VERMONT STATE IMPLEMENTATION PLAN (SIP) REVISION REGIONAL HAZE

STATE OF VERMONT
DEPARTMENT OF ENVIRONMENTAL CONSERVATION

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ACKNOWLEDGMENTS

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1. Background on Regional Haze in the Lye Brook Wilderness

1.1 General Background / History of Federal Visibility Rules

In amendments to the Clean Air Act in 1977, Congress added Section 169 (42 U.S.C. 7491) setting forth the following national visibility goal:

> *Congress hereby declares as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from man-made air pollution.*

The affected Class I areas include many of our best known natural places, including the Grand Canyon, Yosemite, Yellowstone, Mount Rainier, Shenandoah, the Great Smokies, Acadia, and the Everglades. In Vermont, the affected area is the Lye Brook Wilderness.

Section 169 also directed EPA to promulgate regulations to assure reasonable progress toward this national visibility goal and to require State Implementation Plan (SIP) revisions in states containing the affected Class I Federal Areas as well as in states, "the emissions from which may reasonably be anticipated to cause or contribute to impairment of visibility in any such [Class I] area". In 1980, EPA promulgated visibility regulations which focused primarily on impairment attributable to individual sources or small groups of sources ("plume blight"), but which also required long-term strategies to assure reasonable progress toward the national visibility goal.

In April, 1986, the State of Vermont submitted a proposed SIP revision which determined that visibility in the Lye Brook Wilderness was not impaired by plume blight, but was severely impaired by regional haze, composed predominantly of sulfate aerosol transported from SO_2 sources in upwind states. The 1986 VT SIP revision included a summer seasonal sulfate standard of 2 $\mu g/m^3$ (roughly half the estimated prevailing concentration at that time) as an interim measure to assure reasonable progress toward the national visibility goal for Lye Brook. Vermont also requested that EPA implement an Eastern US regional SO_2 emission reduction program to improve visibility in Lye Brook (and other eastern US Class I areas), and also specifically requested that EPA require SIP revisions in 8 upwind states (OH, PA, WV, IN, IL, KY, TN & MI) which were estimated to account for more than half of the sulfate in VT and which could clearly be identified as states "the emissions from which may reasonably be anticipated to cause or contribute to impairment of visibility" in Lye Brook (and many other Eastern US Class I areas).

In July, 1987, EPA ruled on Vermont's proposed visibility SIP. Although it concurred that "Vermont's visibility impairment is predominantly due to out-of-state sulfur emissions", EPA took "no action" on any aspects of the VT proposal that attempted to reduce regional haze, including the state sulfate standards, regional SO_2 emission reductions, and requested SIP calls in major upwind contributing states. EPA argued that it had no current regulatory

basis to address regional haze effects, and that substantial additional research was needed to develop the technical basis for such regulations.

When the CAA was amended in 1990, Congress included (Title IV) a phased program of SO_2 emission reductions in the Eastern US, similar to but somewhat less stringent than and with a longer time delay than what Vermont had requested in its 1986 SIP. The 1990 CAA Amendments also added Section 169B (42 U.S.C. 7492), authorizing further visibility research and periodic assessments of the progress made toward improving visibility in Class I areas that resulted from the required CAA emissions reductions.

In addition to authorizing creation of visibility transport commissions and setting forth their duties, Section 169B(f) of the 1990 CAA mandated creation of the Grand Canyon Visibility Transport Commission (GCVTC) to make recommendations to EPA for the region affecting the visibility of the Grand Canyon National Park. The Grand Canyon Visibility Transport Commission (Commission) submitted its report to EPA in June 1996, following four years of research and policy development. The Commission report, as well as the many research reports prepared by the Commission, contributed invaluable information to EPA in its development of the federal regional haze rule.

1.2 The 1999 Regional Haze Rule

EPA's Regional Haze Rule was adopted July 1, 1999, and went into effect on August 30, 1999. This rule seeks to address the combined visibility effects of various pollution sources over a wide geographic region. This wide reaching pollution net means that many states – including those without Class I Areas – are required to participate in haze reduction efforts.

In consultation with the states and tribes, EPA designated five Regional Planning Organizations (RPO) to assist with the coordination and cooperation needed to address the Haze issue. The Mid-Atlantic / Northeast states, including the District of Columbia, formed the Mid-Atlantic / Northeast Visibility Union (MANE-VU).*

EPA's adoption of the Regional Haze Rule was not without controversy. On May 24, 2002 the U.S. Court of Appeals, for the District of Columbia Circuit ruled on the challenge brought by the American Corn Growers Association against EPA's Regional Haze Rule of 1999. The Court remanded to EPA the BART provisions of the rule, and denied industry's challenge to the haze rule goals of natural visibility and no degradation requirements. On June 15, 2005, EPA finalized a rule addressing the court's remand.

On February 18, 2005, the U.S. Court of Appeals for the District of Columbia Circuit issued another ruling vacating the Regional Haze Rule in part and sustaining it in part. For more information see *Center for Energy and Economic Development v. EPA*, no. 03-1222, (D.C. Cir. Feb. 18, 2005)("*CEED* v. EPA"). In this case, the court granted a petition challenging provisions of the Regional Haze Rule governing the optional emissions trading program for certain Western States and Tribes (the WRAP Annex Rule).

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* A description of MANE-VU and a full list of its members is described in the Regional Planning Section of this SIP

EPA's subsequent final rulemaking provided the following changes to the Regional Haze Regulations:

1. Revised the regulatory text in Section 51.308(e)(2)(i) in response to the *CEED* court's remand, to remove the requirement that the determination of BART "benchmark" be based on cumulative visibility analyses, and to clarify the process for making such determinations, including the application of BART presumptions for EGUs as contained in Appendix Y to 40 CFR 51.
2. Added new regulatory text in Section 51.308(e)(2)(vi), to provide minimum elements for cap and trade programs in lieu of BART
3. Revised regulatory text in Section 51.309, to reconcile the optional framework for certain Western States and Tribes to implement the recommendations of the Grand Canyon Visibility Transport Commission (GCVTC) with the *CEED* decision.

EPA's 1999 regulations address visibility impairment in the form of regional haze. Haze is an atmospheric phenomenon that obscures the clarity, color, texture, and form of what we see. Haze in the Eastern US is caused primarily by anthropogenic (manmade) pollutants but can also be influenced by a number of natural phenomena, including forest fires, dust storms, and sea spray. The optical effects of these pollutants and natural substances result from the scattering and absorption of light by particles and gasses, with the scattering of light by fine particles (less than 2.5 microns diameter) being the predominant contributor at most times and places. Some haze-causing particles are emitted directly to the atmosphere by primary particle emission sources such as electric power plants, factories, automobiles, construction activities, and agricultural burning. Others occur when gases emitted to the air (particle precursors) interact to form secondary particles. Some secondary particles including sulfate and nitrate compounds are hygroscopic, and will grow in size and scatter more light as relative humidity increases.

Fine particles formed from multiple primary and secondary sources can mix together over broad geographic areas and can be transported hundreds or thousands of miles. Consequently, regional haze occurs in every part of the nation. Because of the regional nature of haze, EPA's regulations require the states to consult with one another toward the national goal of improving visibility – specifically, at the 156 parks and wilderness areas designated under the Clean Air Act as mandatory Class I Federal Areas.

The Regional Haze Rule calls for each state to establish reasonable progress goals for visibility improvement and to formulate a long-term strategy for meeting these goals. These requirements apply to any state having a Class I area as well as any state that contributes to visibility impairment at any (downwind) Class I area. The visibility goals must be designed both to improve visibility on the haziest days and to ensure that no degradation occurs on the clearest days.

A state's long-term strategy must include enforceable emission reduction measures designed to meet reasonable progress goals. The first long-term strategy covers the 10 to 15-year period ending in 2018, and subsequent revisions are to be issued every 10 years thereafter. In identifying the emission reduction measures to be included in the long-term

strategy, states should address all types of manmade emissions contributing to visibility degradation in Class I areas, including those from mobile sources; stationary sources (such as factories and power plants); smaller, so-called "area" sources (such as residential wood stoves and small boilers); and prescribed fires.

In developing their plans, states can take into account emission reductions attributable to ongoing air pollution control programs at the state, regional, or national levels. For most states and regions of the country, however, additional emission control measures beyond those already on the books will be necessary if national visibility goals are to be achieved. In addition, the Regional Haze Rule mandates that control measures be implemented for certain existing sources placed into operation between 1962 and 1977. This portion of the rule is known as BART, for Best Available Retrofit Technology.

Each state's plan for addressing regional haze will take the form of a State Implementation Plan (SIP) or SIP revision. Vermont's SIP, was developed after extensive consultations with other states and regional planning organizations. In particular, Vermont contributed to many analyses and reports produced by the member states of the Northeast States for Coordinated Air Use Management (NESCAUM), the Mid-Atlantic Regional Air Managers Association (MARAMA), and the Mid-Atlantic/Northeast Visibility Union (MANE-VU) Regional Planning Organization for the purpose of coordinated regional haze planning. Vermont also consulted with states outside the Northeast and with the provinces of eastern Canada.

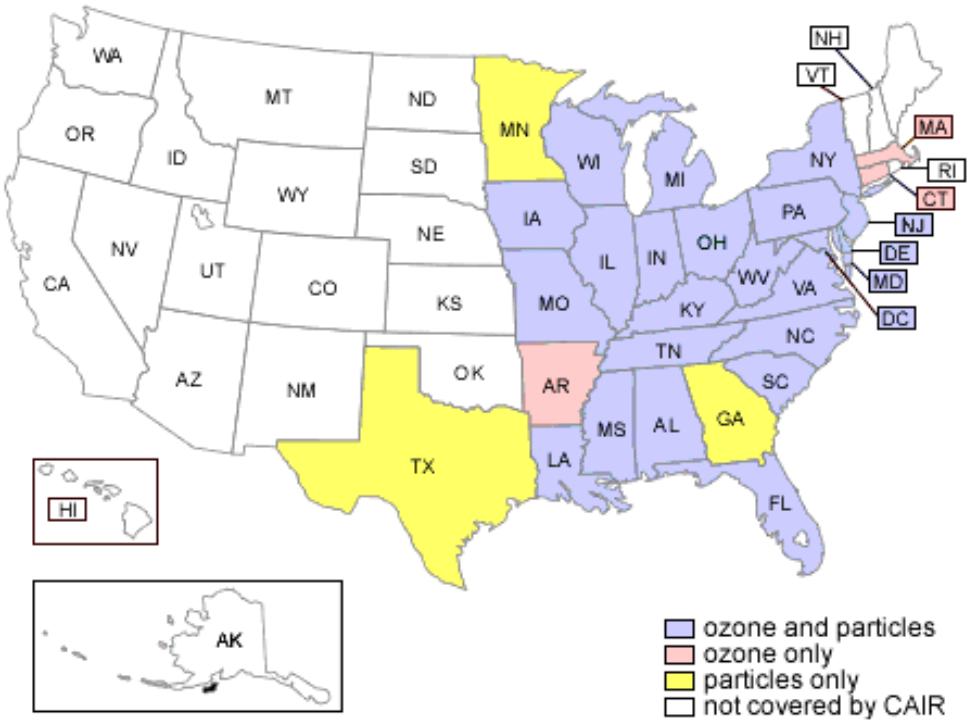
In creating its regional strategy, Vermont and the other MANE-VU states looked beyond the provisions of the federal Clean Air Interstate Rule (CAIR) to identify additional emission control measures that could be effectively employed to mitigate regional haze. In this respect, Vermont and the rest of MANE-VU stand apart from some other states in asserting that additional measures beyond CAIR are essential to meeting established visibility goals at MANE-VU's Class I Areas.

The regulatory, organizational, and technical basis for Vermont's regional haze plan will be found in Sections 1 through 8 of this SIP document. The prescriptive elements of Vermont's plan – BART determinations, reasonable progress goals, and long-term strategy - are described in detail in Sections 9 through 11.

1.3 Regional Haze Planning after the Vacatur of CAIR

On March 10, 2005, EPA issued the Clean Air Interstate Rule (CAIR). This important federal rule was designed to achieve major permanent reductions in sulfur dioxide (SO_2) and nitrogen oxides (NO_X) emissions in the eastern United States through a cap-and-trade system using emission allowances. As promulgated, CAIR permanently caps emissions originating in 28 eastern states and the District of Columbia (Figure 1.1). Although Vermont was not designated as a participating CAIR state, this program would greatly affect future air quality in the state.

Figure 1.1 Map of CAIR States



http://www.epa.gov/cair/

According to EPA's CAIR website, SO_2 emissions in the affected states would be reduced by more than 70 percent from 2003 levels, and NO_X emissions by more than 60 percent from 2003 levels, upon full implementation of CAIR (see http://www.epa.gov/cair/). Resulting improvements in air quality would yield $85 to $100 billion in health benefits and nearly $2 billion in visibility benefits per year by 2015, and premature mortality would be substantially reduced across the eastern U.S.

This program came to an abrupt end, however, on July 11, 2008, when the U.S. Court of Appeals for the District of Columbia Circuit found that CAIR violated basic provisions of the Clean Air Act. The court vacated CAIR in its entirety and remanded to EPA to promulgate a new rule consistent with the court's opinion. On September 24, 2008, EPA petitioned the D.C. Circuit for a rehearing or rehearing *en banc* on the vacatur of CAIR. Thereafter, the D.C. Circuit issued an order requesting briefs on the issue of whether any party is seeking vacatur of CAIR and whether the court should stay its vacatur until EPA promulgates a revised rule. Vermont, along with more than 20 other states, filed an *amicus* brief in support of staying the court decision vacating CAIR while EPA promulgates a revised rule that complies with the court's decision. The states argued that because they "reasonably relied on CAIR in formulating long-term plans for improving air quality, in the short term even a flawed rule is better than no rule at all."

The vacatur of CAIR presented a major difficulty for the individual states in attempting to comply with the Regional Haze Rule. Because CAIR formed the regulatory underpinnings for most of the emission reductions that would produce visibility improvements in

mandatory Class I areas, the probable demise of CAIR left a structural void around which states must build their regional haze SIPs. While all states have depended in varying degree on CAIR in the preparation of their regional haze SIPs, some Southeast states have relied almost entirely on CAIR to demonstrate compliance with the rule. As a major ramification, the vacatur of CAIR invalidated EPA's determination that CAIR satisfies the requirements of BART. The vacatur of CAIR also called into question the validity of MANE-VU's (and other RPO's) emission inventories and air quality modeling studies already completed for the member states' regional haze SIPs.

However, on December 23, 2008, the D.C. Circuit decided that "a remand without vacatur is appropriate in this case" because "notwithstanding the relative flaws of CAIR, allowing CAIR to remain in effect until it is replaced by a rule consistent with our opinion would at least temporarily preserve the environmental values covered by CAIR." *State of North Carolina v. EPA*, No. 05-1244, slip op. at 3 (D.C. Cir. Dec. 23, 2008).

In light of this decision, Vermont believes that future emissions and air quality levels will not be vastly different from values predicted by MANE-VU's completed modeling, even though that modeling was based on implementation of CAIR and did not take into account the remand of CAIR to EPA. Consequently, the reasonable progress goals and long-term strategy developed for Vermont's regional haze SIP still represent a defensible position from which to go forward with measures to improve visibility in MANE-VU's Class I Areas.

Further, Vermont and the other MANE-VU states have maintained all along that the regional haze SIPs should look beyond the provisions of CAIR to identify additional emission control measures that could be effectively employed to mitigate regional haze. In this respect, Vermont and the rest of MANE-VU stand apart from some other states in asserting that additional measures beyond CAIR are essential to meeting established visibility goals at MANE-VU's Class I Areas.

In describing Vermont's present situation, it may be helpful to note that the remand of CAIR without vacatur is a complicating factor for the long term, but does not present impediment to making visibility progress in the near term. The salient points to consider are as follows:

- Because Vermont is a non-CAIR state, CAIR does not directly affect any of Vermont's proposed in-state control strategies for visibility improvement.
- Vermont will meet its "fair share" of emissions in comparison with other MANE-VU states and the original CAIR states, as Vermont's long-term strategy demonstrates (see Section 11.0).
- Sources in upwind states release most of the pollutants contributing to visibility impairment in Vermont's Class I Lye Brook Wilderness area. Therefore, Vermont will continue to depend on mitigative actions by other states if visibility goals are to be achieved for Lye Brook.
- By the time of the first regional haze SIP progress report, in 2012, the regulatory framework should be clearer; and new modeling results should be available. It

should then be possible to fine-tune regional haze plans to take into account any rule that EPA has promulgated to replace CAIR. Vermont is committed to reviewing and updating its regional haze SIP as new information becomes available.

Given the D.C. Circuit's remand without vacatur of CAIR, Vermont has chosen to retain appropriate references to CAIR in the completion of Vermont's Regional Haze SIP, which will help to maintain continuity with the large body of completed work – much of it based on CAIR – that serves as the foundation for regional haze planning in the MANE-VU states to date.

1.4 State Implementation Plan Requirements

In accordance with 40 CFR 51.308(a) and (b), Vermont submits this SIP to meet the requirements of EPA's Regional Haze Rule. This SIP addresses the core requirements of 40 CFR 51.308(d) and the BART components of 40 CFR 50.308(e). In addition, this SIP addresses requirements pertaining to regional planning, and state/tribe and Federal Land Manager (FLM) coordination and consultation.

40 CFR 51.308(f) requires the State of Vermont to submit periodic revisions to its Regional Haze SIP by July 31, 2018, and every ten years thereafter. Vermont acknowledges and will comply with this schedule.

40 CFR 51.308(g) requires the State of Vermont to submit a report to EPA every 5 years that evaluates progress toward the reasonable progress goal for each mandatory Class I area located within the state and each mandatory Class I area located outside the state that may be affected by emissions from within the state. Vermont will submit the first progress report, in the form of a SIP revision, within 5 years from submittal of the initial State Implementation Plan, but no later than December 17, 2012.

Pursuant to 40 CFR 51.308(d)(4)(v), Vermont will also make periodic updates to Vermont's emissions inventory (see Section 6, Emissions Inventory). Vermont proposes to complete these updates to coincide with the progress reports. Lastly, pursuant to 40 CFR 51.308(h), Vermont will submit a determination of adequacy of its regional haze SIP revision whenever a progress report is submitted. Depending on the findings of its five-year review, Vermont will take one or more of the following actions at that time, whichever actions are appropriate or necessary:

- If Vermont determines that the existing State Implementation Plan requires no further substantive revision in order to achieve established goals for visibility improvement and emissions reductions, Vermont will provide to the EPA Administrator a negative declaration that further revision of the plan is not needed.

- If Vermont determines that its implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources in one or more other state(s) which participated in the regional planning process, Vermont will provide notification to the EPA Administrator and to those other state(s). Vermont

will also collaborate with the other state(s) through the regional planning process for the purpose of developing additional strategies to address any such deficiencies in Vermont's plan.

• If Vermont determines that its implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources in another country, Vermont will provide notification, along with available information, to the EPA Administrator.

• If Vermont determines that the implementation plan is or may be inadequate to ensure reasonable progress as a result of emissions from sources within the state, Vermont will revise its implementation plan to address the plan's deficiencies within one year from this determination.

1.5 The Basics of Haze

Small particles and certain gaseous molecules in the atmosphere cause poor visibility by scattering and absorbing light, thereby reducing the amount of visual information about distant objects that reaches an observer. Some light scattering by air molecules (Rayleigh scattering) and naturally occurring aerosols occurs even under natural conditions.* The distribution of particles in the atmosphere depends on meteorological conditions and leads to various forms of visibility impairment. When high concentrations of pollutants are well mixed in the atmosphere, they form a uniform haze. When temperature inversions trap pollutants near the surface, the result can be a sharply demarcated layer of haze. Plume blight – a distinct, frequently brownish plume of pollution from a particular emissions source – occurs under stable atmospheric conditions, where pollutants take a long time to disperse.

Visibility impairment can be quantified using three different, but mathematically related measures: visual range (i.e., how far one can see); light extinction per unit distance (e.g., Mm-1)†; and deciviews (dv), a useful metric for measuring increments of visibility change that are just perceptible to the human eye. Visibility impairment can be measured directly by nephelometer (light scattering) or transmissometer (light transmission – includes both scattering and absorption) and can also be calculated from color slide photographs using slide densitometry measurements, known target distances, and estimated inherent contrast measurements. Light extinction and other visibility metrics can also be "reconstructed" from measured concentrations of ambient particle species components, taking into account their unique light-scattering (or absorbing) properties and making appropriate adjustments for relative humidity effects on hygroscopic species. Assuming natural conditions, visibility in the Northeast and Mid-Atlantic is estimated to be about 23 Mm-1, which corresponds to a visual range of about 170 kilometers or 8 dv. Under current polluted conditions in the region, average visibility ranges from 103 Mm-1 in the south to 55 Mm-1

* The fact that air molecules scatter more short-wavelength (blue) light accounts for the blue color of the sky. The term "aerosol" is defined as a suspension of particles in a gas. In this report, the term refers to particles suspended in the atmosphere.

†. In units of inverse length. An inverse megameter (Mm-1) is equal to one over one thousand kilometers.

in the north; these values correspond to a visual range of 40 to 70 kilometers or 23 to 17 dv, respectively. On the worst 20 percent of days, visibility impairment in Northeast and Mid-Atlantic Class I areas ranges from about 20 to 30 dv. At Lye Brook Wilderness over the 5 year period from 2000 through 2004, reconstructed extinction averaged 6.4 dv (visual range of 222 kilometers) on the 20 percent cleanest days and 24.5 dv (visual range of 38 kilometers) on the 20 percent haziest days.

The photographs in Figure 1.2 illustrate the range of visibility conditions encountered at Lye Brook. They were taken by an automated camera which the USDA Forest Service operated from 1987 through 1991 at a location 2 kilometers south of Lye Brook Meadows. The view looks across the Wilderness area toward Mother Myrick Mountain, 18 kilometers to the NNW (336 degrees). The visibility metrics were calculated using slide densitometry measurements, known target distances, and estimated inherent contrast measurements.

Figure 1.2 Illustrated Spectrum of Visibility Impairment Conditions at Lye Brook Wilderness

The small particles that commonly cause hazy conditions in the East are primarily composed of ammoniated sulfate and nitrate compounds, organic matter (organic carbon and associated oxygen and hydrogen), elemental carbon (soot), crustal material (e.g., soil dust) and sea salt. Of these constituents, only elemental carbon impairs visibility by absorbing visible light; the others scatter light. Sulfates, nitrates, and some of the organics are secondary pollutants that form in the atmosphere from precursor pollutants, primarily sulfur dioxide (SO_2), oxides of nitrogen (NO_X), and volatile organic compounds (VOCs), respectively. By contrast, soot, sea salt, crustal material and some organic carbon particles are released directly to the atmosphere. Particle constituents also differ in their relative effectiveness at reducing visibility. Sulfates and nitrates, for example, contribute disproportionately to haze because of their chemical affinity for water. This property allows them to grow rapidly in the presence of moisture, and scatter much more light than they would under dry conditions.

1.6 Anatomy of Regional Haze

Monitoring data collected over the last decade show that fine particle concentrations, and hence visibility impairment, are generally highest near industrial and highly populated areas of the Northeast and Mid-Atlantic. Particle concentrations are lower, and visibility conditions are better, at the more northerly Class I sites (such as the Lye Brook Wildernesses), where visibility on the 20 percent best days* is close to natural, unpolluted conditions. By contrast, visibility at the more southerly Brigantine site in New Jersey is substantially impaired even on the 20 percent clearest days. On the 20 percent haziest days, visibility impairment is substantial throughout the region.

