenario A2

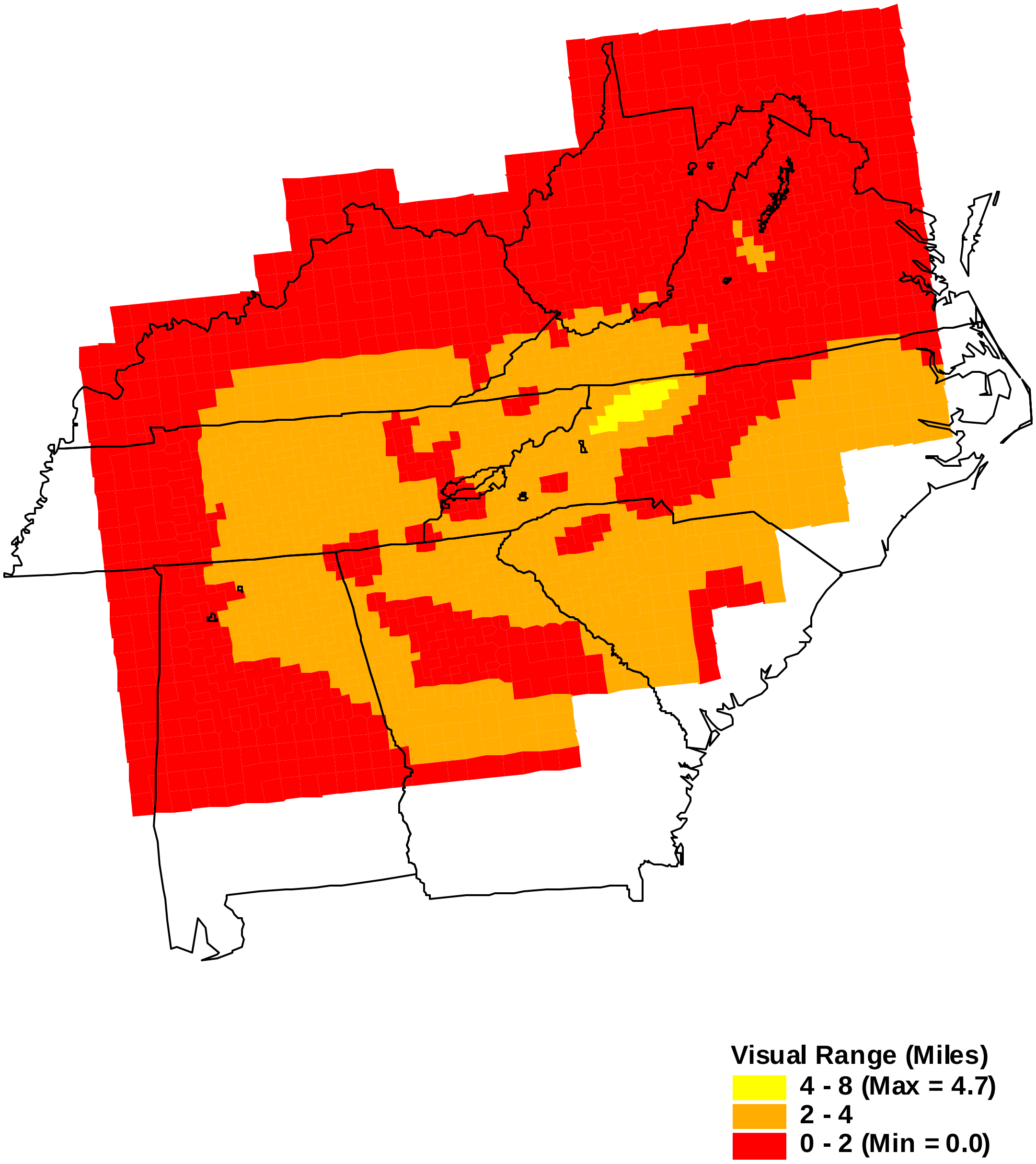

Exhibit C-9
Change in Annual Average Visual Range
2010 Scenario B3 Minus Scenario A2

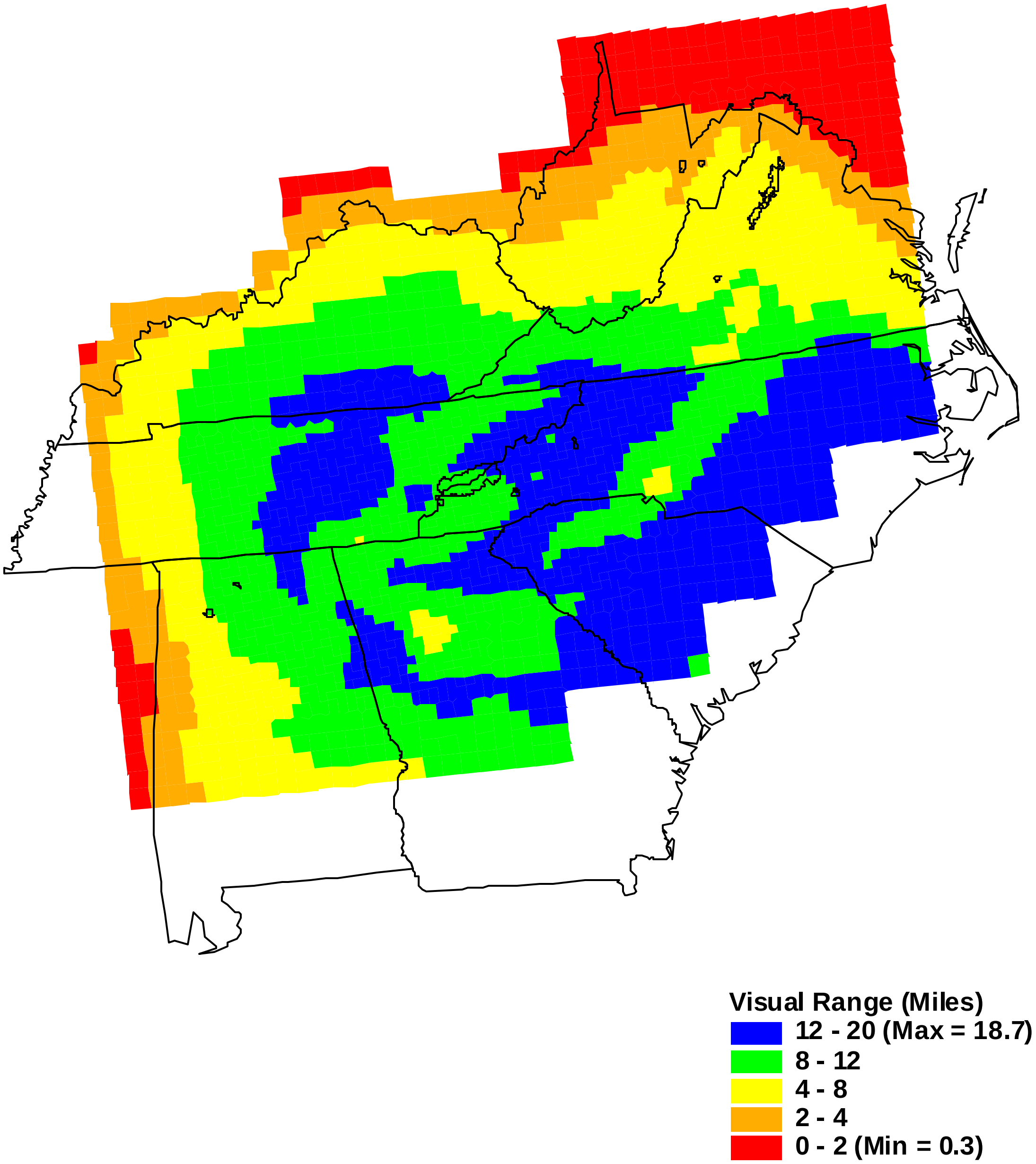

Exhibit C-10
Annual Average Visual Range
2040 Scenario A2