Sulfate is the dominant contributor to fine particle pollution throughout the eastern U.S. On the haziest 20 percent of days, it accounts for one-half to two-thirds of total fine particle mass and is responsible for about three-quarters of total light extinction at Class I sites in the Northeast and Mid-Atlantic. Even on the clearest 20 percent of days, sulfate typically constitutes 40 percent or more of total fine particle mass in the region. Moreover, sulfate accounts for 60 to 80 percent of the difference in fine particle mass concentrations on hazy versus clear days.

Organic carbon consistently accounts for the next largest fraction of total fine particle mass; its contribution typically ranges from 20 to 30 percent on the haziest days. Notably, organic carbon accounts for as much as 40 to 50 percent of total mass on the clearest days, indicating that biogenic hydrocarbon sources (i.e. vegetation) are important at Class I areas in the region.

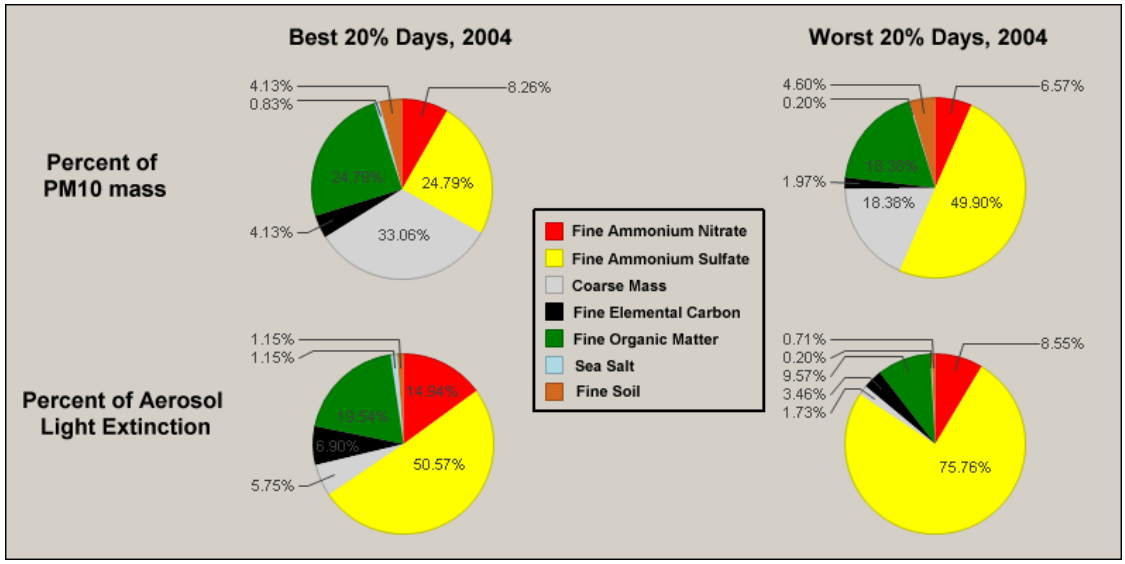
The relative contributions of nitrate, elemental carbon, and fine soil are smaller than those of sulfate and organic carbon – typically less than 10 percent of total mass and varying with location. However, in some settings such as a monitoring site in Washington, DC,

* "20 percent best visibility conditions" are defined throughout this report as the simple average of the lower 20th percentile of a cumulative frequency distribution of available data (expressed in deciviews). Similarly, "20 percent worst visibility conditions" represent the upper 20th percentile of the same distribution of available data.

nitrate plays a considerably larger role, pointing to the importance of local NO_X and/or NH_3 sources to fine-particle pollution in urban environments.

About half of the worst visibility days in Lye Brook occur in the summer when meteorological conditions are more conducive to the formation of sulfate from SO_2 and to the oxidation of organic aerosols. The remaining worst visibility days are divided nearly equally among spring, winter, and fall. In addition, winter and summer transport patterns are different, possibly leading to different contributions from upwind pollutant source regions. In contrast to sulfate and organic carbon, the nitrate contribution is typically higher in the winter months*. The crustal and elemental carbon fractions do not show a clear pattern of seasonal variation. Figure 1.3 shows the relative contributions of aerosol species at Lye Brook in 2004 to PM_{10} mass (top) and aerosol light extinction (bottom) on the 20% best days (left) and 20% worst days (right).

Figure 1.3 Contribution of Aerosol Species to Aerosol Mass and Light Extinction at Lye Brook, 2004



The basis for EPA's regional haze regulations is recognition that visibility impairment is fundamentally a regional phenomenon. Emissions from numerous sources over a broad geographic area commonly create hazy conditions across large portions of the eastern U.S. as a result of the long-range transport of airborne particles and precursor pollutants in the atmosphere. The key sulfate precursor, SO_2, for example, has an atmospheric lifetime of several days and is known to be subject to transport distances of hundreds of miles. Once converted to SO4 aerosol, the atmospheric lifetime and transport distances for sulfur compounds are even greater. Gaseous NO_X, nitric acid, ammonia and some gaseous organic carbon species are also subject to transport, and their transport distances become substantially greater if they are transformed into particle phase. Small particles of soot and crustal material are also subject to long range transport, and in fact some of the highest concentrations of fine soil at rural sites in the Northeastern US have been traced to intercontinental transport of Asian and African dust.

* This is largely due to the fact that the ammonium nitrate bond is more stable at lower temperatures. The role of ammonia in combination with both sulfate and nitrate is discussed further in later sections

The importance of transport dynamics is well illustrated by a particularly severe haze episode that occurred in mid-July of 1999. During this episode, unusually hot and humid conditions coincided with the development of a high-pressure system over the Mid-Atlantic States that produced atmospheric stagnation over the heavily urbanized, southern portion of the northeastern Regional Planning Organization region (i.e., Philadelphia - DC - southern New Jersey). At the same time, wind patterns above the area of stagnation brought a steady flow of air from the Midwest into the New England states. This set of conditions resulted in several days of unusually high concentrations of fine-particle pollution throughout the region. On July 17, 1999, ambient sulfate concentrations at Acadia National Park were 40 percent higher than any previous measurement at that site since the late 1980s. On the same day, visibility at the Burlington, Vermont, airport was limited to just 3 miles. Fine Particle mass concentrations in the Lye Brook Wilderness exceeded 40 $\mu g/m^3$, including nearly 30 $\mu g/m^3$ of ammonium sulfate. As is often the case, high concentrations of ground-level ozone accompanied these severe haze conditions. These coinciding conditions occurred because haze and ground-level ozone – although they are fundamentally different phenomena – tend to form and accumulate under similar meteorological conditions. In addition, high concentrations of ozone and other photochemical oxidants can accelerate the formation of secondary sulfate and organic aerosols, with possible contributions of different precursor gasses – SO_2, NO_x, VOCs – from different sources in different regions mixing together and impairing visibility over large downwind regions.

1.7 The Lye Brook Wilderness Area

The Lye Brook Wilderness Area, within the Green Mountain National Forest, is located east of Manchester Center and Sunderland in the southern Green Mountains of Vermont (Figure 4). It was designated wilderness by Congress in 1975, and is currently comprised of 17,841 acres. It is named after Lye Brook, which flows through the western half of the wilderness before emptying into the Batten Kill near Manchester. Elevation ranges from 900 feet to 2,900 feet above sea level, with most of the wilderness on a high plateau above 2,500 feet. Roughly 80% of the area is forested, with a mix of northern hardwoods with pockets of spruce/fir. The relatively flat southern section of the wilderness, known as Lye Brook Meadows contains several bogs, ponds and marshy areas which form the headwaters of Lye Brook. The western section is extremely steep, descending rapidly from the Green Mountain plateau to the Valley of Vermont. Four and a half miles of Appalachian Trail and Long Trail pass through the northwest corner of the wilderness.

Figure 1.4 Lye Brook Falls

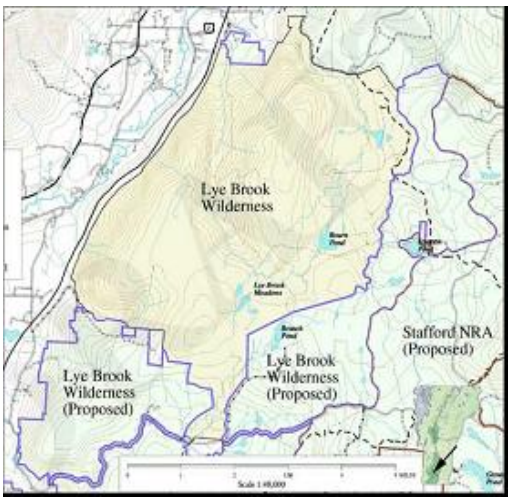
Figure 1.5 Bourne Pond in the Lye Brook Wilderness Area

Figure 1.6 Lye Brook Trail Signs

Lye Brook is just over 100 miles southwest of the Great Gulf and Presidential range Wilderness Areas in New Hampshire, roughly 250 miles west southwest of Acadia National Park in Maine, and 270 miles north of the Brigantine National Wildlife Refuge in New Jersey. The closest urban areas are Albany New York, 50 miles to the Southwest and Boston MA, 110 miles to the east. New York City and Montreal are roughly 170 miles to the south and north, respectively.

Figure 1.7 Lye Brook and Nearby Class I areas

Figure 1.8 Lye Brook Boundary & Topography

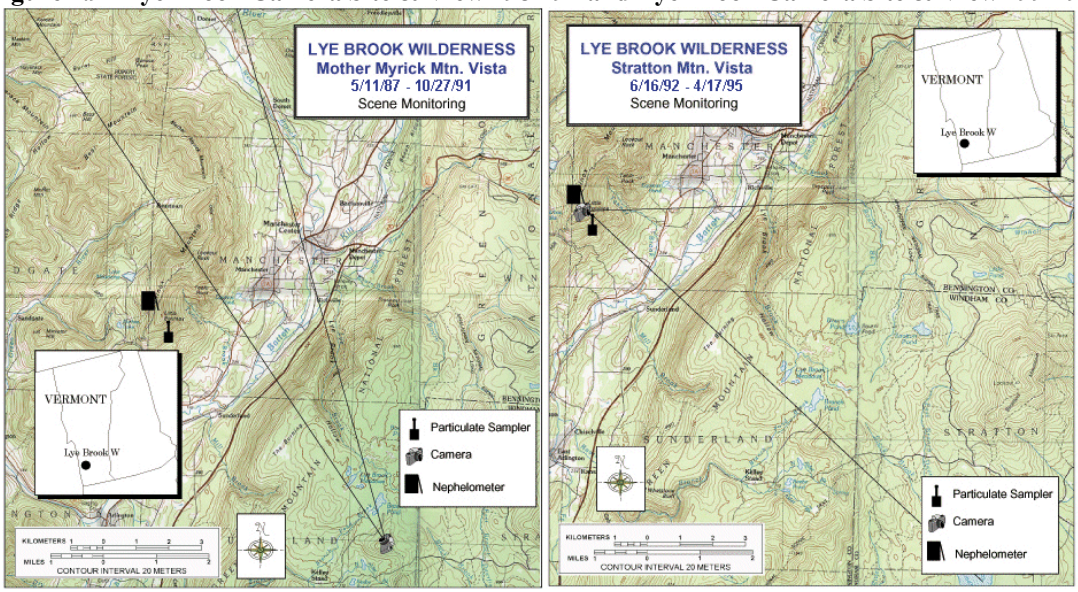


1.8 Monitoring and Recent Visibility Trends

Visibility monitoring at Lye Brook has included scene monitoring by automatic cameras, optical monitoring by integrating nephelometer and aerosol monitoring by the IMPROVE (Interagency Monitoring of PROtected Visual Environments) program. Between 1987 and 1995, the USDA Forest Service operated 2 automated camera sites overlooking Lye Brook. Starting in May, 1987, a camera snapped 3 pictures a day (9 AM, noon and 3 PM) from a site just south of the wilderness looking NNW toward Mother Myrick Mtn. In June 1992, the

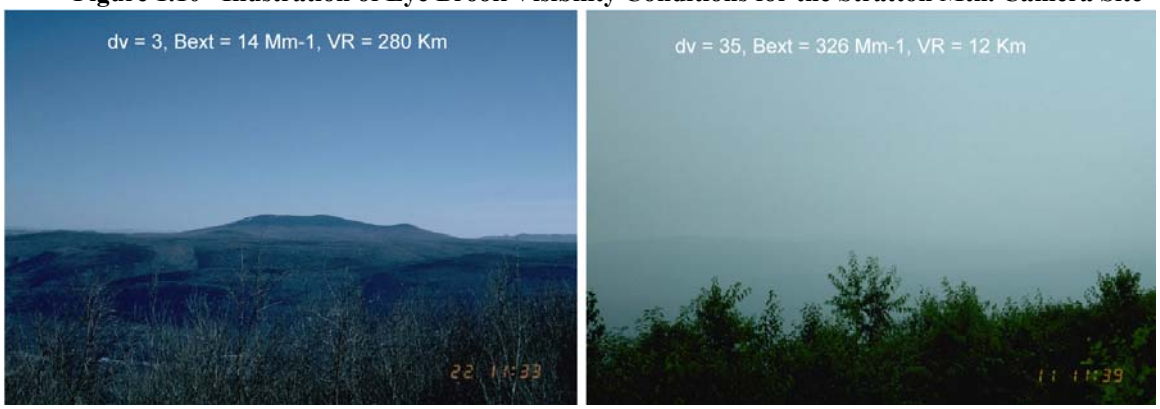
camera was moved to a site on Little Mt. Equinox to the west of the Wilderness, looking ESE toward Stratton Mtn. which is just east of the Wilderness boundary (see Figure 1.9).

Figure 1.9 Lye Brook Camera Site & View 1987-91 and Lye Brook Camera Site & View 1992-95



Photos showing a wide range of visibility conditions from the Mother Myrick Mtn. camera were previously displayed in Figure 1.2. Figure 1.10 shows a range of visibility conditions for the Stratton Mtn. site – ranging from a visual range of 280 km (left) to 12 km (right).

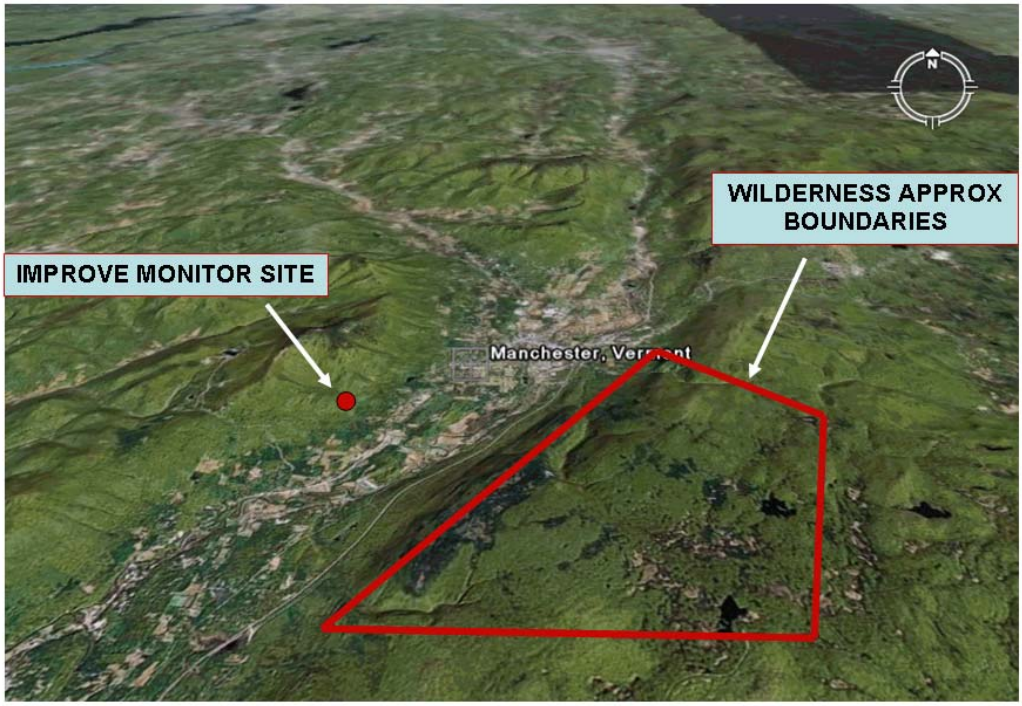
Figure 1.10 Illustration of Lye Brook Visibility Conditions for the Stratton Mtn. Camera Site



Between 1993 and 2003, the USDA Forest Service operated an unheated (Optec NGN2) integrating nephelometer at the Little Mt. Equinox site to the west of the Wilderness. The nephelometer measured light scattering (hourly), was located near the camera site facing Stratton Mtn. and was collocated with the Lye Brook IMPROVE aerosol samplers (see Figure 1.11). Note that this site is west of, and at 1015 meters elevation is slightly higher than the highest elevation (880 meters) in the wilderness (Figure 1.12), but haze and aerosol measurements are considered representative of regional haze conditions in Lye Brook.

Figure 1.11 Lye Brook Aerosol and Nephelometer Monitoring Site on Little Mt. Equinox

Figure 1.12 Location of Lye Brook Monitoring site relative to the Wilderness Area



IMPROVE aerosol sampling was initiated at the Lye Brook Little Equinox site in September 1991. Daily (24-hour midnight to midnight local time) samples were initially taken Wednesdays and Saturdays with the schedule revised to every 3rd day in 2001. Aerosol sampling and filter analysis is conducted according to procedures described in "*IMPROVE Standard Operating Protocols: Particle Monitoring Network* (http://vista.cira.colostate.edu/improve/Publications/IMPROVE_SOPs.htm). The data are stored in and available from the Visibility Information Exchange Web System (VIEWS at: http://vista.cira.colostate.edu/views/).

The haze-relevant aerosol measurements include PM_{10} mass and $PM_{2.5}$ mass (from which coarse mass is calculated), fine sulfate and nitrate ions (from which ammonium sulfate and ammonium nitrate are calculated), fine organic carbon (from which particulate organic matter is calculated), fine elemental carbon, fine elemental chlorine and chloride ion (from which sea salt mass is calculated), and fine crustal elements (Si, Al, Fe, Ca, Ti – from which fine soil is calculated). The calculated aerosol species mass concentrations are then combined with estimated dry light extinction efficiencies, enhanced hygroscopic growth functions (for sulfate nitrate & sea salt) using climatologically derived monthly relative humidity and f(RH) growth functions, and added to Rayleigh Scattering from natural gaseous air molecules (11 Mm^{-1} for Lye Brook). The equation presented below used for these extinction calculations – referred to as the IMPROVE Equation, Version II, and recommended by the IMPROVE Steering Committee is described in "*Review of the IMPROVE Equation for Estimating Ambient Light Extinction Coefficients - Final Report*", J. L. Hand and W. C. Malm, March 2006 http://vista.cira.colostate.edu/improve/Publications/GrayLit/016_IMPROVEeqReview/IMPROVEeqReview.htm.

$$\begin{aligned}
\text{Bext} \approx\ & 2.2 \times fS\,(RH) \times [\text{Small } (NH_4)_2SO_4] + 4.8 \times fL\,(RH) \times [\text{Large } (NH_4)_2SO_4] \\
& + 2.4 \times fS\,(RH) \times [\text{Small } NH_4NO_3] + 5.1 \times fL\,(RH) \times [\text{Large } NH_4NO_3] \\
& + 2.8 \times [\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}] \\
& + 10 \times [\text{Elemental Carbon}] + 1 \times [\text{Fine Soil Mass}] \\
& + 1.7 \times fSS\,(RH) \times [\text{Sea Salt Mass}] + 0.6 \times [\text{Coarse Mass}] \\
& + \text{Rayleigh Scattering (Site Specific)} + 0.33 \times [NO_2\ (\text{ppb})]
\end{aligned}$$

Where:

Bext = The light extinction coefficient in inverse megameters [Mm^{-1}],
fs (RH) and fL (RH) = Humidity factor associated with small and large mode mass size distributions of $(NH_4)_2SO_4$ and NH_4NO_3,
fss (RH) = Humidity factor associated with Sea Salt,
NO_2 data are not available and concentrations are assumed to be negligible

Apportionment of the total concentrations of ammonium sulfate ($(NH_4)_2SO_4$) into the concentrations of small and large size fractions is accomplished using the following equations:

$$[\text{Large } (NH_4)_2SO_4] = [\text{Total } (NH_4)_2SO_4]/20 \times [\text{Total } (NH_4)_2SO_4]$$

$$[\text{Small } (NH_4)_2SO_4] = [\text{Total } (NH_4)_2SO_4] - [\text{Large}(NH_4)_2SO_4]$$

Similar equations are used to apportion total ammonium nitrate (NH_4NO_3) and total particulate organic material (POM = 1.8·OC) concentrations into the small and large size fractions.

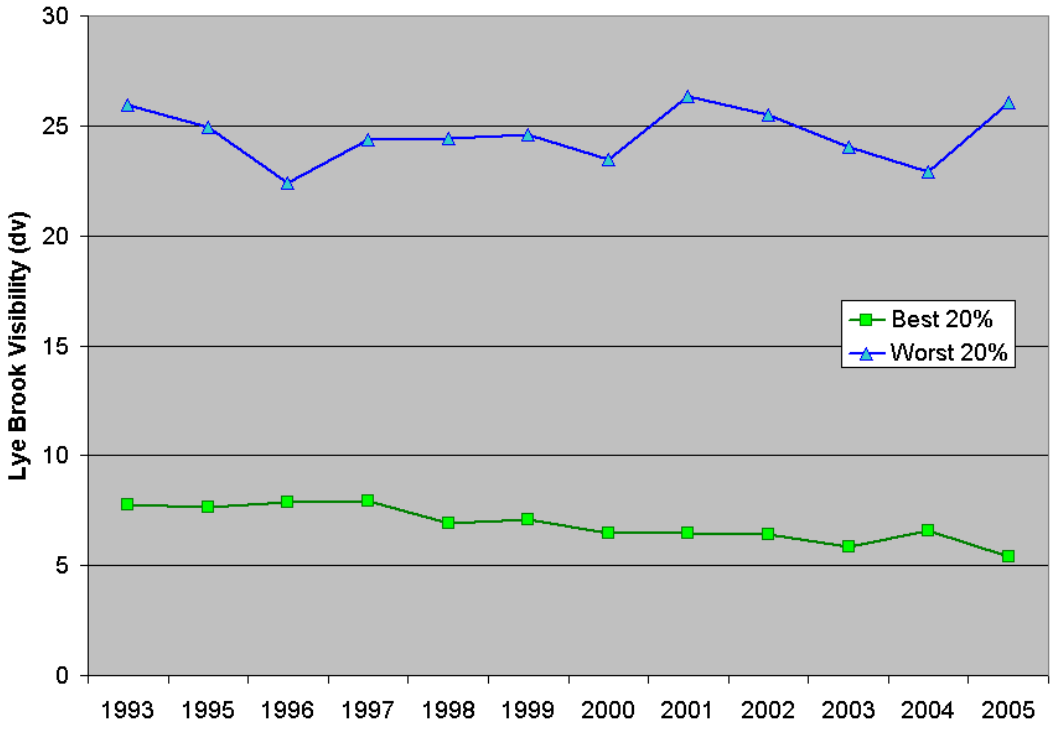
The resulting light extinction estimates (Bext in Mm-1) can be converted to deciviews:

$$\text{Deciviews (dv)} = 10 \ln B_{ext}/10$$

The calculated deciviews are unitless values where the higher the value, the greater amount of visibility impairment exists. A change of one deciview is considered to be the smallest change that would be humanly perceptible.

Figure 1.13 displays the trends in Lye Brook visibility averaged over the clearest 20 % of days in each year and the haziest 20% of days each year since 1993. It may be noted that there has been a general improvement in visibility on the cleanest days, but no consistent change has occurred on the haziest days over this 13-year period.

Figure 1.13 Trends in Visibility on Clean and Hazy Days at the Lye Brook IMPROVE Site

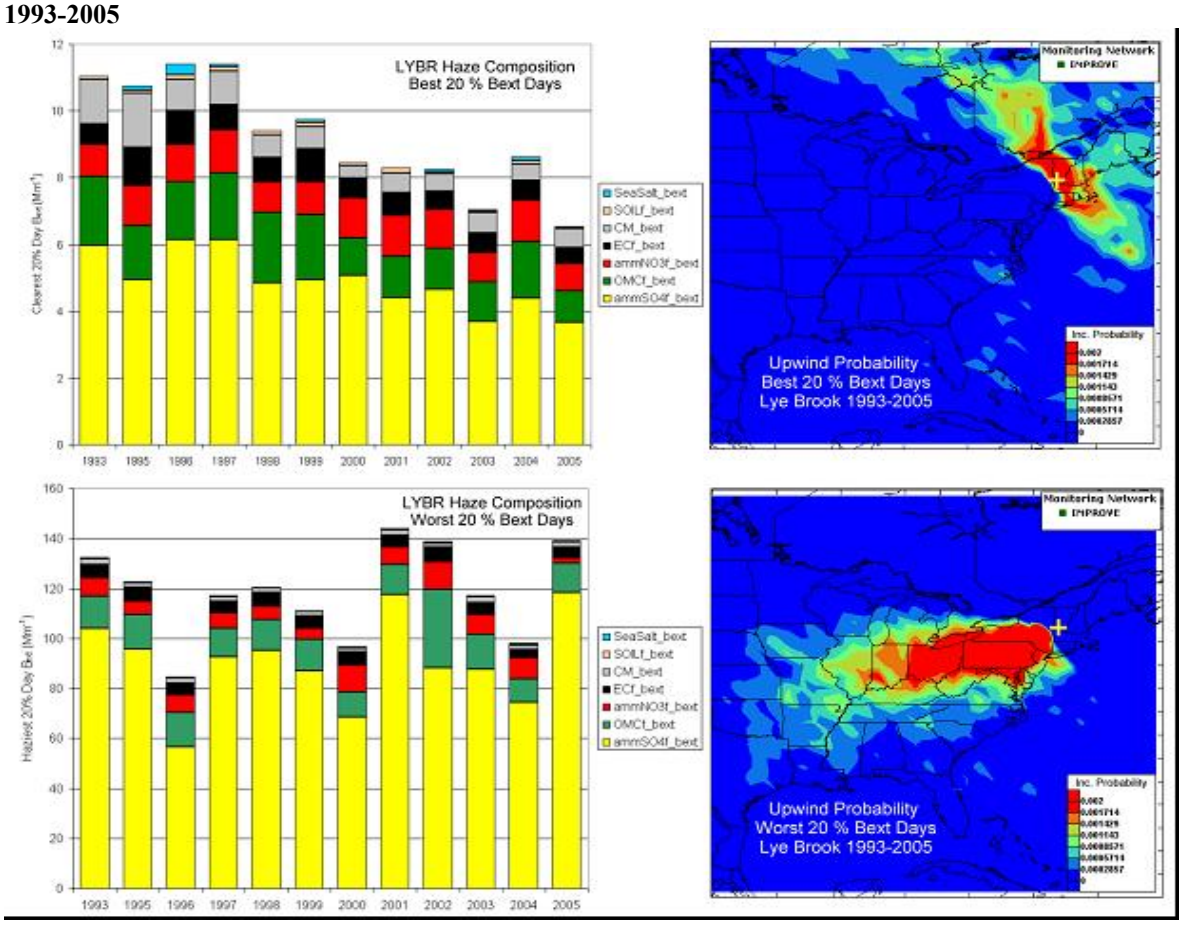


The EPA Regional Haze Rule requires that there be no deterioration of visibility on the cleanest 20% days, and that visibility impairment on the haziest days should improve from current "baseline conditions" (1999-2004 average of worst 20% days, currently estimated to be 24.5 dv for Lye Brook) to natural background conditions (currently estimated to be 11.7 dv on worst 20% days for Lye Brook) by the year 2064.

Figure 1.14 shows the trends in aerosol light extinction at Lye Brook for the period 1993 through 1995 for the best 20 % days (top left) and worst 20% days (bottom left) along with the contributions of individual aerosol species. While sulfate is the largest contributor to haze

on the cleanest days, the improvement on clean days has also been due to a reduction in sulfate on these clean days over this 13-year period. On the haziest 20% days, sulfate has been an even more predominant proportionate contributor to haze, but there has been no significant reduction in sulfate or total light extinction on the haziest days.

Figure 1.14 Trends in LYBR Aerosol Bext on Clear Days (top left) and Hazy Days (bottom left), 1993-2005 & Upwind Incremental Probability Plots for Clear Days (top right) and Hazy Days (bottom right), 1993-2005



The right side of Figure 1.14 shows ATAD trajectory-based incremental probability fields (areas most likely to have been upwind for a selected condition at the receptor) calculated by the Combined Aerosol Trajectory Tool (http://datafedwiki.wustl.edu/index.php/CATT) for the clearest 20% days (top right) and haziest 20% days (bottom right) at Lye Brook 1993 through 2005. On the clearest days (on which Lye Brook sulfate has improved over time), the air has previously resided over Vermont, other New England States, the North Atlantic and/or Eastern Canada. On the haziest days (on which Lye Brook sulfate has not improved), the air has previously resided well to the southwest of Vermont. Any reasonable progress toward improving conditions on the haziest days at Lye Brook can only be achieved by substantial sulfur emission reductions from these upwind regions.

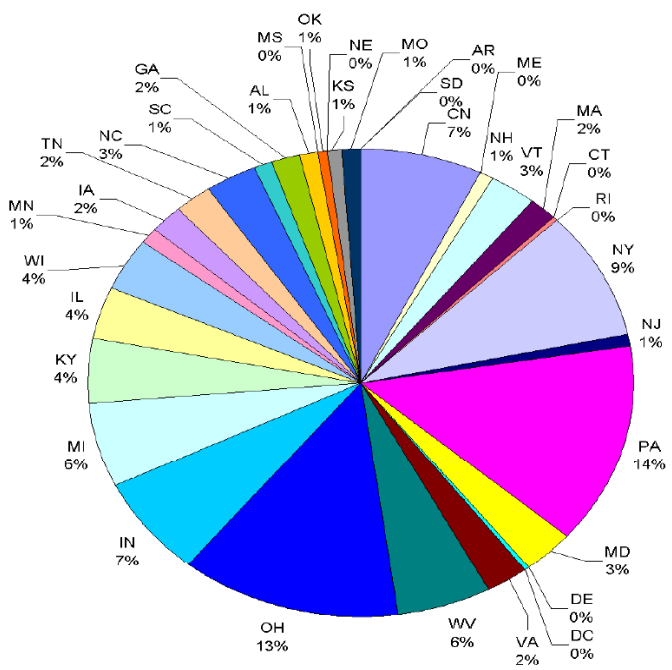
2. Areas Contributing to Regional Haze

40 CFR 51.308(c)(1)(ii) of the Regional Haze Rule requires states to determine their contributions to visibility impairment at mandatory Class I areas. Using a variety of source apportionment modeling techniques, MANE-VU has identified and evaluated the major contributors to regional haze and specifically to sulfate aerosol at MANE-VU Class I Areas as well as Class I areas in nearby Regional Planning Organization (RPO) regions. These technical source apportionment approaches are summarized in Table 2.1 below, and presented in detail in the Appendix I Report "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States," August 2006, otherwise known as the Contribution Assessment.

Table 2.1 Technical approaches for attributing contributions to sulfate in MANE-VU Class I areas

Analytical technique	Approach
Emissions/distance	Empirical
Incremental probability	Lagrangian trajectory technique
Cluster-weighted probability	Lagrangian trajectory technique
Emissions × upwind probability	Empirical/trajectory hybrid
Source apportionment approaches	Receptor model/trajectory hybrid
REMSAD tagged species	Eulerian source model
CALPUFF with MM5-based meteorology	Lagrangian source dispersion model
CALPUFF with observation-based meteorology	Lagrangian source dispersion model

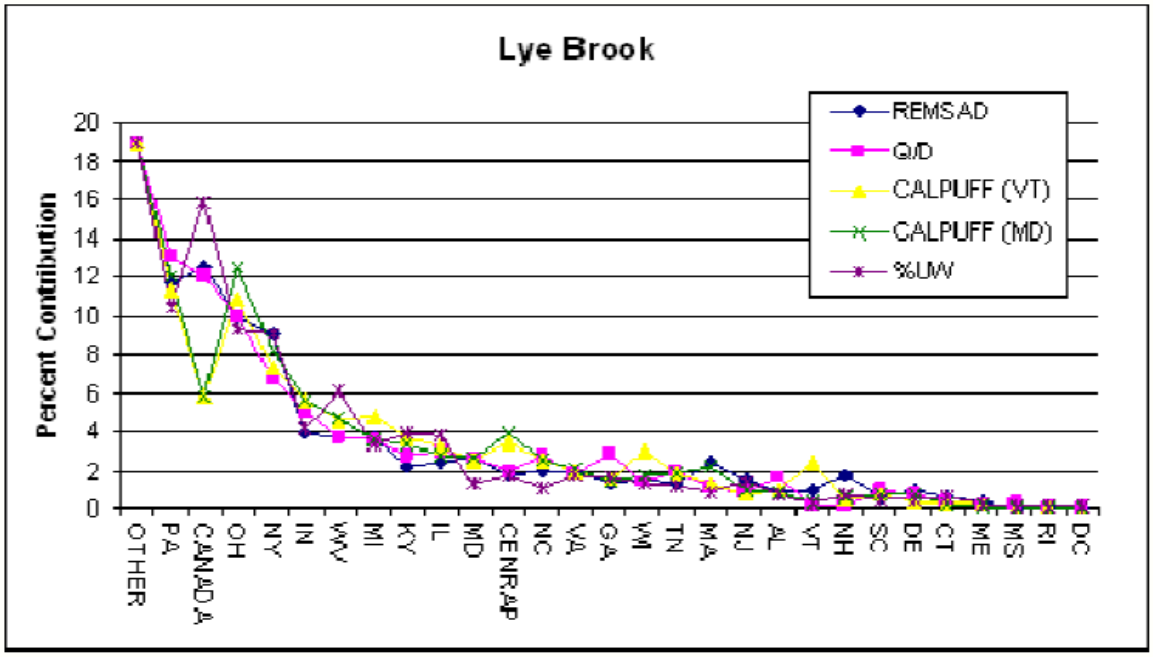
Figure 2.1 CALPUFF State Percent Contributions to Ambient Sulfate Concentrations at Lye Brook, 2002



Example results for the apportionment of 2002 sulfate at Lye Brook using the CALPUFF Lagrangian model combined with observation - based meteorology (modeling conducted by

VT DEC staff) are displayed in Figure 2.1. Slightly different proportionate contributions to sulfate in Lye Brook and in other MANE-VU Class I areas were estimated by the other source apportionment techniques, but as indicated in Figure 2.2, the results were generally quite consistent across all the different methods – both in terms of percent and rank of the different state contributions.

Figure 2.2 Normalized Percent Contributions to LYBR Sulfate using Alternative Assessment Techniques



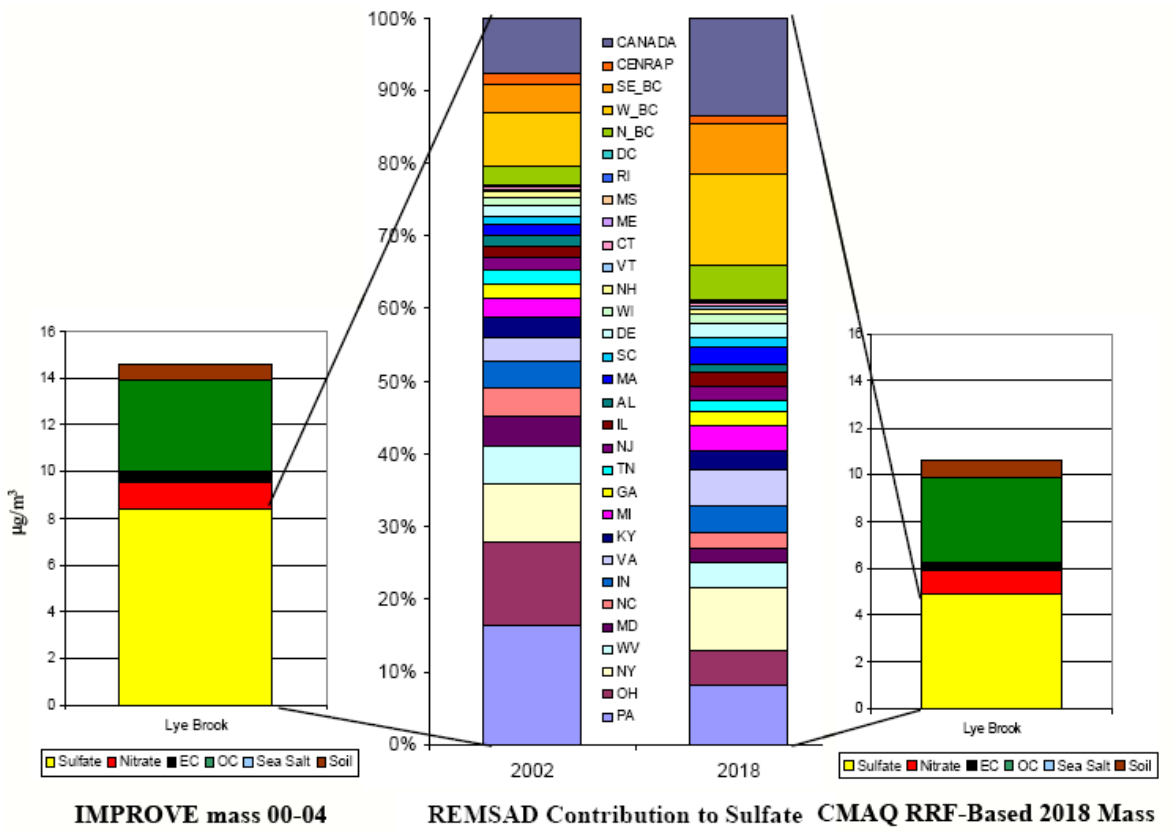
The regional REMSAD modeling performed by MANE-VU used a pollutant tagging scheme to produce a comprehensive assessment of the individual contributions from 28 nearby states to visibility impairment at Lye Brook and seven other nearby Class I areas. The modeling also provided a partial accounting of the contributions from several states along the western and southern edges of the modeling domain (i.e., boundary conditions) where only a portion of the states' emissions were tracked. Modeling was conducted for the base year 2002 and then projected to year 2018, when currently anticipated emission control programs would be in place.

Modeling results indicate that the relative contributions of states within the modeling domain were expected to decrease significantly by 2018 as a result of anticipated SO_2 emission reductions from implementation of existing state programs, the federal Clean Air Interstate Rule (CAIR), and additional state and federal control measures described in following sections of this document. At the same time, there are estimated to be large increases in the relative contributions from Canada and the boundary areas. These predicted percentage increases are due simply to the fact that contributions from outside the modeling domain will represent a larger share of the total after the various emission control programs have reduced contributions from within the domain.

According to the completed MANE-VU CMAQ modeling, sulfate concentrations at the Lye Brook Wilderness Area on the 20 percent worst visibility days will decline from 8.5 $\mu g/m^3$ in 2002 (representing the baseline period of 2000-2004) to 5.5 $\mu g/m^3$ in 2018. Mirroring the results for sulfate, fine particulate matter ($PM_{2.5}$) concentrations from all sources are projected to fall by a similar percentage, from 14.6 $\mu g/m^3$ in 2002 to 11.2 $\mu g/m^3$ in 2018. The modeling that produced these results is described in Section 7.0, Air Quality Modeling, and in "2018 Visibility Projections," May 13, 2008 (Appendix X). The emission control programs responsible for the projected visibility improvements are described in Section 11.0, Long-Term Strategy.

Figure 2.3 shows the magnitude of the 2002 (measured) and 2018 (projected) sulfate concentrations at the Lye Brook Wilderness, as well as the relative mass contributions of each state (or portion thereof in the model domain), on the 20 percent worst visibility days. Similar findings apply to other Class I areas in the MANE-VU region.

Figure 2.3 Measured and Projected Sulfate Mass Contributions in 2002 and 2018 at Lye Brook Wilderness on 20 Percent Worst Visibility Days



2.1 States Contributing to Visibility Impairment at Lye Brook

Based on the combined results from the multiple assessment techniques employed in the MANE-VU Contribution Assessment, Vermont and other MANE-VU states concluded that it was appropriate to define an area of influence including all of the states participating in MANE-VU plus other states that modeling indicated contributed at least 2% of the annual average sulfate ion at MANE-VU Class I areas in 2002.

Through participation in the MANE-VU regional haze planning process, Vermont has identified the following States as causing or contributing to visibility impairment in the following Class I areas Acadia National Park, Brigantine Wildlife Refuge, Great Gulf Wilderness Area, Lye Brook Wilderness Area, Moosehorn Wildlife Refuge, Presidential Range-Dry River Wilderness Area, and Roosevelt-Campobello International Park.*

Table 2.2 States that Contribute to Visibility Impairment in the MANE-VU Class I Areas of Acadia, Moosehorn, Great Gulf, Lye Brook, and Brigantine

State	RPO
Connecticut	MANE-VU
Delaware	MANE-VU
Maine	MANE-VU
Maryland	MANE-VU
Massachusetts	MANE-VU
New Hampshire	MANE-VU
New Jersey	MANE-VU
New York	MANE-VU
Pennsylvania	MANE-VU
Rhode Island	MANE-VU
Vermont	MANE-VU
Georgia	VISTAS
Kentucky	VISTAS
North Carolina	VISTAS
South Carolina	VISTAS
Tennessee	VISTAS
Virginia	VISTAS
West Virginia	VISTAS
Illinois	MRPO
Indiana	MRPO
Michigan	MRPO
Ohio	MRPO
New Brunswick, Canada	N/A
Ontario, Canada	N/A
Quebec, Canada	N/A

* Vermont independently determined based on CALPUFF modeling, which was not considered in developing Table 2.2, that Wisconsin has the potential to contribute to visibility impairment in Lye Brook. Therefore, Vermont asked Wisconsin to consult. See Section 3.2.1 and Table 3.4.

Table 2.3 shows the REMSAD estimates of percent contributions to 2002 annual average sulfate concentrations at Lye Brook Wilderness from states within the MANE-VU RPO as well as from other RPO regions, Canada and "Other" areas outside the REMSAD modeling domain. Taken from MANE-VU's Contribution Assessment, the data provide clear evidence that the large majority of sulfate pollution at Lye Brook originates from sources outside the Vermont (>99%) and that nearly 70% of Lye Brook sulfate results from sources outside the MANE-VU RPO.

Table 2.3 Contributions of Individual States and Regions to Total Annual Average Sulfate Impact (Percent, Mass Basis) at the Lye Brook Wilderness in 2002

State or Region	Percent Contribution
Pennsylvania	11.72
New York	9.00
Maryland	2.66
Massachusetts	2.45
New Hampshire	1.68
New Jersey	1.44
Vermont	0.95
Delaware	0.93
Connecticut	0.55
Maine	0.31
Rhode Island	0.06
District of Columbia	0.02
MANE-VU	31.78
MIDWEST RPO	21.48
VISTAS	13.65
CENRAP	1.67
CANADA	12.43
OTHER	18.99

2.2 Other Class I Areas Affected by Vermont Emissions

In accordance with 40 CFR 51.308(d)(4)(iii) the MANE-VU Contribution Assessment indicates that emissions sources within the State of Vermont have or may have impacts on the Lye Brook Wilderness Area, but do not have significant impacts on other Class I Areas in the MANE-VU region or in other RPO regions. The tagged REMSAD results indicate VT emissions account for less than 1% of average sulfate concentrations in Lye Brook and less than 0.5% of average sulfate concentrations in any other Class I area.

Table 2.4 Vermont's Contributions to Total Annual Average Sulfate Impact (Percent, Mass Basis) at Eastern Class I Areas in 2002

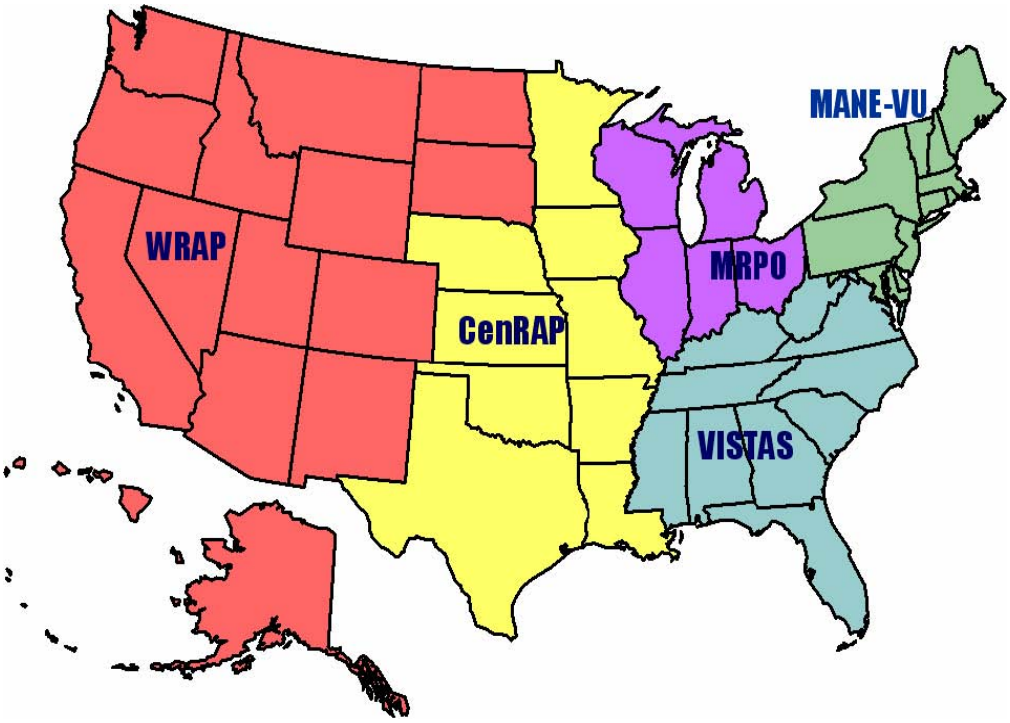
Mandatory Class I Area(s)	Percent Contribution
Lye Brook Wilderness*	0.95
Acadia National Park*	0.13
Brigantine Wilderness Area*	0.06
Dolly Sods Wilderness	0.00
Great Gulf Wilderness* & Presidential Range – Dry River Wilderness*	0.41
Moosehorn Wilderness* & Roosevelt Campobello International Park*	0.09
Shenandoah National Park	0.01

* MANE-VU Class 1 Area

3. Regional Planning and Consultation

In 1999, EPA and affected states/tribes agreed to create five Regional Planning Organizations (RPOs) to facilitate interstate coordination on State Implementation Plans (SIPs) addressing regional haze. The RPOs, and states/tribes within each RPO, are required to consult on emission management strategies toward visibility improvement in affected Class I areas. As shown in the accompanying map (Figure 3.1), the five RPOs are MANE-VU (Mid-Atlantic/Northeast Visibility Union), VISTAS (Visibility Improvement State and Tribal Association of the Southeast), MRPO (Midwest Regional Planning Organization), CenRAP (Central Regional Air Planning Association), and WRAP (Western Regional Air Partnership). Vermont is a member of MANE-VU.