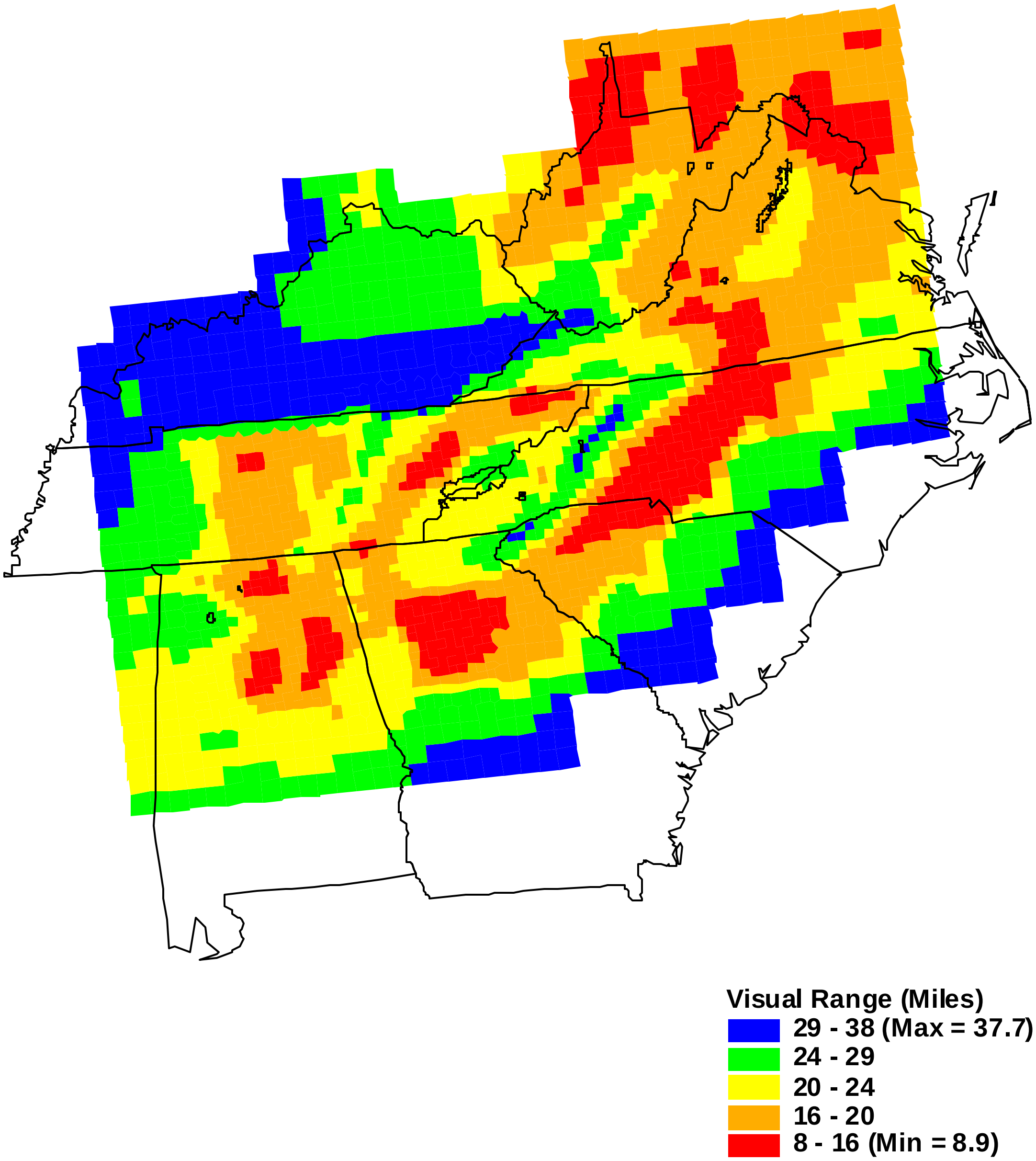

Exhibit C-11
Change in Annual Average Visual Range
2040 Scenario B1 Minus Scenario A2