Figure 3.1 EPA-Designated Regional Planning Organizations (RPOs)



3.1 Mid-Atlantic / Northeast Visibility Union (MANE-VU)

MANE-VU's work is managed by the Ozone Transport Commission (OTC) and carried out by OTC, the Mid-Atlantic Regional Air Management Association (MARAMA), and the Northeast States for Coordinated Air Use Management (NESCAUM). The states, tribes, and federal agencies comprising MANE-VU are listed in Table 3.1. Individuals from the member states, tribes, and agencies, along with professional staff from OTC, MARAMA, and NESCAUM, make up the various committees and workgroups. MANE-VU also established a Policy Advisory Group (PAG) to provide advice to decision-makers on policy questions. EPA, Federal Land Managers, states, and tribes are represented on the PAG, which meets on an as-needed basis.

Table 3.1 MANE-VU Members

Connecticut	Rhode Island
Delaware	Vermont
Maine	District of Columbia
Maryland	Penobscot Nation
Massachusetts	St. Regis Mohawk Tribe
New Hampshire	U.S. Environmental Protection Agency*
New Jersey	U.S. Fish and Wildlife Service*
New York	U.S. Forest Service*
Pennsylvania	U.S. National Park Service*

*Non-voting member

Since its inception on July 24, 2001, MANE-VU has created an active committee structure to address both technical and non-technical issues related to regional haze. The primary committees are the Technical Support Committee (TSC) and the Communications Committee. While the work of these committees is instrumental to policies and programs, all policy decisions reside with and are made by the MANE-VU Board.

The TSC is charged with assessing the nature and magnitude of the regional haze problem within MANE-VU, interpreting the results of technical work, and reporting on such work to the MANE-VU Board. This committee has evolved to function as a valuable resource on all technical projects and issues for MANE-VU. The TSC has established a process to ensure that important regional-haze-related projects are completed in a timely fashion, and members are kept informed of all MANE-VU tasks and duties. In addition to the formal working committees, there are three standing workgroups of the TSC assigned by topic area: the Emissions Inventory Workgroup, the Modeling Workgroup, and the Monitoring/Data Analysis Workgroup.

The Communications Committee is charged with developing approaches to inform the public about the regional haze problem and making recommendations to the MANE-VU Board to facilitate that goal. This committee oversees the production of MANE-VU's newsletter and outreach tools, both for stakeholders and the public, regarding regional issues affecting MANE-VU's members.

3.2 Regional Consultation and the MANE-VU "Ask"

On May 10, 2006, MANE-VU adopted the Inter-RPO State/Tribal and FLM Consultation Framework (Attachment B). That document set forth the principles presented in Table 3.2. The MANE-VU states and tribes applied these principles to the regional haze consultation and SIP development process. Issues addressed included regional haze baseline assessments, natural background levels, and development of reasonable progress goals – described at length in later sections of this SIP.

Table 3.2 MANE-VU Consultation Principles for Regional Haze Planning

1. All State, Tribal, RPO, and Federal participants are committed to continuing dialogue and information sharing in order to create understanding of the respective concerns and needs of the parties
2. Continuous documentation of all communications is necessary to develop a record for inclusion in the SIP submittal to EPA.
3. States alone have the authority to undertake specific measures under their SIP. This inter-RPO framework is designed solely to facilitate needed communication, coordination and cooperation among jurisdictions but does not establish binding obligation on the part of participating agencies
4. There are two areas which require State-to-State and/or State-to-Tribal consultations ("formal" consultations): (i) development of the reasonable progress goal for a Class I area, and (ii) development of long-term strategies. While it is anticipated that the formal consultation will cover the technical components that make up each of these policy decision areas, there may be a need for the RPOs, in coordination with their State and Tribal members, to have informal consultations on these technical considerations.
5. During both the formal and informal inter-RPO consultations, it is anticipated that the States and Tribes will work collectively to facilitate the consultation process through their respective RPOs, when feasible.
6. Technical analyses will be transparent, when possible, and will reflect the most up-to-date information and best scientific methods for the decision needed within the resources available.
7. The State with the Class I area retains the responsibility to establish reasonable progress goals. The RPOs will make reasonable efforts to facilitate the development of a consensus among the State with a Class I area and other States affecting that area. In instances where the State with the Class I area can not agree with such other States that the goal provides for reasonable progress, actions taken to resolve the disagreement must be included in the State's regional haze implementation plan (or plan revisions) submitted to the EPA Administrator as required under 40 CFR §51.308(d)(1)(iv).
8. All States whose emissions are reasonably anticipated to contribute to visibility impairment in a Class I area, must provide the Federal Land Manager ("FLM") agency for that Class I area with an opportunity for consultation, in person, on their regional haze implementation plans. The States/Tribes will pursue the development of a memorandum of understanding to expedite the submission and consideration of the FLM's comments on the reasonable progress goals and related implementation plans. As required under 40 CFR §51.308(i)(3), the plan or plan revision must include a description of how the State addressed any FLM comments.
9. States/Tribes will consult with the affected FLMs to protect the air resources of the State/Tribe and Class I areas in accordance with the FLM coordination requirements specified in 40 CFR §51.308(i) and other consultation procedures developed by consensus.
10. The consultation process is designed to share information, define and document issues, develop a range of options, solicit feedback on options, develop consensus advice if possible, and facilitate informed decisions by the Class I States.
11. The collaborators, including States, Tribes and affected FLMs, will promptly respond to other RPOs'/States'/Tribes' requests for comments.

The following points offer a snapshot of several important ways in which MANE-VU member states and tribes have cooperatively addressed regional haze:

- ***Prioritization:*** MANE-VU developed a process to coordinate MARAMA, OTC, and NESCAUM staff in developing budget priorities, project rankings, and the eventual federal grant requests.

- ***Issue Coordination:*** MANE-VU established a conference call and meeting schedule for each of its committees and workgroups. In addition, its MANE-VU directors regularly discussed pertinent issues.

- ***SIP Policy and Planning***: MANE-VU states/tribes collaborated on the development of a regional haze SIP template and the technical aspects of the SIP development process.

- ***Capacity Building***: To educate its staff and members, MANE-VU included technical presentations on conference calls and organized workshops with nationally recognized experts. Presentations on data analysis, Best Available Retrofit Technology (BART) applicability, inventory topics, modeling, and control measures were effective education and coordination tools.

- ***Routine Operations***: MANE-VU staff at OTC, MARAMA, and NESCAUM established a coordinated approach to budget tracking, project deliverables and due dates, workgroup meetings, inter-RPO consultations, etc.

The consultations among MANE-VU states and other states/tribes and provinces occurred through much of 2007. Documentation of consultation meetings and calls is summarized in Table 3.3, and further documentation is provided in Attachment C.

Table 3.3 Summary of MANE-VU Consultations on Regional Haze Planning

MANE-VU Intra-Regional Consultation Meeting, March 1, 2007:	MANE-VU members reviewed the requirements for regional haze plans, preliminary modeling results, the work being done to prepare the MANE-VU report on reasonable progress factors, and control strategy options under review.
MANE-VU Intra-State Consultation Meeting, June 7, 2007:	The MANE-VU Class I states adopted a statement of principles, and all MANE-VU members discussed draft statements concerning reasonable controls within and outside of MANE-VU. Federal Land Managers also attended the meeting, which was open to stakeholders.
MANE-VU Conference Call, June 20, 2007:	The MANE-VU states concluded discussions of statements concerning reasonable controls within and outside MANE-VU and agreed on the statements called the MANE-VU "Ask" (see Part 3.2.2 of this SIP), including a statement concerning controls within MANE-VU, a statement concerning controls outside MANE-VU, and a statement requesting a course of action by the U.S. EPA. Federal Land Managers also participated in the call. Upon approval, all statements as well as the statement of principles adopted on June 7 were posted and publicly available on the MANE-VU website. The MANE-VU Ask was determined to represent Vermont's needs for meeting Regional Haze rule requirements and was thus adopted as the Vermont Ask.

MANE-VU Class I States' Consultation Open Technical Call, July 19, 2007:	The MANE-VU/Vermont Ask was presented to states in other RPOs, RPO staff, and Federal Land Managers; and an opportunity was provided to request further information. This call was intended to provide information to facilitate informed discussion at follow-up meetings.
MANE-VU Consultation Meeting with MRPO, August 6, 2007:	This meeting, held at LADCO offices in Chicago, was attended by representatives of MANE-VU and MRPO states as well as staff. The meeting provided an opportunity to formally present the MANE-VU/ Vermont Ask to MRPO states and to consult with them on the reasonableness of the requested controls. Federal Land Manager agencies also attended the meeting.
MANE-VU Consultation Meeting with VISTAS, August 20, 2007:	This meeting, held at State of Georgia offices in Atlanta, was attended by representatives of MANE-VU and VISTAS states. The meeting provided an opportunity to formally present the MANE-VU/Vermont Ask to VISTAS states and to consult with them on the reasonableness of the requested controls. Federal Land Manager agencies also attended the meeting
MANE-VU / MRPO Consultation Conference Call, September 13, 2007:	As a follow-up to the meeting held on August 6 in Chicago, this call provided an opportunity for MANE-VU to clarify further what was being asked of the MRPO states. The flexibility in the Ask was explained. MRPO and MANE-VU staff agreed to work together to facilitate discussion of further controls on ICI boilers and EGUs.
MANE-VU Air Directors' Consultation Conference Call, September 26, 2007:	MANE-VU members clarified their understanding of the Ask and provided direction to modeling staff regarding interpretation of the Ask for purposes of estimating visibility impacts of the requested controls.

3.2.1 Vermont-Specific Consultations

40 CFR 51.308(d)(3)(i) of the Regional Haze Rule requires the State of Vermont to consult with other states/tribes to develop coordinated emission management strategies. This requirement applies both when emissions from a state/tribe are reasonably anticipated to contribute to visibility impairment in Class I areas outside the state/tribe and when emissions from other states/tribes are reasonably anticipated to contribute to visibility impairment at mandatory Class I areas within a state/tribe.

Vermont consulted with other states/tribes by participating in the MANE-VU and inter-RPO processes leading to the creation of coordinated strategies on regional haze. This coordinated effort considered the individual and aggregated impacts of states'/tribes' emissions on Class I areas within and outside the states/tribes. Through the MANE-VU process, more than twenty states and Canadian provinces have been identified as contributing to visibility degradation in the Lye Brook Wilderness Area. On February 23, 2007, Vermont sent letters formally requesting consultation under the Regional Haze Rule to states and Canadian provinces – specifically, those shown via modeling to contribute at least 2 percent of visibility-impairing sulfates at Lye Brook and all other states located within MANE-VU.

To maintain consistency within MANE-VU, every MANE-VU member was requested to consult with Vermont. Several states outside MANE-VU were also requested to join this consultation in response to the findings of MANE-VU's evaluations. Independent of the other MANE-VU states with Class I areas, Vermont separately identified Wisconsin as having the potential to impact the Lye Brook Wilderness Area based on CALPUFF regional modeling using the VTDEC modeling platform which predicts Wisconsin impacts on sulfate there as equivalent to those from Illinois, ie 4% {see page D-54 of the NESCAUM report, "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States", August 2006 (Attachment A}. In addition, the Canadian Provinces of Ontario and Quebec were invited to join in informal consultation with Vermont, although they are under no legal obligation to meet U.S. requirements. Table 3.4 provides a complete listing of states, provinces, and regional planning organizations invited to participate in consultations with Vermont on measures to mitigate regional haze. Note that all MANE-VU states with Class I areas have similarly requested consultation with Vermont on the regional haze issue.

Table 3.4 States (Listed by Regional Planning Organization) and Provinces Contributing to Visibility Impairment at Vermont's Lye Brook Wilderness Area

MANE-VU	VISTAS	MRPO	INTERNATIONAL
Connecticut	Georgia	Illinois	Ontario, Canada
Delaware	Kentucky	Indiana	Quebec, Canada
District of Columbia	North Carolina	Michigan	
Maine	South Carolina	Ohio	
Maryland	Tennessee	Wisconsin	
Massachusetts	Virginia		
New Jersey	West Virginia		
New York			
Pennsylvania			
Rhode Island			
New Hampshire			

As a result of the invitation to consult, Ontario, Canada, invited representatives of Vermont Department of Environmental Conservation (VTDEC), New Hampshire Department of Environmental Services (NHDES), Maine Department of Environmental Protection (MEDEP), New York Department of Environmental Conservation (NYDEC), and NESCAUM to join the Shared Air Summit in Toronto on June 12, 2007, followed by an informal consultation meeting with representatives from Ontario on June 13, 2007. At these meetings, Ontario announced its plan to shut down all coal electrical generation and challenged participating states to pursue similar goals. Considerable discussion took place regarding trans-border air pollution transport and its affect on human health.

Formal inter-regional consultation meetings took place on August 6, 2007, in Rosemont, Illinois, (for Midwestern states) and on August 20, 2007, in Atlanta, Georgia, (for Southern states). Consultation continues with the Midwestern states, seeking common approaches for reducing power plant emissions beyond the levels defined under the federal CAIR rule,

controls on industrial boilers, and cleaner-burning fuels for mobile sources. Ongoing consultation with MRPO focuses mainly on the health benefits of reducing ozone and small particulate emissions; however, the control measures being considered would also result in visibility improvements.

3.2.2 The MANE-VU "Ask"

In addition to having a set of guiding principles for consultation (as described in Table 3.2, above), MANE-VU needed a consistent technical basis for emission control strategies to combat regional haze. After much research and analysis, on June 20, 2007, MANE-VU adopted the following pair of documents (available in Attachment D), which provide the technical basis for consultation among the interested parties and define the basic strategies for controlling pollutants that cause visibility impairment at Class I areas in the eastern U.S.:

- "*Statement of the Mid-Atlantic / Northeast Visibility Union (MANE-VU) Concerning a Course of Action within MANE-VU toward Assuring Reasonable Progress*," and

- "*Statement of the Mid-Atlantic / Northeast Visibility Union (MANE-VU) Concerning a Request for a Course of Action by States outside of MANE-VU toward Assuring Reasonable Progress*."

Together, these documents are known as the MANE-VU "Ask." Because Vermont agrees in total to the language and substance of these documents, the MANE-VU's Ask is also the Vermont Ask. The particular emission management strategies that comprise the Ask are described in Subparts 3.2.2.1 through 3.2.2.3, below.

3.2.2.1 Meeting the "Ask" – MANE-VU States

The member states of MANE-VU have stated their intention to meet the terms of the Ask in their individual State Implementation Plans. The Ask for member states promises that each state will pursue the adoption and implementation of the following emission management strategies, as appropriate and necessary:

- ***Timely implementation of BART requirements***, in accordance with 40 CFR 51.308(e).

- ***A low-sulfur fuel oil strategy in the inner zone states*** (New Jersey, New York, Delaware and Pennsylvania, or portions thereof) to reduce the sulfur content of: distillate oil to 0.05% sulfur by weight (500 ppm) by no later than 2012, of #4 residual oil to 0.25% sulfur by weight by no later than 2012, of #6 residual oil to 0.3-0.5% sulfur by weight by no later than 2012, and to reduce the sulfur content of distillate oil further to 15 ppm by 2016;

- ***A low-sulfur fuel oil strategy in the outer zone states*** (the remainder of the MANE¬VU region) to reduce the sulfur content of distillate oil to 0.05% sulfur by weight (500 ppm) by no later than 2014, of #4 residual oil to 0.25-0.5% sulfur by

weight by no later than 2018, and of #6 residual oil to no greater than 0.5 % sulfur by weight by no later than 2018, and to reduce the sulfur content of distillate oil further to 15 ppm by 2018, depending on supply availability;

• ***A targeted EGU strategy*** for the top 100 electric generating unit (EGU) emission points, or stacks, identified by MANE-VU as contributing to visibility impairment at each mandatory Class I area in the MANE-VU region. (The combined list for all seven MANE-VU Class I Areas contains 167 distinct emission points. Consequently, this strategy is sometimes referred to as the 167-stack strategy.) The targeted EGU strategy calls for a ninety percent or greater reduction in sulfur dioxide (SO_2) emissions from all identified units. If it is infeasible to achieve that level of reduction from specific units, equivalent alternative measures will be pursued in such state; and

• ***Continued evaluation of other control measures***, including improvements in energy efficiency, use of alternative (clean) fuels, further control measures to reduce SO_2 and nitrogen oxide (NO_X) emissions from all coal-burning facilities by 2018, and new source performance standards for wood combustion. These and other measures will be evaluated during the consultation process to determine whether they are reasonable strategies to pursue.

Vermont supports the SIPs of each of its fellow MANE-VU states, provided that these commitments are incorporated into approvable State Implementation Plans.

3.2.2.2 Meeting the "Ask" – Vermont

Vermont, being a MANE-VU member state, adopted the Ask at the MANE-VU Board meeting on June 7, 2007. Vermont contains no BART-eligible sources, but intends to meet the terms of the MANE-VU agreement by pursuing the low-sulfur fuel oil strategy. Vermont intends to adopt a rule specifying the low sulfur fuel limits for "outer zone" MANE-VU states in the near future. After this rule is adopted, Vermont will submit the rule to EPA for approval into the Vermont SIP. Vermont will also continue investigating sources of cleaner energy.

3.2.2.3 Meeting the "Ask" – States outside MANE-VU

Vermont agrees with the MANE-VU Ask for consulting states outside the MANE-VU region. This Ask requests the affected states to pursue adoption and implementation of the following control strategies, as appropriate and necessary:

• ***Timely implementation of BART requirements***, as described for the MANE-VU states;

• ***A targeted EGU strategy***, as described for the MANE-VU states, for the top 167 EGU stacks contributing the most to visibility impairment at mandatory Class I areas in the MANE-VU region, or an equivalent SO_2 emission reduction within each state;

- ***Installation of reasonable control measures on non-EGU sources by 2018*** to achieve an additional 28 percent reduction in non-EGU SO_2 emissions beyond current on-the-books/on-the-way (OTB/OTW) measures, resulting in an emission reduction that is equivalent to that from MANE-VU's low-sulfur fuel oil strategy (see Section 11.0, Long-Term Strategy);

- ***Continued evaluation of other control measures***, including additional reductions in SO_2 and NO_X emissions from all coal-burning facilities by 2018 and promulgation of new source performance standards for wood combustion. These and other measures will be evaluated during the consultation process to determine whether they are reasonable strategies to pursue.

Vermont looks for each consulting state to address specifically, in its Regional Haze SIP, each element of the MANE-VU Ask.

Vermont is concerned that non-MANE-VU states may be inclined not to adopt MANE-VU's Ask because of the associated costs, potential conflicts, and relative lack of perceived benefits within their jurisdictions. On the basis of consultations held, MANE-VU members believe that some non-MANE-VU states will choose not to pursue reductions beyond CAIR controls and other measures pertaining to BART requirements.

There are some positive exceptions, however. Many states of the MRPO are working with MANE-VU states to investigate the potential for widespread use of low-sulfur fuel oil and installation of emission controls on ICI boilers within their region. The Midwest states would be more likely than Southeast states to adopt a low-sulfur oil strategy because the VISTAS states do not have the same extent of fuel oil usage and lack the inventory infrastructure found in more northerly states. Both MRPO and VISTAS claim that a substantial portion of the top 167 contributing EGU stacks will be controlled. However, instead of taking concrete actions on uncontrolled or under-controlled facilities, many of these states appear to be satisfied with meeting CAIR requirements and not looking beyond CAIR for additional emission reductions. Further discussion of these issues is provided in Part 3.2.4, below.

3.2.3 Technical Ramifications of Differing Approaches

MANE-VU states intended to develop a modeling platform that was common in terms of meteorology and emissions with each of the other nearby RPOs. The RPOs worked hard to form a common set of emissions with similar developmental assumptions. Even with the best of intentions, it became difficult to keep up with each RPO's updates and corrections. Each rendition of emissions inventory improved its quality, but even a single update to one RPO's emissions required each of the other RPOs to adopt the updates. With each rendition, the revised emissions had to be re-blended with the full set of emission files for all associated RPOs in the modeling domain. Because each rendition put previous modeling efforts out of date, and a single modeling run could take more than a month to complete, inventory updates have contributed to SIP delays. The emission inventory conflicts have been excessively time-consuming and caused most states to miss the official filing date of December 17, 2007.

The RPOs also took differing perspectives on which version of the EGU dispatching model to use. At the beginning of the process, International's Integrated Planning Model (IPM) version 2.1.9 was available, and EPA agreed to its use for emissions preparation. Subsequently, IPM version 3.0 became available and was preferred by some users because of its updated fuel costs. MRPO adopted IPM v3.0 for its use, but VISTAS stayed with IPM v2.1.9. Rather than develop non-comparative datasets for its previous IPM analyses, MANE-VU opted also to remain with IPM v2.1.9. Therefore, for the three eastern RPOs, differing emissions assumptions eventually worked their way into the final set of modeling assumptions.

MANE-VU's most recent visibility projections take into account on-the-books/on-the-way (OTB/OTW) emissions control programs for 2018, and go further by including additional reasonable controls in the region, as developed through the MANE-VU Ask. It should be noted that other RPOs may not have included such measures in their final modeling and, as a result, may have been able to complete their analyses ahead of MANE-VU's. Where that is the case, those states' modeling results will be inconsistent with meeting the terms of the Ask – a situation that may not be adequately addressed in their individual SIPs.

3.2.4 Consultation Issues

40 CFR 51.308(d)(1)(iv) of the Regional Haze Rule describes another consultation requirement for Class I states. If a contributing state does not agree with a Class I state on its reasonable progress goal, the Class I state must describe in its SIP submittal the actions taken to resolve the disagreement.

While states without Class I areas are required to consult at the request of states with Class I areas, the Regional Haze Rule does not actually require the states to agree on a common course of action. Instead, if agreement cannot be reached, the disagreement needs to be described in each state's SIP along with a description of what actions were taken to resolve the disagreement. Most states willingly consulted with Vermont and took Vermont's regional haze Ask under serious consideration. In fact, all of the MANE-VU states worked together to strategize on how to develop a common approach to meeting the Ask. All states involved in these discussions found that working together helped them to develop plans that would produce region-wide visibility and health benefits. In particular, reductions in SO_2 emissions, because they would yield lower ambient concentrations of fine particle ($PM_{2.5}$) pollution, would help all MANE-VU states in meeting the NAAQS and would have direct benefits to public health and welfare.

Some states in the MRPO and VISTAS regions had interpretations of the requirements for BART and for establishing Reasonable Progress Goals which differed from those in the MANE-VU states. Some states claimed that CAIR alone set the standard for reasonableness. By this rationale, any measure more expensive than CAIR on a cost-per-ton basis would not be reasonable. A uniform rate of progress was all that some states felt was required; and if that set of conditions could be met with CAIR, then no other measures needed to be considered. Also a concern for Vermont is the possibility that some states may have performed modeling for establishment of reasonable progress goals without including the effects of a rigorous BART determination for the non-EGU sector. It is apparent that the

various regions of the country have differing interpretations of how the Regional Haze Rule should be applied.

In a letter to MANE-VU dated April 25, 2008 (Attachment E), VISTAS indicates that most actions beyond CAIR by states within this region would not be reasonable. MANE-VU takes a more rigorous position with respect to additional control measures – including the belief that controls on ICI boilers and use of low-sulfur fuels are reasonable measures and that it is not reasonable to assume reductions from EGUs for planning purposes unless they are explicitly incorporated into a State Implementation Plan. More specifically, MANE-VU believes that a sector-wide average of 50-percent control on coal-fired boilers and 75-percent control on oil-fired boilers are reasonable targets that can be achieved cost-effectively. Also, MANE-VU believes that low sulfur fuels – even though they are less widely available in the Southeast U.S. than in the Northeast – still represent a reasonable control measure in light of the widespread requirement for use of such fuels throughout the MANE-VU region. The reasonableness of these additional controls is examined more fully in Section 10.0, Reasonable Progress Goals.

During the consultation process, disagreements such as these were worked through to the maximum extent possible, and the results of these consultations are summarized below:

• ***Situation***: BART analyses and projected controls were not fully incorporated into the VISTAS emissions inventory provided to MANE-VU. VISTAS stated that they would further review BART-applicable controls.

→ ***Outcome***: In MANE-VU's modeling to determine reasonable progress goals, MANE-VU made no adjustments to controls in the VISTAS region to reflect application of BART beyond the information that VISTAS provided.

• ***Situation***: The low-sulfur fuel oil strategy adopted by MANE-VU elicited concerns from MRPO and VISTAS as not being reasonable because of the limited availability of low-sulfur fuel oil and the historically lower usage of this fuel within their regions.

→ ***Outcome***: MANE-VU agreed to modify the Ask to reflect greater flexibility in providing for alternative measures that would produce a comparable rate of emission reductions. Accordingly, the Ask for non-MANE-VU states was modified to provide for an overall 28 percent reduction in SO_2 emissions wherever they were found to be reasonable. In MANE-VU's modeling to determine reasonable progress goals, SO_2 emissions from non-EGU sources in non-MANE¬VU contributing states were reduced by this same amount.

• ***Situation***: MANE-VU received no response from other RPOs concerning non-EGU control measures that they did consider reasonable.

→ ***Outcome***: As a default position, MANE-VU's modeling included emission adjustments for those regions based on MANE-VU's own analyses of what constituted reasonable control measures from non-EGU sources (see Section 10.0, Reasonable Progress Goals).

• ***Situation***: The targeted EGU strategy was thought by some non-MANE-VU states to be too restrictive and too difficult to achieve. MANE-VU recognized that a 100¬percent compliance with this portion of the Ask was unlikely to occur because the CAIR trading market would probably dominate. However, MANE-VU had hoped that non-MANE-VU states would make a more concerted effort toward meeting this request. MANE-VU did receive a partial list of facilities that were expected to comply.

> → ***Outcome***: For the top contributing EGU stacks located within the MANE-VU, MRPO, and VISTAS regions, expected emission reductions resulting from the Ask were distributed among facilities on the basis of recommendations received during inter- and intra-regional consultations. To maintain the CAIR emissions budget as predicted by the modeling, excess emission reductions (also predicted by the modeling) were uniformly added back to EGUs in all three regions.

While CAIR is the primary determinant of which EGUs among the top 167 stacks are to be fitted with emission controls, at the same time, MANE-VU recognized that these units are the primary sources affecting visibility in the MANE-VU states. For the initial planning, MANE-VU has allowed flexibility as to how other RPOs meet the Ask. However, MANE-VU expects that, over time, these actual facilities will need to be controlled if significant improvements in visibility at affected Class I areas are to be realized.

MANE-VU believes that the goals of the Ask will be attained only by means of binding obligations to EGU emission reductions beyond what CAIR was expected to provide. MANE-VU therefore maintains that additional federal action is needed to achieve the visibility benefits shown to be feasible through sensitivity modeling (see Attachment F, "MANE-VU Modeling for Reasonable Progress Goals: Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," Feb. 7, 2008) and demonstrated to be available at reasonable cost (see Attachment H, Alpine Geophysics, LLC, "Documentation of 2018 Emissions from Electric Generating Units in the Eastern United States for MANE-VU's Regional Haze Modeling," Revised Final Draft, April 28, 2008).

MANE-VU's position on this issue is formally expressed in its "Statement of the Mid-Atlantic / Northeast Visibility Union (MANE-VU) Concerning a Request for a Course of Action by the U.S. Environmental Protection Agency (EPA) toward Assuring Reasonable Progress," adopted June 20, 2007. This statement, more commonly known as MANE-VU's National Ask, is included in Attachment D. Although other RPOs did not adopt all of the same philosophies or processes for their regional haze SIPs, the consultation process maintains a central role in regional haze planning. Vermont is pleased with the significant opportunities identified for ongoing consultation with other states concerning long-term strategies not only for regional haze mitigation but also for improved air quality in general.

Vermont and other MANE-VU states are committed to continuing consultation with states in the MRPO and VISTAS regions, through participation in the State Collaborative Process, in which new regional control strategies are discussed to reduce future emissions of multiple pollutants of common regional concern.

3.2.5 State/Tribe and Federal Land Manager Coordination

Vermont will continue to coordinate and consult with the Federal Land Managers during the development of future progress reports and plan revisions, as well as during the implementation of programs having the potential to contribute to visibility impairment in the mandatory Class I areas.

40 CFR 51.308(i) of the Regional Haze Rule requires coordination between states/tribes and the Federal Land Managers (FLMs). Opportunities have been provided by MANE-VU for FLMs to review and comment on the technical documents developed by MANE-VU and included in this SIP. Vermont has identified agency contacts to the FLMs as required under 40 CFR 51.308(i)(1). Vermont has consulted with the FLMs in the development of this plan and, in accordance with 40 CFR 51.308(i)(2), has provided the FLMs an opportunity for consultation, in person, at least 60 days prior to holding any public hearing on the SIP.

On December 22, 2008, Vermont submitted a 12/18/08 draft of this Regional Haze SIP Revision to the Federal Land Management Agencies (FLMs), including the Forest Service of the U.S. Department of Agriculture and the National Park Service and U.S. Fish and Wildlife Service of the U.S. Department of the Interior (DOI) for a 60-day review and comment period. On January 15, 2009, Vermont submitted a slightly revised 1/15/09 draft of this Regional Haze SIP Revision for 30-day review and comment by the U.S. Environmental Protection Agency (EPA). The 1/15/09 draft was identical to the 12/18/08 draft with the exception that it included minor revisions to reflect the 12/23/08 D.C. Circuit Court decision to remand the EPA Clean Air Interstate (CAIR) Rule without vacatur.

The 1/15/09 draft Regional Haze SIP revision was also posted on the Vermont APCD website at http://www.anr.state.vt.us/air/Planning/htm/DraftRegionalHazeSIP.htm and was noticed in the newspapers of record in Vermont on Thursday January 15, 2009. The newspaper notices and the APCD website provided an opportunity for public hearing to be held, if requested, on February 23, 2009 in Waterbury, Vermont. As no additional public comments or requests for a public hearing were received prior to February 17, 2009, the public hearing was cancelled.

Vermont did receive written comments from the Forest Service and the Department of the Interior on February 19, 2009, and from EPA on February 24, 2009. These comments are included in Attachment H. Vermont has subsequently made a number of revisions which are incorporated into the current May 11, 2009 version of this VT Regional Haze SIP. A listing of the specific FLM and EPA comments and Vermont's responses to them are summarized in the document entitled "Vermont Responses to FLM and EPA Comments" included in Attachment H.

40 CFR 51.308(i)(4) requires procedures for continuing consultation between the states/tribes and FLMs on the implementation of the visibility protection program. Vermont will consult periodically with the FLMs as necessary on the status of the following implementation items. In particular, consultations will be conducted with the designated visibility protection program coordinators for the National Park Service, U.S. Fish and Wildlife Service, and the U.S. Forest Service on:

1. Status of emissions strategies identified in the SIP as contributing to improvements in the worst-day visibility;

2. Summary of major new source permits issued;

3. Status of Vermont's actions toward completing any future assessments or rulemakings on sources identified as probable contributors to visibility impairment, but not directly addressed in the most recent SIP revision;

4. Any changes to the monitoring strategy or status of monitoring stations that might affect tracking of reasonable progress;

5. Work underway for preparing the 5-year SIP review and/or 10-year SIP revision, including any items where the FLMs' consideration or support is requested; and

6. Summary of topics discussed in ongoing communications (e.g., meetings, emails, etc.) between Vermont and the FLMs regarding implementation of the visibility improvement program.

4. Assessment of Baseline and Natural Visibility Conditions

Pursuant to 40 CFR 51.308(d)(2) of the Regional Haze Rule, states must determine baseline and natural visibility conditions for each Class I area within their jurisdictions. This information allows states to assess current levels of visibility degradation and provides a basis for setting reasonable progress goals toward restoration of natural visibility conditions in Class I areas.

The effectiveness of any plan to reduce regional haze in Class I areas is dependent on the availability of reliable data. The Interagency Monitoring of Protected Visual Environments (IMPROVE) program was established in 1985 to provide the data necessary to support the creation of Federal and State implementation plans for the protection of visibility in Class I areas. IMPROVE has made it possible to assess current visibility conditions, track changes in visibility, and identify the chemical species and emission sources responsible for visibility impairment. In particular, IMPROVE data were used to calculate baseline and natural conditions for MANE-VU Class I Areas.

The IMPROVE monitors listed in Table 4.1 provide data representative of Class I Areas in the MANE-VU region.

Table 4.1 IMPROVE Monitors for MANE-VU Class I Areas

IMPROVE Site / Location	Class I Area(s) Served	Latitude, Longitude	State
ACAD1 Acadia National Park	Acadia National Park	44.38, -68.26	ME
BRIG1 Brigantine National Wildlife Refuge	Brigantine National Wildlife Refuge	39.47, -74.45	NJ
GRGU1 Great Gulf Wilderness	Great Gulf Wilderness Presidential Range – Dry River Wilderness	44.31, -71.22	NH
LYBR1 Lye Brook Wilderness	Lye Brook Wilderness	43.15, -73.13	VT
MOOS1 Moosehorn Wilderness	Moosehorn Wilderness, Roosevelt Campobello International Park	45.13, -67.27	ME

http://www.vista.circa.colostate.edu/views/ ; http://vista.cira.colostate.edu/improve/

4.1 Calculation Methodology

In September 2003, EPA issued guidance for the calculation of natural background and baseline visibility conditions. The guidance provided a default method and described certain refinements that states might consider in order to tailor their estimates to any Class I areas not adequately represented by the default method. At that time, MANE-VU calculated natural visibility for each of the MANE-VU Class I Areas using the default method for the 20 percent best and 20 percent worst visibility days. MANE-VU also evaluated ways to refine the estimates. Potential refinements included 1) increasing the multiplier used to calculate impairment attributed to carbon, 2) adjusting the formula used to calculate the 20 percent best and worst visibility days, and 3) accounting for visibility impairment caused by sea salt at coastal sites. However, MANE-VU found that these refinements did not significantly improve the accuracy of the estimates, and MANE-VU states desired a consistent approach to visibility assessment. Therefore, default estimates were used with the understanding that this methodology would be reconsidered upon demonstrated improvements in the science.

Once the technical analysis of visibility conditions was complete, MANE-VU provided an opportunity to comment to federal agencies and stakeholders. The proposed approach to visibility assessment was posted on the MANE-VU website on March 17, 2004, and a stakeholder briefing was held on the same day. Comments were received from the Electric Power Research Institute (EPRI), the Midwest Ozone Group (MOG), the Appalachian Mountain Club, the National Parks Conservation Association, the National Park Service, and the US Forest Service.

Several comments supported the proposed approach in general; other comments were divided among four main topics: 1) the equation used to calculate visibility, 2) the statistical technique used to estimate the 20 percent best and worst visibility days, 3) the inclusion of transboundary effects and fires, and 4) the timing as to when new information should be included. All comments were reviewed and summarized by MANE-VU; and air directors were briefed on comments, proposed response options, and implications. Attachment J provides a compilation of comments received and a summary of stakeholders' comments.

MANE-VU's position on natural background conditions was presented in a report issued in June 2004 (see Attachment I, "Natural Background Visibility Conditions: Considerations and Proposed Approach to the Calculation of Natural Background Visibility Conditions at MANE-VU Class I Areas," June 10, 2004). The report stated, "Refinements to other aspects of the default method (e.g., refinements to the assumed distribution or treatment of Rayleigh extinction, inclusion of sea salt, and improved assumptions about the chemical composition of the organic fraction) may be warranted prior to submission of SIPs depending on the degree to which scientific consensus is formed around a specific approach…"

In 2006, the IMPROVE Steering Committee adopted an alternative reconstructed extinction equation to revise certain aspects of the default method. The scientific basis for these revisions was well understood, and the Committee determined that the revisions improved the performance of the equation at reproducing observed visibility at Class I sites. This Revised IMPROVE extinction equation was presented in Section 1.7 of this document.

In 2006, MANE-VU conducted an assessment of the default and alternative approaches for calculation of baseline and natural background conditions at MANE-VU Class I Areas. Based on that assessment, in December 2006, MANE-VU recommended adoption of the alternative reconstructed extinction equation for use in the regional haze SIPs. (See Attachment J, "Baseline and Natural Background Visibility Conditions: Considerations and Proposed Approach to the Calculation of Baseline and Natural Background Visibility Conditions at MANE-VU Class I Areas," December 2006.) MANE-VU will continue to participate in further research efforts on this topic and will reconsider the calculation methodology as scientific understanding evolves.

4.2 MANE-VU Baseline Visibility

The IMPROVE program has calculated the 20 percent best and 20 percent worst baseline (2000-2004) and natural visibility conditions using the EPA-approved alternative method described above for each MANE-VU Class I Area. The data are posted on the Visibility Information Exchange Web System (VIEWS) operated by the regional planning organizations. The information can be accessed at http://vista.cira.colostate.edu/views/) and is summarized in Table 4.2 below. Displayed are the five-year average baseline visibility values for the period 2000-2004, natural visibility levels, and the difference between baseline and natural visibility values for each of the MANE-VU Class I Areas. The difference columns (best and worst) are of particular interest because they describe the magnitude of visibility impairment attributable to manmade emissions, which are the focus of the Regional Haze Rule.

The five-year averages for 20 percent best and worst visibility were calculated in accordance with 40 CFR 51.308(d)(2), as detailed in NESCAUM's Baseline and Natural Background document found in Attachment J.

Table 4.2 Summary of Baseline Visibility and Natural Visibility Conditions for the 20 Percent Best and 20 Percent Worst Visibility Days at MANE-VU Class I Areas

Class I Area(s)	2000-2004 Baseline (deciviews)		Natural Conditions (deciviews)		Difference (deciviews)	
	Best 20%	Worst 20%	Best 20%	Worst 20%	Best 20%	Worst 20%
Acadia National Park	8.8	22.9	4.7	12.4	4.1	10.5
Moosehorn Wilderness and Roosevelt Campobello International Park	9.2	21.7	5.0	12.0	4.1	9.7
Great Gulf Wilderness and Presidential Range – Dry River Wilderness	7.7	22.8	3.7	12.0	3.9	10.8
Lye Brook Wilderness	6.4	24.4	2.8	11.7	3.6	12.7
Brigantine Wilderness	14.3	29.0	5.5	12.2	8.8	16.8

Source: VIEWS (http://vista.circa.colostate.edu/views/), prepared on 6/22/2007

4.3 Lye Brook Wilderness Baseline Visibility

As indicated in the table above, the 2001-2004 baseline visibility for the Lye Brook Wilderness was 6.4 deciviews for the 20 percent best visibility days and 24.5 deciviews for the 20 percent worst visibility days. As described in the Section 5.0 Monitoring Strategy of this SIP, Vermont accepts designation of this monitoring site as representative of the Lye Brook Wilderness Area in accordance with 40 CFR 51.308(d)(2)(i). Tables 4.3 and 4.4 list the baseline visibility for the 20 percent best and 20 percent worst visibility days for each year of the period 2000-2004, from which the valid four-year average values in Table 4.2 were calculated. The averages were determined in accordance with 40 CFR 51.308(d)(2), as detailed in the NESCAUM Baseline and Natural Background document found in Attachment J of this SIP. The deciview visibility values for best and worst days were obtained from data included in Attachment J.

Table 4.3 Baseline Visibility for the 20 Percent Best Days During 2000-2004 in the Lye Brook Wilderness Area

Class I Area(s)	Year	Deciviews (dv)
Lye Brook Wilderness Area	2000	6.5
	2001	6.5
	2002	6.4
	2003	5.8
	2004	6.6
	Average	6.4

Source: VIEWS (http://vista.circa.colostate.edu/views)

Table 4.4 Baseline Visibility for the 20 Percent Worst Days During 2000-2004 in the Lye Brook Wilderness Area

Class I Area(s)	Year	Deciviews (dv)
Lye Brook Wilderness Area	2000	23.5
	2001	26.3
	2002	25.5
	2003	24.0
	2004	22.9
	Average	24.4

Source: VIEWS (http://vista.circa.colostate.edu/views)

4.4 Lye Brook Wilderness Area – Natural Background

Natural background refers to the visibility conditions that existed before human activities affected air quality in the region. Consistent with the stated visibility goals of the Clean Air Act, natural background is identified as the visibility target to be reached by 2064 in each Class I area.

The Lye Brook Wilderness Area has an estimated natural background visibility of 2.8 deciviews on the 20 percent best days and 11.7 deciviews on the 20 percent worst days. These best and worst 20 percent visibility values were calculated using the above-referenced EPA guidelines and approved alternative method described in NESCAUM's Baseline and Natural Background document (Attachment J). This method of calculating natural background using the revised IMPROVE algorithm is also described in detail by Copeland et al. (2008)* and the calculations are available on the VIEWS website at:
http://vista.cira.colostate.edu/Docs/IMPROVE/Aerosol/NaturalConditions/NaturalConditionsII_Format2_v2.xls.

* Copeland, S. A., M. Pitchford and R. Ames (2008) Regional Haze Rule Natural Level Estimates Using the Revised IMPROVE Aerosol Reconstructed Light Extinction Algorithm, AWMA Specialty Conference on Aerosol & Atmospheric Optics: Visual Air Quality and Radiation at Moab, Utah, April 2008

5. Monitoring Strategy

In the mid-1980's, the IMPROVE program (Interagency Monitoring of Protected Visual Environments) was established to measure visibility impairment in mandatory Class I areas throughout the United States. The monitoring sites are operated and maintained through a formal cooperative relationship between the U.S. EPA, National Park Service, U.S. Fish and Wildlife Service, Bureau of Land Management, and U.S. Forest Service. In 1991, several additional organizations joined the effort: State and Territorial Air Pollution Program Administrators and the Association of Local Air Pollution Control Officials (which now goes by The National Association of Clean Air Agencies), Western States Air Resources Council, Mid-Atlantic Regional Air Management Association, and Northeast States for Coordinated Air Use Management.

5.1 IMPROVE Program Objectives and Vermont Monitoring Commitments

Data collected at these sites are used by land managers, industry planners, scientists, public interest groups, and air quality regulators to understand and protect the visual air quality resource in Class I areas. Most importantly, the IMPROVE program scientifically documents for American citizens, the visual air quality of their wilderness areas and national parks. Program objectives include:

- Establish current visibility and aerosol conditions in mandatory Class I areas,
- Identify chemical species and emission sources responsible for existing anthropogenic visibility impairment,
- Document long-term trends for assessing progress towards the national visibility goals,
- Provide regional haze monitoring representing all visibility-protected federal Class I areas where practical, as required by EPA's Regional Haze Rule.

Section 51.308(d)(4) of EPA's Regional Haze Rule requires a monitoring strategy for measuring, characterizing, and reporting regional haze visibility impairment that is representative of the mandatory Class I Lye Brook Wilderness Area within the State of Vermont. The monitoring strategy relies upon participation in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network.

The State/Tribe will evaluate the monitoring network periodically and make those changes needed to be able to assess whether reasonable progress goals are being achieved in the Lye Brook Wilderness Area. Vermont commits to meet the requirements under 40 CFR 51.308(d)(4)(iv) to report to EPA visibility data for the Lye Brook Wilderness Area annually, via the VIEWS (Visibility Information Exchange Web Site) at: http://vista.cira.colostate.edu/views/) .

Section 51.308(d)(4)(ii) of EPA's Regional Haze Rule requires the inclusion of procedures by which monitoring data and other information are used in determining the contribution of emissions from within the State to regional haze visibility impairment at mandatory Class I

Federal areas both within and outside the State. MANE-VU and the State of Vermont accepts the contribution assessment analysis completed by NESCAUM entitled, *Contributions to Regional Haze in the Northeast and Mid-Atlantic States*. See Attachment A and associated appendices. We agree that NESCAUM is providing quality technical information by using the IMPROVE program data and the VIEWS site. Information about the use of the default and alternative approaches to the calculation of baseline and natural background conditions can be found in Section 4 Assessment of Baseline, Natural and Current Conditions of this SIP.

Section 51.308 of the Federal Regulation Haze Rule requires each state containing a mandatory Class I Federal area to include in its SIP a strategy for evaluating reasonably attributable visibility impairment (RAVI) in any such Class I Area by visual observation or other appropriate monitoring techniques. The plan must provide for the consideration of available visibility data and must provide a mechanism for its use. This requirement does not apply to the State of Vermont because no specific sources have been identified as subject to RAVI requirements.

Section 51.308(d)(4)(v) of EPA's Regional Haze Rule requires a statewide inventory of emissions of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in mandatory Class I Federal areas within the State of Vermont. The Emissions Inventory Section (Section 7) of this SIP addresses this requirement.

Section 51.308(d)(4)(vi) of EPA's Regional Haze Rule requires the inclusion of other monitoring elements, including reporting, recordkeeping, and other measures, necessary to assess and report visibility. While the state of Vermont feels that the current IMPROVE network provides sufficient data to adequately measure and report progress toward the goals set for MANE-VU and other Class I sites that we may contribute to, Vermont has also found additional monitoring information useful to assess visibility and fine particle pollution in the region in the past. Examples of these data include results from the MANE-VU RAIN network, which provides continuous, speciated information on rural aerosol characteristics and visibility parameters; the EPA CASTNET program, which has provided complementary rural fine particle speciation data at non-class I sites; the EPA Speciation Trends Network (STN), which provides speciated, urban fine particle data to help develop a comprehensive picture of local and regional sources; state-operated rural and urban speciation sites using IMPROVE or STN methods; and the Supersites program, which has provided information through special studies that generally expands our understanding of the processes that control fine particle formation and transport in the region. Vermont will continue to utilize these and other data -- as they are available and fiscal realities allow -- to improve our understanding of visibility impairment and to document progress toward our reasonable progress goals under the Regional Haze Rule.