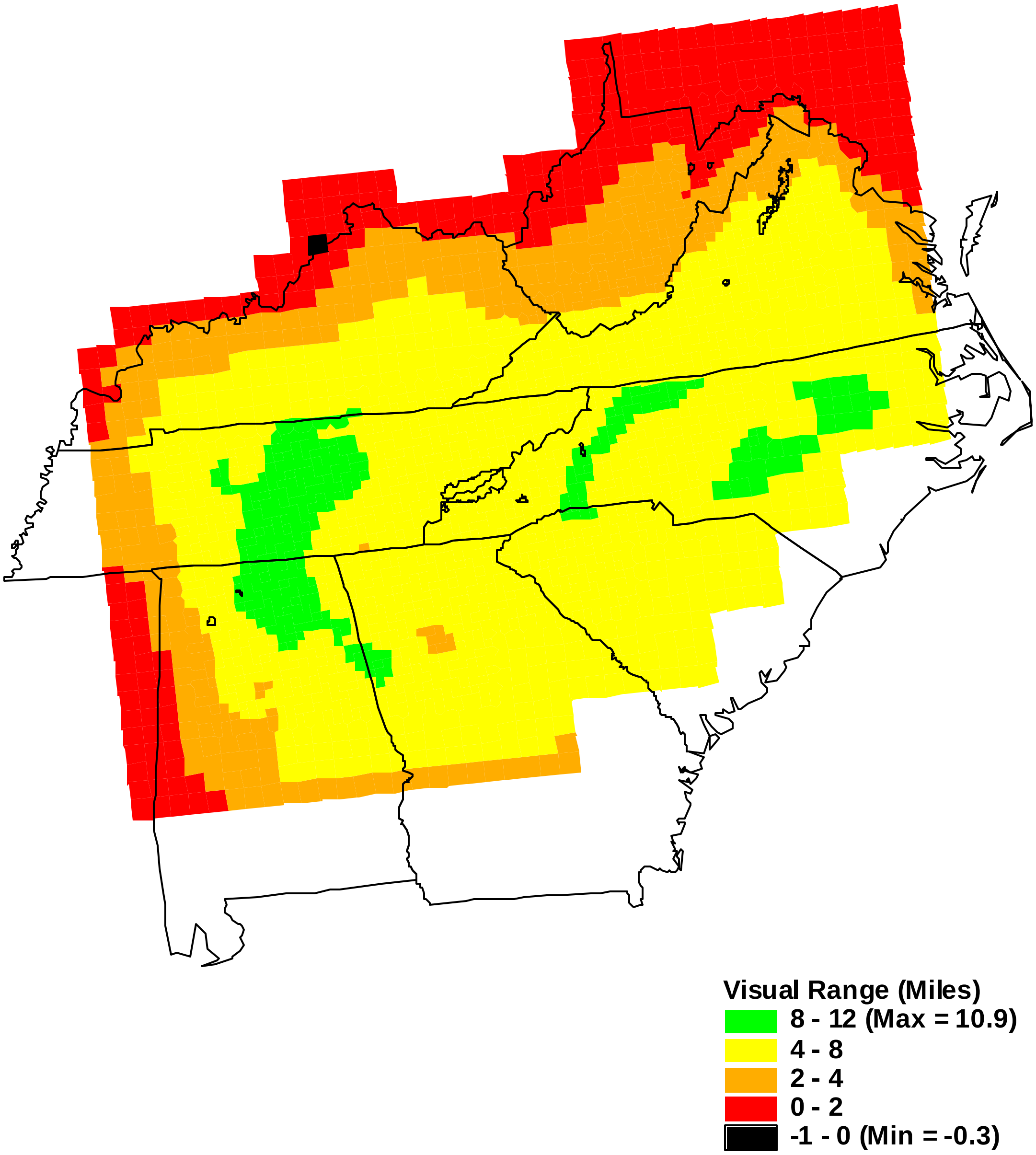

Exhibit C-12
Change in Annual Average Visual Range
2040 Scenario B3 Minus Scenario A2