5.2 Lye Brook Wilderness, Vermont - Monitor Location

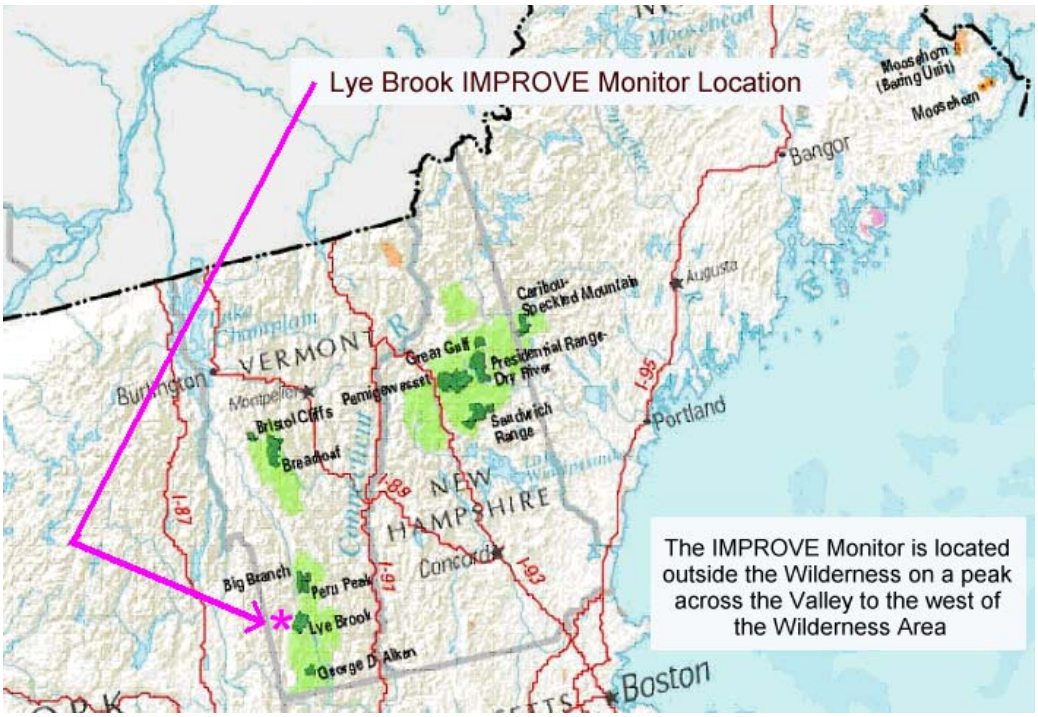
The IMPROVE monitor for the Lye Brook Wilderness Area (indicated as LYBR1) is located on Mount Equinox at the windmills in Manchester Vermont. (see Figures 5.1 through 5.3) The monitor is not in the Wilderness Area but is located on a mountain ridge across the valley to the west of the wilderness. The Wilderness Area is at high elevation in the Green

Mountains and the IMPROVE site across the valley is at about the same height as the Wilderness Area at 1015 meters elevation, a latitude of 43.15˚ and a longitude of -73.13˚.

5.3 Lye Brook Wilderness Monitoring Strategy

The haze data for Lye Brook Wilderness Area is collected by an IMPROVE monitor (LYBR1) that is operated and maintained by the Forest Service. The State considers the LYBR1 site as adequate for assessing reasonable progress goals of the Lye Brook Wilderness Area and no additional monitoring sites or equipment are necessary at this time. Vermont routinely participates in the IMPROVE monitoring program by serving as the NESCAUM regional representativeto the IMPROVE Steering Committee. Vermont is committed to working with other state, regional and federal IMPROVE partners to assure that adequate resources are available to provide continued monitoring representative of visibility conditions and trends in Lye Brook and other Class 1 areas.

Figure 5.1 Lye Brook Wilderness Area Location



Vermont currently lacks the funding and personnel resources to support enhancements to existing IMPROVE visibility monitoring at Lye Brook, but would be interested in discussing future options, including possibilities for sharing a haze camera with multiple Class I areas, with the Forest Service, other states and/or other Federal Land Management agencies. Additional details on the Lye Brook IMPROVE monitoring site, and on use of the aerosol monitoring data to calculate extinction are provided in Section 1 of this Plan.

Figure 5.2 Map of Lye Brook Wilderness Area and the IMPROVE Monitoring site

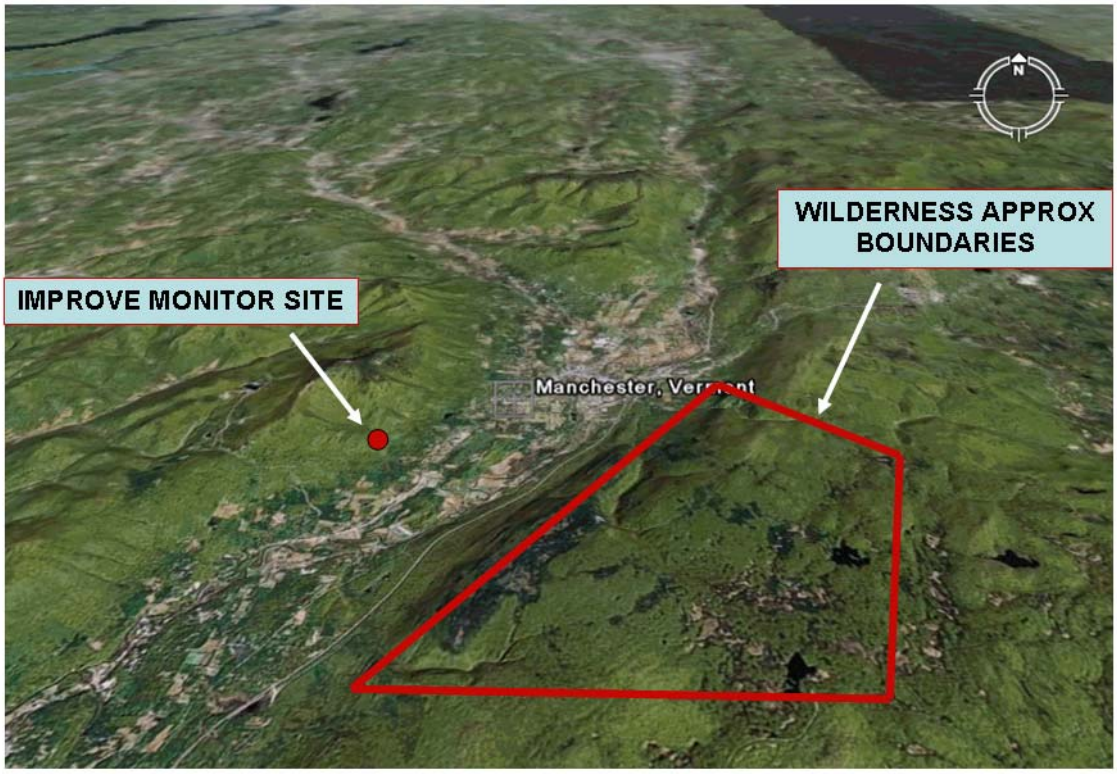


Figure 5.3 Lye Brook IMPROVE Monitoring Site on Little Mt. Equinox

6. Emission Inventory

40 CFR 51.308(d)(4)(v) of EPA's Regional Haze Rule requires a statewide emissions inventory of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any mandatory Class I area. The inventory must include emissions for a baseline year, future (projected) year, and the most recent year for which data are available. Vermont's baseline year is 2002,. The pollutants inventoried by Vermont include nitrogen oxides (NO_X), sulfur dioxides (SO_2), volatile organic compounds (VOCs), fine particles (particulate matter less than 2.5 micrometers in diameter, or $PM_{2.5}$), coarse particles (particulate matter less than 10 micrometers in diameter, or PM_{10}), and ammonia (NH_3). The following source categories were included in Vermont's emissions inventory: stationary point sources, stationary area sources, on-road mobile sources, non-road mobile sources, and biogenic sources. These emissions categories are discussed further in Subsection 7.3, Model Platforms.

6.1 Baseline and Future-Year Emissions Inventories for Modeling

40 CFR 51.308(d) (3) (iii) of EPA's Regional Haze Rule requires that the State of Vermont identify the baseline emissions inventory on which emission control strategies are founded. The baseline inventory is intended to be used for assessing progress in making emission reductions. In accordance with EPA's guidance memorandum "2002 Base Year Emission Inventory SIP Planning: 8-hour Ozone, $PM_{2.5}$, and Regional Haze Programs," November 18, 2002, all of the MANE-VU states are using 2002 as the baseline year for regional haze.

With contractor assistance, MARAMA developed a 2002 baseline modeling inventory using the inventories that Vermont and other states submitted to EPA to meet their SIP obligations and the requirements of the Consolidated Emissions Reporting Rule (CERR). To create the 2002 baseline inventory for modeling, MARAMA and its contractor quality-assured and augmented states' inventories and generated the necessary input files for the emissions processing model. As described in Part 6.1.1 below, work on this effort underwent several versions. Therefore, the 2002 baseline emissions summarized in this document may differ slightly from Vermont's original 2002 baseline inventory submittal.

Future-year inventories for 2009, 2012, and 2018 were projected from the 2002 base year. These future-year emissions inventories include emissions growth due to projected increases in economic activity as well as emissions reductions expected from the implementation of control measures. While the 2009 and 2012 emissions projections were originally developed in support of other MANE-VU states' ozone attainment demonstrations, the inventory for 2018 (the year targeted by the Regional Haze Rule) was developed for the specific purposes of regional haze SIP planning. Therefore, although the 2009 and 2012 projected inventories are mentioned in subsequent sections, only the 2002 baseline inventory and 2018 projected inventory are described below in Subsection 6.4, Summary of Emissions Inventories.

Accurate baseline and future-year emissions inventories are crucial to the analyses required for the regional haze SIP process. These emissions inventories were used to drive the air quality modeling simulations undertaken to assess the visibility improvements that would

result from possible control measures. Air quality modeling was also used to perform a pollution apportionment, which evaluates the contribution to visibility impairment by geographic region and emission source sector.

To be compatible with the air quality modeling simulations, the baseline and future-year emissions inventories were processed with the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions pre-processor for subsequent input into the CMAQ and REMSAD air quality models described in Subsection 7.3. Further description of the base and future-year emissions inventories is provided below.

6.1.1 Baseline Inventory (2002)

The starting point for the 2002 baseline emissions inventory was the 2002 inventory submittals that were made to EPA by state and local agencies as part of the Consolidated Emissions Reporting Rule (CERR). With contractor assistance (E.H. Pechan & Associates, Inc.,), MANE-VU then coordinated and quality-assured the 2002 inventory data, and prepared it for input into the SMOKE emissions model. The 2002 emissions from non-MANE-VU areas within the modeling domain were obtained from other Regional Planning Organizations for their corresponding areas. These Regional Planning Organizations included the Visibility Improvement State and Tribal Association of the Southeast (VISTAS), the Midwest Regional Planning Organization (MRPO), and the Central Regional Air Planning Association (CENRAP).

The 2002 baseline inventory went through several iterations. Work on Version 1 of the 2002 MANE-VU inventory began in April 2004, and the final inventory and SMOKE input files were completed during January 2005. Work on Version 2 (covering the period of April through September 2005) involved incorporating revisions requested by some MANE-VU state/local agencies on the point, area, and on-road categories. Work on Version 3 (covering the period from December 2005 through April 2006) included additional revisions to the point, area, and on-road categories as requested by some states. Thus, the Version 3 inventory for point, area, and on-road sources was built upon Versions 1 and 2. This work also included development of the biogenic inventory. In Version 3, the non-road inventory was completely redone because of changes that EPA made to the NONROAD2005 non-road mobile emissions model.

Version 3 of the MANE-VU 2002 baseline emissions inventory was used in the regional air quality modeling simulations. Further description of the data sources, methods, and results for this version of the 2002 baseline inventory is presented in E.H. Pechan & Associates, Inc., "Technical Support Document for 2002 MANE-VU SIP Modeling Inventories, Version 3, November 20, 2006, also known as the Baseline Emissions Report (Attachment K). Emissions inventory data files are available on the MARAMA website at: http://www.marama.org/visibility/EI_Projects/index.html.

6.1.2 Future-Year Emissions Inventories

Future-year emissions inventories are provided in MACTEC's technical support document, "Development of Emissions Projections for 2009, 2012, and 2018 for NonEGU Point, Area, and Nonroad Sources in the MANE-VU Region," Final Report, February 28, 2007, also known as the Emission Projections Report (Attachment L). This document describes the data sources, methods, and modeling results for three future years, five emission source sectors, two emission control scenarios, seven pollutants, and eleven states plus the District of Columbia. The following summarizes the basic framework of the future-year inventories that were developed:

- ***Projection years:*** 2009, 2012, and 2018;

- ***Emission source sectors:*** point-source electric generating units (EGUs), point-source non-electric generating units (non-EGUs), area sources, non-road mobile sources, and on-road mobile sources.

- ***Emission control scenarios*:**

  - *A combined on-the-books/on-the-way (OTB/OTW) control strategy* accounting for emission control regulations already in place as of June 15, 2005, as well as some emission control regulations that are not yet finalized but are expected to achieve additional emission reductions by 2009; and

  - *A beyond-on-the-way (BOTW) scenario* to account for controls from potential new regulations that may be necessary to meet attainment and other regional air quality goals, mainly for ozone.

  - *An updated scenario* (sometimes referred to as "best-and-final") to account for additional potentially reasonable control measures. For the MANE-VU region, these include: SO_2 reductions at a set of 167 EGUs which were identified as contributing to visibility impairment at northeast Class I areas; implementation of a low-sulfur fuel strategy for non-EGU sources; and implementation of a Best Available Retrofit Technology (BART) strategy for BART-eligible sources not controlled under other programs.

  (Note: Refer to Section 11.0, Long-Term Strategy, for detailed descriptions of specific control strategies.)

- **Pollutants:** ammonia, carbon monoxide (CO), oxides of nitrogen (NO_X), sulfur dioxide (SO2), volatile organic compounds (VOCs), fine particulate matter ($PM_{2.5}$, sum of filterable and condensable components), and coarse particulate matter (PM_{10}, sum of filterable and condensable components).

- ***States:*** Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, and Vermont, plus the District of Columbia (all members of the MANE-VU region).

6.2 Emission Processor Selection and Configuration

The Sparse Matrix Operator Kernel Emissions (SMOKE) model was used to format the emissions inventories for use with the air quality models that are discussed in Subsection 7.3. SMOKE is primarily an emissions processing system, as opposed to a true emissions inventory preparation system, in which emissions estimates are simulated from "first principles." This means that, with the exception of mobile and biogenic sources, SMOKE's purpose is to provide an efficient, modern tool for converting emissions inventory data into the formatted emissions files required for a photochemical air quality model. The SMOKE emissions processing that was performed in support of the air quality modeling for regional haze is described further in Subsection 7.2.

6.3 Inventories for Specific Source Categories

There are five emission source classifications in the emissions inventory, as follows:

- Stationary point,
- Stationary area,
- Non-road mobile,
- On-road mobile, and
- Biogenic.

Stationary point sources are large sources that emit greater than a specified tonnage per year, as described below. **Stationary area sources** are those sources whose individual emissions are relatively small (i.e., dry cleaners, service stations, agricultural areas, fires, etc.), but because of the large number of these sources, their collective emissions are significant. **Non-road mobile sources** are equipment that can move but do not use the roadways (i.e., lawn mowers, construction equipment, railroad locomotives, marine vessels, aircraft, etc.). **On-road mobile sources** include automobiles, trucks, buses, and motorcycles that use the roadway system. **Biogenic sources** include natural sources such as trees, crops, grasses, and natural decay of plants.

The subsections below give an overview of each of the source categories and the methods that were used to develop their corresponding baseline and future-year emissions estimates. All emissions data were prepared for modeling in accordance with EPA guidance.

6.3.1 Stationary Point Sources

Point source emissions are emissions from large individual sources. Generally, point sources have permits to operate, and their emissions are individually calculated based on source-specific parameters. Emissions estimates for point sources are usually made on a regular basis, and the largest point sources are inventoried annually. Sources with emissions greater than or equal to 100 tons per year (tpy) of a criteria pollutant, 10 tpy of a single hazardous air pollutant (HAP), or 25 tpy for total HAPs are considered to be major sources. Emissions from smaller point sources are also calculated individually but less frequently. Point sources are further subdivided into EGUs and non-EGUs.

6.3.1.1 Electric Generating Units (EGUs)

The base-year inventory for EGU sources were based on 2002 continuous emissions monitoring (CEM) data reported to EPA in compliance with the Acid Rain Program or 2002 state emissions inventory data. The CEM data provided actual hourly emission values used in the modeling of SO_2 and NO_x emissions from these large sources. Emissions of other pollutants (e.g., VOCs, CO, NH_3, and $PM_{2.5}$) were provided by the states in most instances.

Future-year inventories of EGU emissions for 2009, 2012 and 2018 were developed using ICF International's Integrated Planning Model (IPM) to forecast growth in electric demand and replacement of older, less efficient and more polluting power plants with newer, more efficient and cleaner units. This effort was undertaken by an inter-RPO workgroup. While the output of the IPM model predicts that a certain number of older plants will be replaced by newer units to meet future electric growth and state-specific NO_x and SO_2 caps, the Vermont/MANE-VU inventory did not directly rely on the closure of any particular plant in establishing the 2018 inventory upon which the reasonable progress goals were set.

The IPM model results do not provide a reliable basis upon which to predict EGU closures. Specific plant closures in the Vermont / MANE-VU inventory are addressed in Section 11.0, Reasonable Progress Goals. Preliminary modeling was performed with unchanged IPM 2.1.9 model results. However, prior to the most recent modeling, future-year EGU inventories were adjusted as follows:

- First, IPM predictions were reviewed by permitting and enforcement staff of the MANE-VU states. In many cases, staff believed that the IPM shutdown predictions were unlikely to occur. In particular, many oil-fired EGUs in urban areas were predicted to be shut down by IPM. Similar source information was solicited from states in both VISTAS and MRPO. As a result of this model validation, the IPM modeling output was adjusted before the most recent modeling to reflect staff knowledge of specific plant status in MANE-VU, VISTAS, and MRPO states. Where expected EGU operating status was contrary to what was predicted by IPM modeling, the future-year emissions inventory was adjusted to reflect the expected operation of those plants.

- Second, as a result of inter- and intra-RPO consultations, MANE-VU agreed to pursue certain emission control measures (see Section 3.0, Regional Planning). For EGUs, the agreed-upon approach was to pursue emission reductions from each of the top 167 stacks located in MANE-VU, MRPO, and VISTAS that contributed the most to visibility impairment at any Class I area in the MANE-VU region. This approach, known as the targeted EGU strategy, is further described in Section 11.0 of this SIP.

6.3.1.2 Non-EGU Point Sources

The primary basis for the 2002 baseline non-EGU emissions inventory was data reported by state and local agencies for the CERR. As described in Part 6.1.1, MANE-VU's contractor, E.H. Pechan & Associates (Pechan), coordinated the quality assurance of the inventory and prepared the necessary files for input into the SMOKE emissions model. Further information

on the preparation of the MANE-VU 2002 baseline point source modeling emissions inventory can be found in Chapter II of the Baseline Emissions Report (Attachment K). Projected non-EGU point source emissions were developed for the MANE-VU region by MACTEC Federal Programs, Inc. under contract to Mid-Atlantic Regional Air Management Association (MARAMA). The specific methodologies that were employed are described in Section 2 of the Emission Projections Report (Attachment L). MACTEC used state-supplied growth factor data, where available, to project future-year emissions. Where state-supplied data were not available, MACTEC used EPA's Economic Growth and Analysis System, Version 5.0 (EGAS 5.0) to develop applicable growth factors for the non-EGU component. MACTEC also incorporated the applicable federal and state emissions control programs to account for the expected emissions reductions that will take place under the OTB/OTW and BOTW scenarios.

6.3.2 Stationary Area Sources

Stationary area sources include sources whose individual emissions are relatively small but, because the number of sources is large, their collective emissions are significant. Some examples include dry cleaners, service stations, and residential heating. For each area source, emissions are estimated by multiplying an appropriate emission factor by some known indicator of collective activity, such as fuel usage, number of households, or population.

The area source emissions inventory submittals made for the CERR became the basis for the area source portion of the 2002 baseline inventory. MANE-VU's consultant, Pechan, prepared the area source modeling inventory using the CERR submittals as a starting point. Pechan quality-assured the inventory and augmented it with additional data, including MANE-VU-sponsored inventories for categories such as residential wood combustion and open burning. Details on the preparation of MANE-VU's 2002 baseline area source emissions inventory can be found in Chapter III of the Baseline Emissions Report (Attachment K).

In similar fashion, MACTEC prepared future-year area source emission projections for the MANE-VU region. The specific methodologies employed are described in Section 3 of the Emission Projections Report (Attachment L). MACTEC applied growth factors to the 2002 baseline area source inventory using state-supplied data, where available, or using the EGAS 5.0 growth factor model. MACTEC also accounted for the appropriate control strategies in the future year projections.

6.3.3 Non-Road Mobile Sources

Non-road mobile sources are equipment that can move but do not use the roadways, such as construction equipment, aircraft, railroad locomotives, and lawn & garden equipment. For the majority of non-road mobile sources, emissions are estimated using the EPA's NONROAD model. Aircraft, railroad locomotives, and commercial marine vessels are not included in the NONROAD model; and their emissions are estimated using applicable references and methodologies. Again, Pechan prepared the 2002 baseline modeling inventory using the state and local CERR submittals as a starting point. Details on the preparation of the 2002 baseline

non-road inventory are described in Chapter IV of the Baseline Emissions Report (Attachment K).

Future-year non-road mobile source emissions were projected for the MANE-VU region by MACTEC. The methodologies employed are discussed in Section 4 of the Emission Projections Report (Attachment L). MACTEC used EPA's NONROAD2005 non-road vehicle emissions model as contained in EPA's National Mobile Inventory Model (NMIM). Since the calendar year is an explicit input into the NONROAD model, future-year emissions for non-road vehicles could be calculated directed for the applicable projection years. For the non-road vehicle types that are not included in the NONROAD model (i.e. aircraft, locomotives, and commercial marine vessels), MACTEC used the 2002 baseline inventory and the projected inventories that EPA developed for these categories for the Clean Air Interstate Rule (CAIR) to develop emission ratios and subsequent combined growth and control factors. Since the future years for the CAIR projections did not precisely match those required for the purposes of ozone, particulate matter, and regional haze analyses (i.e. 2009, 2012, and 2018), MACTEC used linear interpolation to develop factors for the required future years.

6.3.4 On-Road Mobile Sources

The on-road emissions source category consists of vehicles that are meant to travel on public roadways, including cars, trucks, buses, and motorcycles. The basic methodology used for on-road mobile source calculations is to multiply vehicle-miles-traveled (VMT) by emission factors developed using the EPA's MOBILE6 motor vehicle emission factors model. The on-road mobile category requires that SMOKE model inputs be prepared instead of the SMOKE/IDA emissions data format that is required by the other emission source categories. Therefore, for the 2002 baseline inventory, Pechan prepared the necessary VMT and MOBILE6 inputs in SMOKE format.

Projected on-road mobile source inventories were developed by NESCAUM for the MANE-VU region for ozone, particulate matter, and regional haze SIP purposes. As with the other emissions source categories, projected on-road mobile inventories were developed for calendar years 2009, 2012, and 2018. As part of this effort, MANE-VU member states were asked to provide VMT data and MOBILE6 model inputs for the applicable calendar years. Using the inputs supplied by the MANE-VU member states, NESCAUM compiled and generated the required SMOKE/MOBILE6 emissions model inputs. Further details regarding the on-road mobile source projections can be found in NESCAUM's "Technical Memorandum, Development of MANE-VU Mobile Source Projection Inventories for SMOKE/MOBILE6 Application," June 2006 (Attachment M).

6.3.5 Biogenic Emission Sources

For the purposes of the 2002 baseline modeling emissions inventory, biogenic emissions were calculated for the modeling domain by the New York State Department of Environmental Conservation (NYSDEC). NYSDEC used the Biogenic Emissions Inventory System (BEIS) Version 3.12 as contained within the SMOKE emissions processing model. Biogenic

emissions estimates were made for CO, nitrous oxide (NO) and VOCs. Further details about the biogenic emissions processing can be found in NYSDEC's technical support document TSD-1c, "Emission Processing for the Revised 2002 OTC Regional and Urban 12 km Base Case Simulations," September 19, 2006 (Appendix P), and in Chapter VI of Pechan's "Technical Support Document for 2002 MANE-VU SIP Modeling Inventories," Version 3, November 20, 2006 (Appendix M). Biogenic emissions were assumed to remain constant for the future-years analysis.

6.4 Summary of Vermont Emissions Inventories

Vermont's baseline and future-year emissions inventories are summarized in Tables 6.1 through 6.4, below. All values are reported in tons per year (tpy).

Table 6.1 2002 Emissions Inventory Summary Vermont (tpy)

Emission Sector	VOC	NO_X	$PM_{2.5}$	PM_{10}	NH_3	SO_2
Point	1,097	787	267	304	6,194	905
Area	23,265	3,208	11,065	56,131	9,848	4,087
Mobile	17,288	20,670	483	670	934	894
Non-Road Mobile	10,548	4,217	486	530	5	372
Biogenic	118,377	1,142				
TOTAL	170,574	30,024	12,300	57,634	16,981	6,258

Table 6.2 2018 OTB/OTW Emissions Inventory Summary for Vermont (tpy)

Emission Sector	VOC	NO_X	$PM_{2.5}$	PM_{10}	NH_3	SO_2
Point	1,733	571	271	322	9	1,162
Area	26,198	3,430	12,059	66,916	14,580	4,764
Mobile	4,072	4,744	144	145	936	82
Non-Road Mobile	7,566	2,262	303	331	6	13
Biogenic	118,377	1,142				
TOTAL	157,946	12,149	12,777	67,714	15,531	6,020

Table 6.3 2018 BOTW Emissions Inventory Summary for Vermont (tpy)

Emission Sector	VOC	NO_X	$PM_{2.5}$	PM_{10}	NH_3	SO_2
Point	1,710	571	271	322	9	1,162
Area	26,196	3,430	12,060	66,916	14,580	4,764
Mobile	4,072	4,744	144	145	936	82
Non-Road Mobile	7,566	2,262	303	331	6	13
Biogenic	118,377	1,142				
TOTAL	157,921	12,149	12,778	67,714	15,531	6,020

It may be noted that there is virtually no change in Vermont's estimated emissions from the 2018 OTB/OTW scenario to the 2018 BOTW (beyond on the way) scenario. This is because Vermont is currently in attainment of old (and new) NAAQS for both ozone and $PM_{2.5}$ (nor is VT a CAIR state for ozone or $PM_{2.5}$). Thus no additional emissions reductions are anticipated for those specific programs.

Table 6.4 2018 Most Recent ("Updated Scenario") Emissions Inventory Summary for Vermont (tpy)

Emission Sector	VOC	NO_X	$PM_{2.5}$	PM_{10}	NH_3	SO_2
Point	1,711	572	271	322	9	407
Area	26,197	3,430	7,214	22,585	14,580	2,990
Mobile	4,072	4,744	144	145	936	82
Non-Road Mobile	7,566	2,262	303	331	6	13
Biogenic	118,377	1,142				
TOTAL	157,922	12,149	7,932	23,383	15,531	3,493

7. Air Quality Modeling

Air quality modeling to assess regional haze has been performed cooperatively between Vermont and its regional planning organization, MANE-VU. These modeling efforts include emissions data processing, meteorological input analyses, and chemical transport modeling to perform regional air quality simulations for calendar year 2002 and several future periods, including the primary target date, 2018, for this SIP. Modeling was conducted in order to assess contributions from upwind areas as well as Vermont's contribution to Class I areas in downwind states. Further, the modeling evaluated visibility benefits of specific control measures being considered to achieve reasonable progress goals and establish a long-term emissions management strategy for MANE-VU Class I Areas.

Several modeling tools were utilized for these analyses:

- The Fifth-Generation Pennsylvania State University/National Center for Atmospheric Research (NCAR) Mesoscale Model (MM5) was used to derive the required meteorological inputs for the air quality simulations.
- The Sparse Matrix Operator Kernel Emissions (SMOKE) emissions modeling system was used to process and format the emissions inventories for input into the air quality models.
- The Community Mesoscale Air Quality model (CMAQ) was used for the primary SIP modeling.
- The Regional Model for Aerosols and Deposition (REMSAD) was used during contribution apportionment.
- The California Puff Model (CALPUFF) and its associated meteorological wind field pre-processor (CALMET) was used to assess the contribution of individual states' emissions to sulfate levels at selected Class I receptor sites.

Each of these tools has been evaluated and found to perform adequately. The SIP-pertinent modeling underwent full performance testing, and the results were found to meet the specifications of EPA modeling guidance. Modeling using CALPUFF for the contribution assessment of sulfate impacts at selected Class I receptor sites involved two different platforms for regional scale modeling which each used the exact same source inputs but different meteorological inputs, one using the MM5 meteorology and the other using National Weather Service Data driven CALMET wind fields. The two platforms were each evaluated separately as described in the NESCAUM report, "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States", August 2006 (Attachment A).

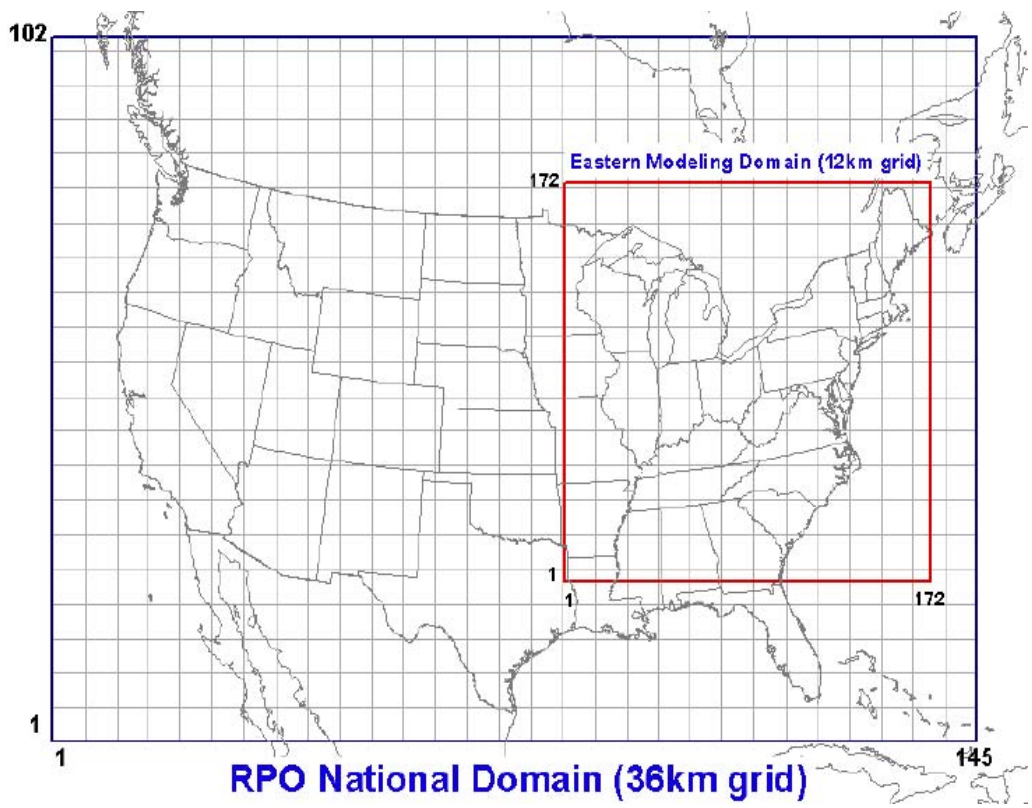
For more details on the regional haze modeling, refer to the NESCAUM report, "MANE-VU Modeling for Reasonable Progress Goals: Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment F). The detailed modeling approach for the most recent 2018 projections can be found in NESCAUM's "2018 Visibility Projections," May 13, 2008 (Attachment O).

7.1 Meteorology

The meteorological inputs for the air quality simulations were developed by the University of Maryland (UMD) using the MM5 meteorological modeling system. Meteorological inputs were generated for 2002 to correspond with the baseline emissions inventory and analysis year. The MM5 simulations were performed on a nested grid (Figure 7.1). The modeling domain is composed of a 36-km, 145 x 102 continental grid and a nested 12-km, 172 x 172 grid encompassing the eastern United States and parts of Canada. In cooperation with the New York State Department of Conservation (NYSDEC), an assessment was made for the period of May-September 2002 to compare the MM5 predictions with observations from a variety of data sources, including:

- Surface observations from the National Weather Service and the Clean Air Status and Trends Network (CASTNET),
- Wind-profiler measurements from the Cooperative Agency Profilers (CAP) network,
- Satellite cloud image data from the UMD Department of Atmospheric and Oceanic Science, and
- Precipitation data from the Earth Observing Laboratory at NCAR.

Figure 7.1 National and Northeast Regional RPO Modeling Grid Domains



Note: Outer (blue) domain is 36-km grid. Inner (red) domain is 12-km grid. Gridlines are shown at 180-km intervals (5×5 36-km cells and 15×5 12-km cells).

Further details regarding the MM5 meteorological processing and the modeling domain can be found in NYSDEC's technical support document TSD-1a, "Meteorological Modeling Using Penn State/NCAR 5th Generation Mesoscale Model (MM5)," February 1, 2006 (Attachment P), and in the NESCAUM report, "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," November 27, 2007 (Attachment F

7.2 Data Preparation

Emissions data were prepared for input into the CMAQ and REMSAD air quality models using the SMOKE emissions modeling system. SMOKE supports point, area, mobile (both on-road and non-road), and biogenic emissions. The SMOKE emissions modeling system uses flexible processing to apply chemical speciation as well as temporal and spatial allocation to the emissions inventories. SMOKE incorporates the Biogenic Emission Inventory System (BEIS) and EPA's MOBILE6 motor vehicle emission factor model to process biogenic and on-road mobile emissions, respectively. Vector-matrix multiplication is used during the final processing step to merge the various emissions components into a single model-ready emissions file. Examples of processed emissions outputs are shown in Fig. 7. 2.

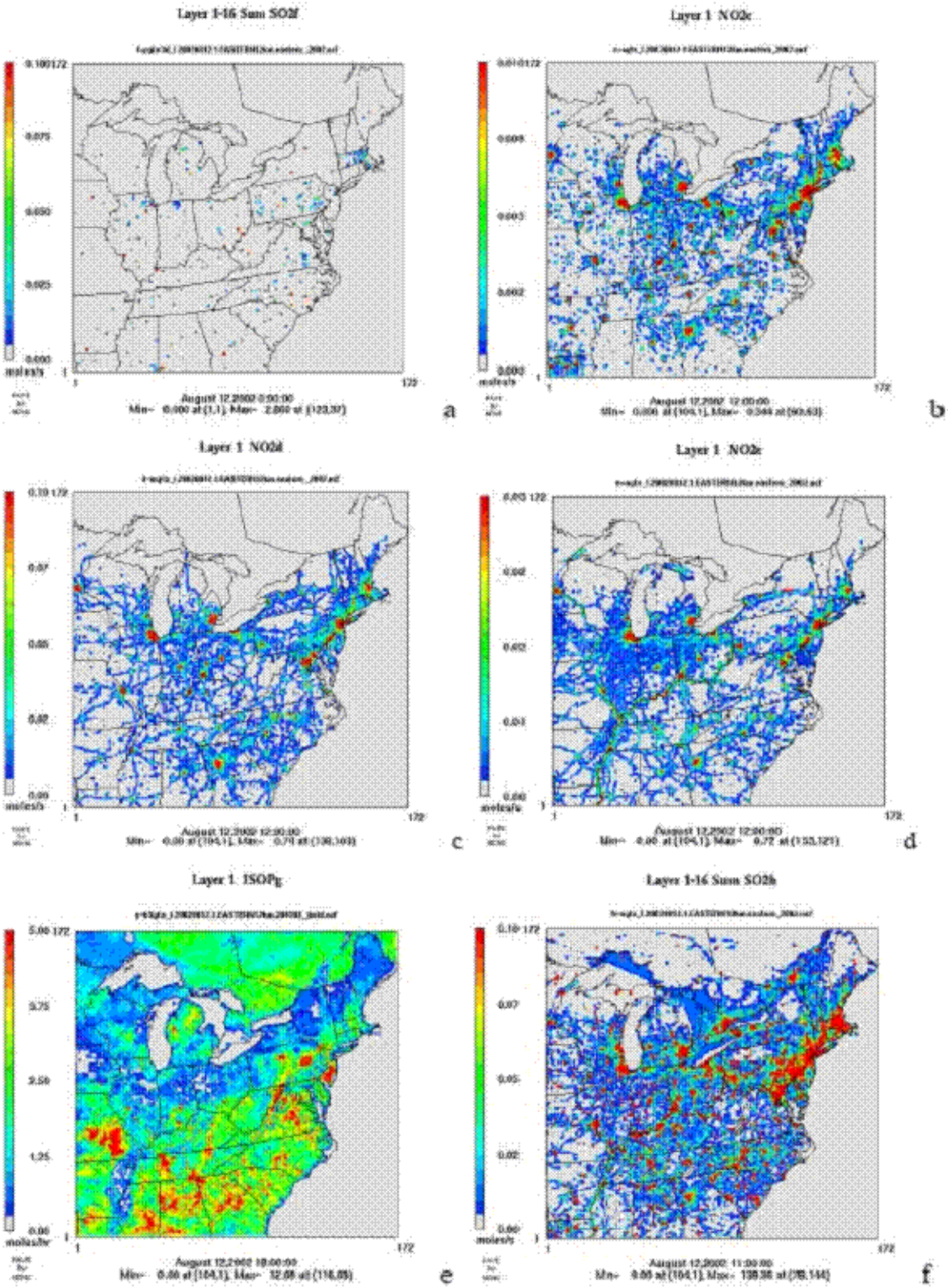
Further details on the SMOKE processing conducted in support of the air quality simulations is provided in NYSDEC's technical support document TSD-1c, "Emission Processing for the Revised 2002 OTC Regional and Urban 12 km Base Case Simulations," September 19, 2006 (Attachment N), and in NESCAUM's report, "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G). Additional details on the emissions inventory preparation can be found in Section 6.0 of this plan.

7.3 Model Platforms

Two regional-scale air quality models, CMAQ and REMSAD, were used for the air quality simulations that directly supported the regional haze SIP effort. CMAQ was developed by EPA and was used to perform the primary SIP-related modeling. The CMAQ modeling simulations were also an important tool for the 8-hour ozone SIP process. REMSAD was developed by ICF Consulting/Systems Applications International with support from EPA. REMSAD was used by NESCAUM to perform a source apportionment (contribution assessment) analysis. All of the air quality simulations that were used in the SIP efforts were performed on the 12-km eastern modeling domain shown in Figure 7.11 above.

NYSDEC performed an extensive model performance analysis to evaluate CMAQ model predictions against observations of ozone, $PM_{2.5}$, and other pollutant species. This model performance evaluation is described in detail in NYSDEC's technical support document TSD¬1e, "CMAQ Model Performance and Assessment, 8-Hr OTC Ozone Modeling," February 23, 2006 (Attachment Q). A model performance evaluation for $PM_{2.5}$ species, aerosol extinction coefficient, and the haze index is provided in NESCAUM's report, "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment F).

Figure 7.2 Examples of Processed Model-Ready Emissions: (a) SO_2 from Point, (b) NO_2 from Area, (c) NO_2 from On-Road, (d) NO_2 from Non-Road, (e) ISOP from Biogenic, and (f) SO_2 from all Source Categories



7.3.1 CMAQ

The CMAQ air quality simulations were performed cooperatively among five modeling centers: NYSDEC, the New Jersey Department of Environmental Protection (NJDEP) in association with Rutgers University, the Virginia Department of Environmental Quality (VADEQ), UMD, and NESCAUM. NYSDEC also performed an annual 2002 CMAQ simulation on the 36-km domain shown in Figure 7.1. This simulation was used to derive the boundary conditions for the inner 12-km eastern modeling domain. Boundary conditions for the 36-km simulations were obtained from a run of the GEOS-Chem (Goddard Earth Observing System) global chemistry transport model that was performed by researchers at Harvard University. The technical options that were used in performing the CMAQ simulations are described in detail in NYSDEC's technical support document TSD-1d, "8hr Ozone Modeling Using the SMOKE/CMAQ System," February 1, 2006 (Attachment R). Further technical details regarding the CMAQ model and its execution are also provided in NESCAUM's report, "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G).

7.3.2 REMSAD

The REMSAD modeling simulations were used to produce the contribution assessment required by the Regional Haze Rule. REMSAD's species tagging capability makes it an important tool for this purpose. The REMSAD model simulations were performed on the same 12-km eastern modeling domain as shown in Figure 7.1. NESCAUM's report, "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G), further describes the REMSAD model and its application to the regional haze SIP efforts.

7.3.3 CALPUFF

CALPUFF is a non-steady-state Lagrangian puff model that simulates the dispersion, transport, and chemical transformation of atmospheric pollutants. Two parallel CALPUFF modeling platforms were developed by the Vermont Department of Environmental Conservation (VTDEC) and the Maryland Department of the Environment (MDE). The VTDEC CALPUFF modeling platform utilized meteorological observation data from the National Weather Service (NWS) to drive the CALMET meteorological model. The MDE platform utilized the same MM5 meteorological inputs that were used in the modeling done in support of the ozone and regional haze SIPs. These two platforms were run in parallel to evaluate individual states' contributions to sulfate levels at Northeast and Mid-Atlantic Class I areas.

The VTDEC CALPUFF modeling effort was tailored to accurately simulate long-term average flow patterns over the Northeastern U.S., in areas removed from the Atlantic coastline. The modeling effort was carefully evaluated for bias and error, both in the base meteorological fields and the final air pollution dispersion calculations. This modeling was performed in 2003 for calendar year 2002 meteorology and emissions and utilized a 'beta'

model version, which, in 2003, was not yet formally approved by the EPA for Air Pollution applications. Since then, the fundamental changes to the CALPUFF modeling system that were first made available in the 2003 beta model version have been largely incorporated into the EPA- approved version.

The CALPUFF modeling system is designed to allow great variety in its application. One example is the scale of spatial transport modeled, which may range from less than a kilometer, to long range transport applications on the order of 200 kilometers or more. A fundamental manner in which the model performance may be 'tailored' for a given application, involves the interpolation methods for various observational, and/or prognostic model outputs that the CALMET models interpolates to produce final wind, temperature and other fields. In the VTDEC CALPUFF modeling for the contribution assessment a non-regulatory setting was the 'radius of influence parameter' for interpolation of surface stations. The default (recommended) setting was not used for 'radius of influence parameter' because evaluation of the wind fields produced when this parameter was set at the default mode (i.e. off), revealed problems with the wind fields in regions where the surface wind observations were sparse.

The CALPUFF modeling effort is described in detail in NESCAUM's report, "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States," August 2006 (Attachment A).

7.4 References for Section 7

Pennsylvania State University/National Center for Atmospheric Research. Mesoscale Model (MM5). http://www.mmm.ucar.edu/mm5/mm5-home.html.

Center for Environmental Modeling for Policy Development, University of North Carolina at Chapel Hill. Sparse Matrix Operator Kernel Emissions (SMOKE) Model. http://www.smoke-model.org/index.cfm.

Community Modeling and Analysis System (CMAS) Center, University of North Carolina at Chapel Hill. Community Multiscale Air Quality (CMAQ) Modeling System. http://www.cmaq-model.org.

ICF International/Systems Applications International. Regional Modeling System for Aerosols and Deposition (REMSAD). http://remsad.saintl.com.

Scire, J.S., Strimaitis, D.G., and Yamartino, R.J. A User's Guide for the CALPUFF Dispersion Model (Version 5). January 2000.

8. Understanding the Sources of Haze-Causing Pollutants

This section explores the origins, quantities, and roles of visibility-impairing pollutants emitted in the eastern United States and Canada that contribute significantly to regional haze at MANE-VU's mandatory Class I areas.

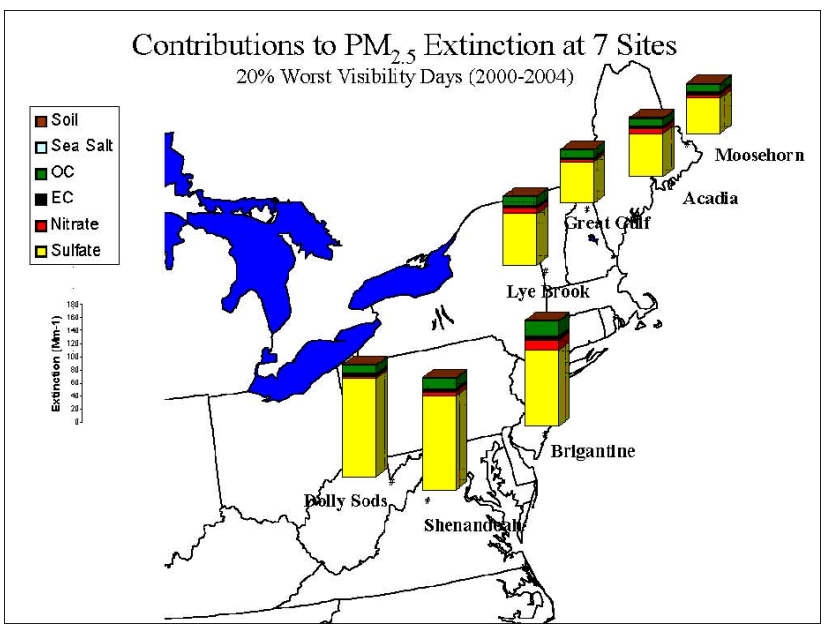
8.1 Fine-Particle Pollutants

The pollutants primarily responsible for fine particle formation, and thus contributing to regional haze, include SO_2, NO_X, VOCs, NH_3, PM_{10}, and $PM_{2.5}$. The MANE-VU Contribution Assessment (Attachment A), finalized in August 2006, reflects a conceptual model in which sulfate emerges as the most important single constituent of haze-forming fine particle pollution and the principle cause of visibility impairment across the Northeast region. Sulfate alone accounts for anywhere from ½ to ⅔ of total fine particle mass on the 20 percent haziest days at MANE-VU Class I Areas. This translates to about ⅔ to ¾ of visibility extinction on those days. Organic carbon was shown to be the second largest contributor to haze at MANE-VU Class I sites. As a result of the dominant role of sulfate in the formation of regional haze in the Northeast and Mid-Atlantic Regions, MANE-VU concluded that an effective emissions management approach would rely heavily on broad-based regional SO_2 control measures in the eastern United States.

Atmospheric light extinction is a fundamental metric used to characterize air pollution impacts on visibility. It is the fractional loss of intensity in a light beam per unit distance due to scattering and absorption by the gases and particles in the air. Extinction is expressed in units of inverse mega-meters (Mm^{-1}). Light extinction, light scattering, and light absorption can be measured by transmissometer, nephelometer and aethalometer, respectively.

Figure 8.1 Contributions to $PM_{2.5}$ Extinction at 7 Class 1 Areas

Extinction can also be calculated from measurements of aerosol species using equations such as those presented on page 1-14 of this plan. Figure 8.1 shows the dominance of sulfate in visibility extinction calculated from 2000-2004 baseline data for seven Northeast Class I Areas.



8.2 Contributing States and Regions

The MANE-VU Contribution Assessment used various modeling techniques, air quality data analysis, and emissions inventory analysis to identify source categories and states that contribute to visibility impairment in MANE-VU and nearby Class I areas. Based on estimates obtained by several evaluation methods, emissions that originated within MANE¬VU states contributed approximately one-fourth of the total sulfate aerosol recorded at in the Lye Brook Wilderness Area in 2002. More specifically, four different estimation methods yielded the following contribution ranges: MANE-VU, 21-32 percent; MRPO, 22-27 percent; VISTAS, 14-19 percent; CenRAP, 2-5 percent; Eastern Canada, 6-16 percent; and all other regions, 19 percent (see Tables 8.1 through 8.5 of the Contribution Assessment for details). These findings highlight the importance of emissions from outside MANE-VU to visibility impairment inside the region. Note that, although there is some variation in the contribution estimates among the different assessment methods employed, there is a general consistency of results from one method to another.

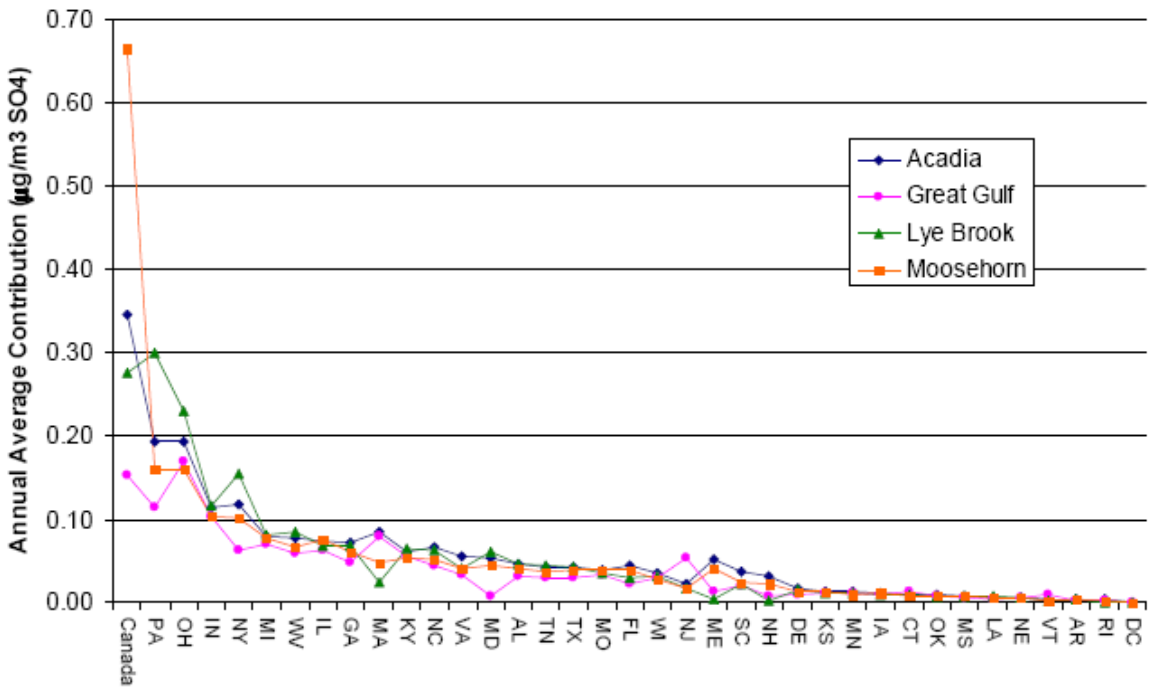
Table 8.1 displays the results of one of the methods used (the REMSAD model) to assess state-by-state and regional contributions to annual sulfate impacts in nine Class I areas.

Table 8.1 Percent Contributions (Mass Basis) of Individual States and Regions to total Annual Sulfate Impacts at Northeast Class I Areas (REMSAD)

Contributing State or Region	Mandatory Class I Area						
	Acadia ME	Brigantine NJ	Dolly Sods WV	Great Gulf & Presidential Range – Dry River, NH	Lye Brook VT	Moosehorn & Roosevelt Campobello ME	Shenandoah VA
Connecticut	0.76	0.53	0.04	0.48	0.55	0.56	0.08
Delaware	0.96	3.20	0.30	0.63	0.93	0.71	0.61
District of Columbia	0.01	0.04	0.01	0.01	0.02	0.01	0.04
Maine	6.54	0.16	0.01	2.33	0.31	8.01	0.02
Maryland	2.20	4.98	2.39	1.92	2.66	1.60	4.84
Massachusetts	10.11	2.73	0.18	3.11	2.45	6.78	0.35
New Hampshire	2.25	0.60	0.04	3.95	1.68	1.74	0.08
New Jersey	1.40	4.04	0.27	0.89	1.44	1.03	0.48
New York	4.74	5.57	1.32	5.68	9.00	3.83	2.03
Pennsylvania	6.81	12.84	10.23	8.30	11.72	5.53	12.05
Rhode Island	0.28	0.10	0.01	0.11	0.06	0.19	0.01
Vermont	0.13	0.06	0.00	0.41	0.95	0.09	0.01
MANE-VU	36.17	34.83	14.81	27.83	31.78	30.08	20.59
MRPO	11.98	18.16	30.26	20.10	21.48	10.40	26.84
VISTAS	8.49	21.99	36.75	12.04	13.65	6.69	33.86
CenRAP	0.88	1.12	1.58	1.65	1.67	0.82	1.48
Canada	8.69	7.11	3.90	14.84	12.43	7.85	4.75
Other	33.79	16.78	12.70	23.54	18.99	44.17	12.48

Figures 8.2 and 8.3, also borrowed from the Contribution Assessment, illustrate several other simple methods for identifying and ranking individual states' contributions to sulfate at northeastern Class I areas using the 2002 emissions data and regional meteorology. Figure 8.2 shows results from a simple technique for deducing the relative impact of emissions from local and upwind source areas on specific receptor sites. It involves calculating the ratio of annual emissions (Q) to source-receptor distance (d). The ratio (Q/d) is then multiplied by a factor to account for the frequency effect of prevailing winds. The use of this technique is explained in the Contribution Assessment (see pages 4-12 to 4-17 of Attachment A).

Figure 8.2 Ranked state percent sulfate contributions to Northeast Class I receptors based on emissions divided by distance (Q/d) results



Results from another simple source apportionment method described in the Contribution Assessment are displayed here in Figure 8.3. In this method, an "upwind probability field is calculated for each receptor site using 5 years of backward air trajectory calculations. This long-term, climatological upwind probability field (UP) is then multiplied by the 2002 SO_2 emissions data to provide an estimate of proportionate state by state contributions to sulfate contributions to the northern MANE-VU Class I Areas. The use of this technique is explained in the Contribution Assessment (see pages 4-17 to 4-19 of Attachment B).

Although these techniques are relatively simple, it may be noted that they generally show proportions and rankings of upwind contributions which are quite similar to results from the more sophisticated CALLPUFF and REMSAD models. See for example the comparative ranking results in Figure 8.4, also borrowed from the Contribution Assessment.

Figure 8.3 Ranked state percent sulfate contributions to Mid-Atlantic Class I receptors based on emissions times upwind probability (E x UP) results

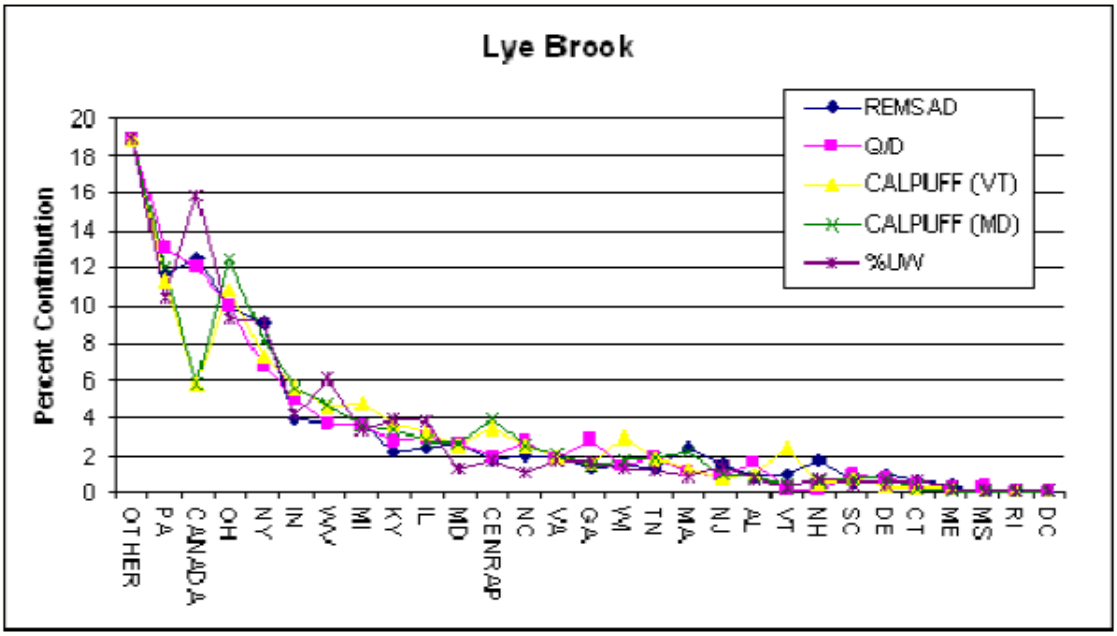
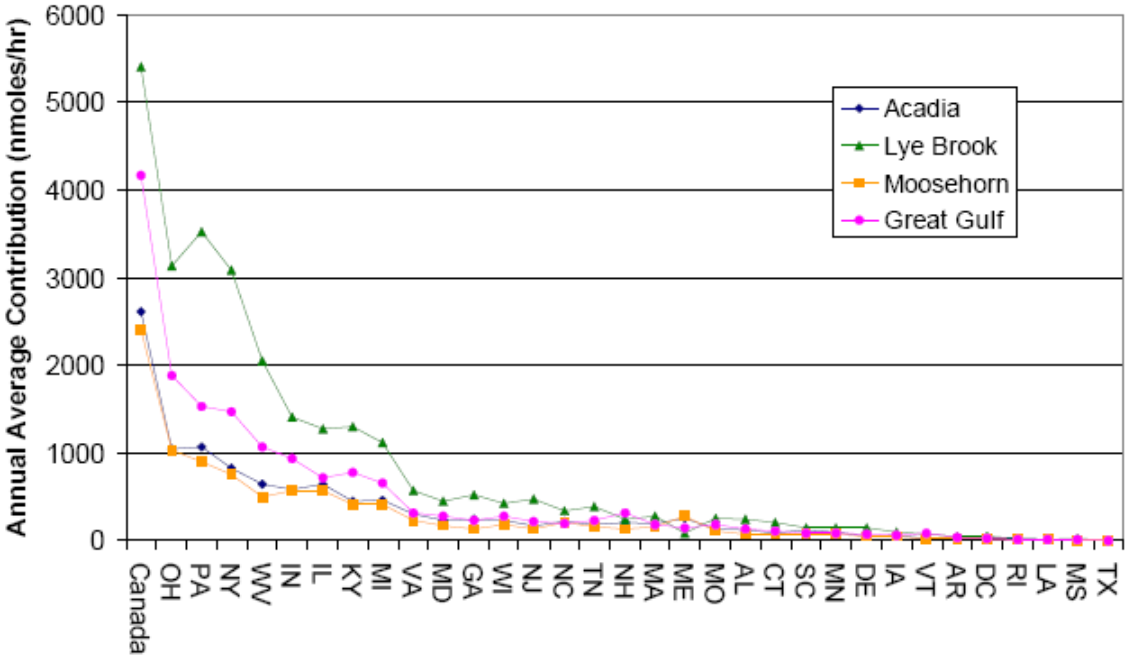


Figure 8.4 Comparison of normalized (percent contribution) results using different techniques for ranking state contributions to sulfate levels at the MANE-VU Class I sites



The ranking of emission contributions to visibility impairment in the MANE-VU Class I Areas by methods such as these has direct relevance to the consultation process described previously in Section 3.0, Regional Planning and Consultation. Using results from the REMSAD model, MANE-VU applied the following three criteria to identify states and regions for the purposes of consultation on regional haze:

1. Any state/region that contributed 0.1 µg/m3 sulfate or greater on the 20 percent worst visibility days in the base year (2002),

2. Any state/region that contributed at least 2 percent of total sulfate observed on the 20 percent worst visibility days in 2002, and

3. Any state/region among the top ten contributors on the 20 percent worst visibility days in 2002.

For the purposes of deciding how broadly to consult, the MANE-VU States settled on the second of the three criteria: any state/region that contributed at least 2 percent of total sulfate observed on the 20 percent worst visibility days in 2002.

In Figures 8.5, states and regions meeting the three listed criteria are identified graphically for Lye Brook. Similar results are available for other MANE-VU and nearby Class I areas (Shenandoah and Dolly Sods in the VISTAS region that are impacted by emissions from MANE-VU states) in Attachment G (MANE-VU Modeling for Reasonable Progress Goals). .

Figure 8.5 Modeled 2002 Sulfate Contributions at Lye Brook on the 20% Worst Days

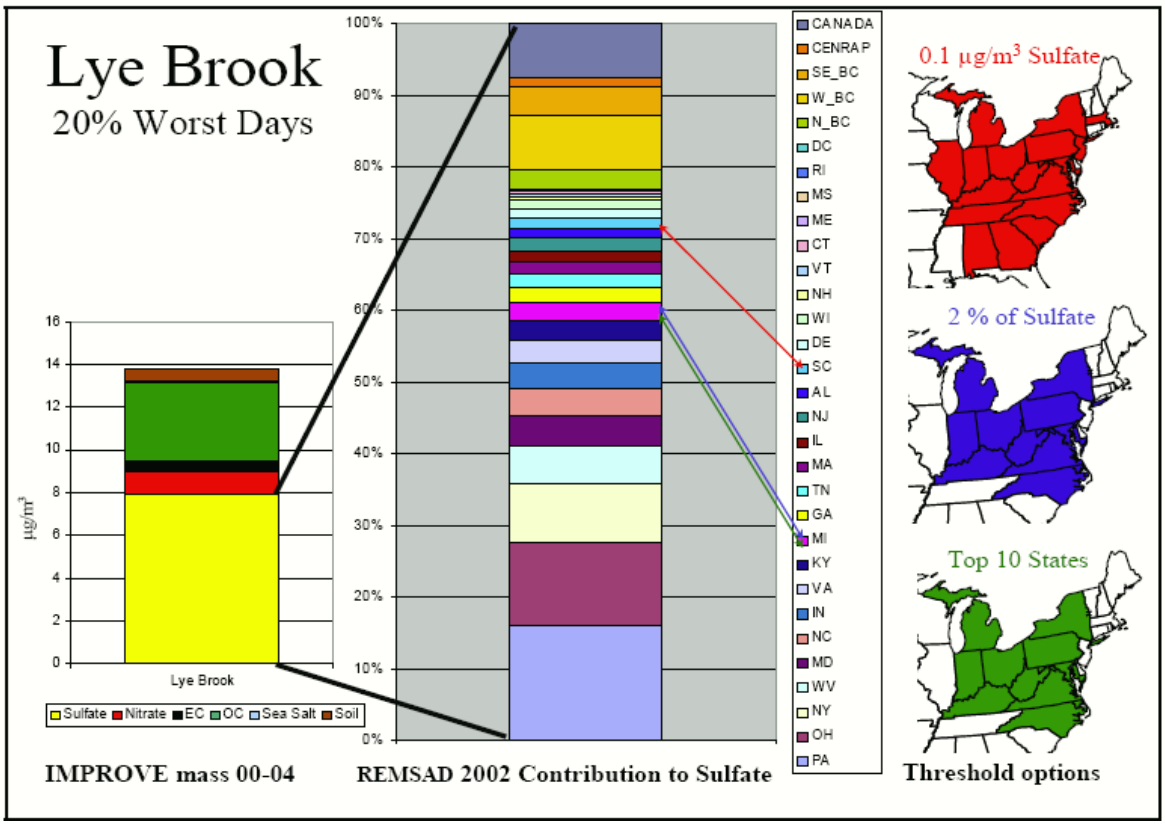


Figure 8-5 has three components:

- On the left is a single bar graph of the IMPROVE-monitored $PM_{2.5}$ mass concentration (μg/m3) by constituent species for the baseline years 2000-2004. The yellow, bottom portion of the bar represents the measured sulfate concentration.
- The middle component of each figure provides a bar graph of the 2002 total sulfate contribution of each state or region as estimated by REMSAD.
- Finally, the right segment contains three maps showing which states meet the criteria described above.

Vermont, Connecticut, Rhode Island, and the District of Columbia were not identified as being among the political or regional units contributing at least 2 percent of sulfate at any of the seven Class I areas. However, as participants in MANE-VU, those entities have agreed to pursue adoption of regional control measures aimed at visibility improvement on the haziest days and prevention of visibility degradation on the clearest days.

8.3 Emission Sources and Characteristics

As previously mentioned, the major pollutants responsible for regional haze are SO_2, NO_X, VOCs, NH_3, PM_{10}, and $PM_{2.5}$. The following is a description of the sources (e.g., point, area, and mobile) and characteristics of pollutant emissions contributing to haze in the eastern United States. Emissions data and graphics presented for the purposes of this section are taken from the MANE-VU 2002 Baseline Emissions Inventory, Version 2.0 (note that the more recent MANE-VU 2002 Baseline Emissions Inventory, Version 3.0, released in April 2006, has superseded Version 2.0 for modeling purposes). Although the emissions inventory database also includes carbon monoxide (CO), this primary pollutant is not considered here because it does not contribute to regional haze.

In addition to the MANE-VU inventory, useful emissions inventories include the 1996 EPA National Emissions Trends database (NET) and the 1999 National Emissions Inventory (NEI)*. Trends among the three emissions inventories – NET 1996, NEI 1999, and MANE-VU 2002 – are highlighted in the text and graphics presented below.

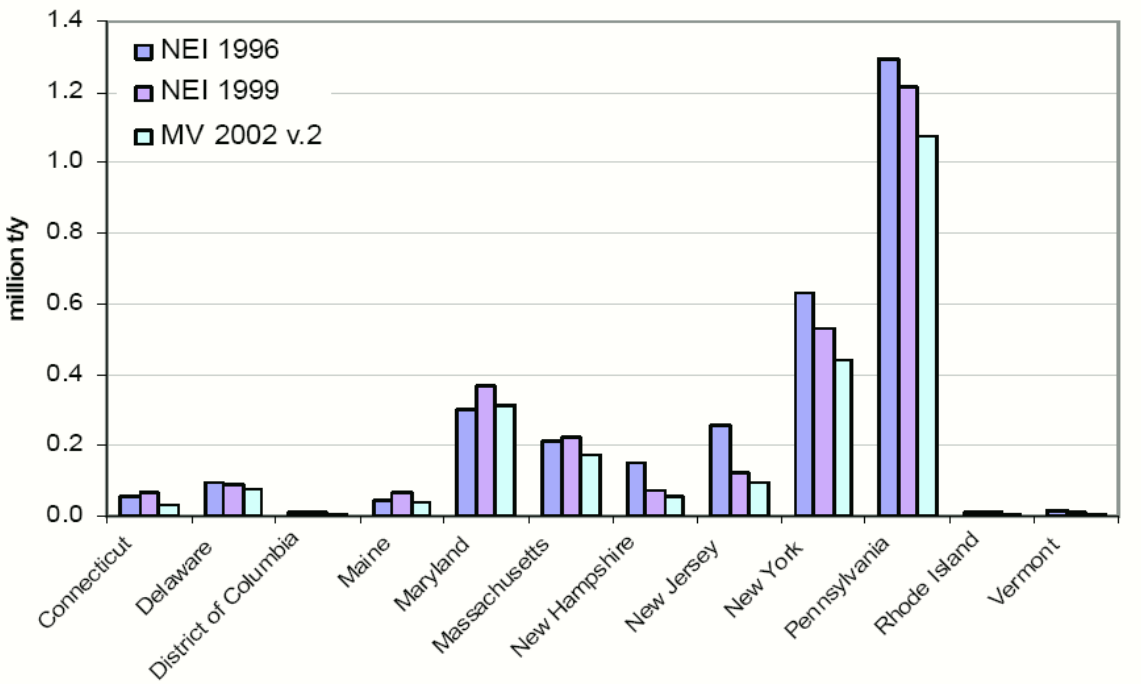
* EPA's Emission Factor and Inventory Group, Office of Air and Radiation, Office of Air Quality Planning and Standards, Emissions, Monitoring and Analysis Division (EMAD) prepares a national database of air emissions information with input from state and local air agencies, tribes, and industry. This NEI database contains information on stationary and mobile sources that emit criteria air pollutants and their precursors, as well as hazardous air pollutants (HAPS). The database includes estimates of annual emissions, by source, in each area of the country on an annual basis. NEI includes emission estimates for all 50 states, the District of Columbia, Puerto Rico, and the Virgin Islands. Emission estimates for individual point or major sources (facilities), as well as county-level estimates for area, mobile, and other sources, are available currently for 1985 through 1999 for criteria pollutants. NEI data help support air dispersion modeling, regional strategy development, setting regulations, air toxics risk assessment, and tracking trends in emissions over time. For inventories prior to 1999, the National Emission Trends (NET) database maintained criteria pollutant emissions, and the National Toxics Inventory (NTI) database maintained HAP emissions. Beginning with 1999, the NEI began preparing criteria and HAP emissions data in a more integrated fashion to take the place of the NET and the NTI.

8.3.1 Sulfur Dioxide (SO_2)

SO_2 is the primary precursor pollutant for sulfate particles. Sulfate particles commonly account for more than 50 percent of particle-related light extinction at northeastern Class I areas on the clearest days and for as much as 80 percent or more on the haziest days. Hence, SO_2 emissions are an obvious target of opportunity for reducing regional haze in the eastern United States. Combustion of coal and, to a lesser extent, of certain petroleum products accounts for most anthropogenic SO_2 emissions. In fact, in 1998, a single source category – coal-burning power plants – was responsible for two-thirds of total SO_2 emissions nationwide (NESCAUM, 2001a).

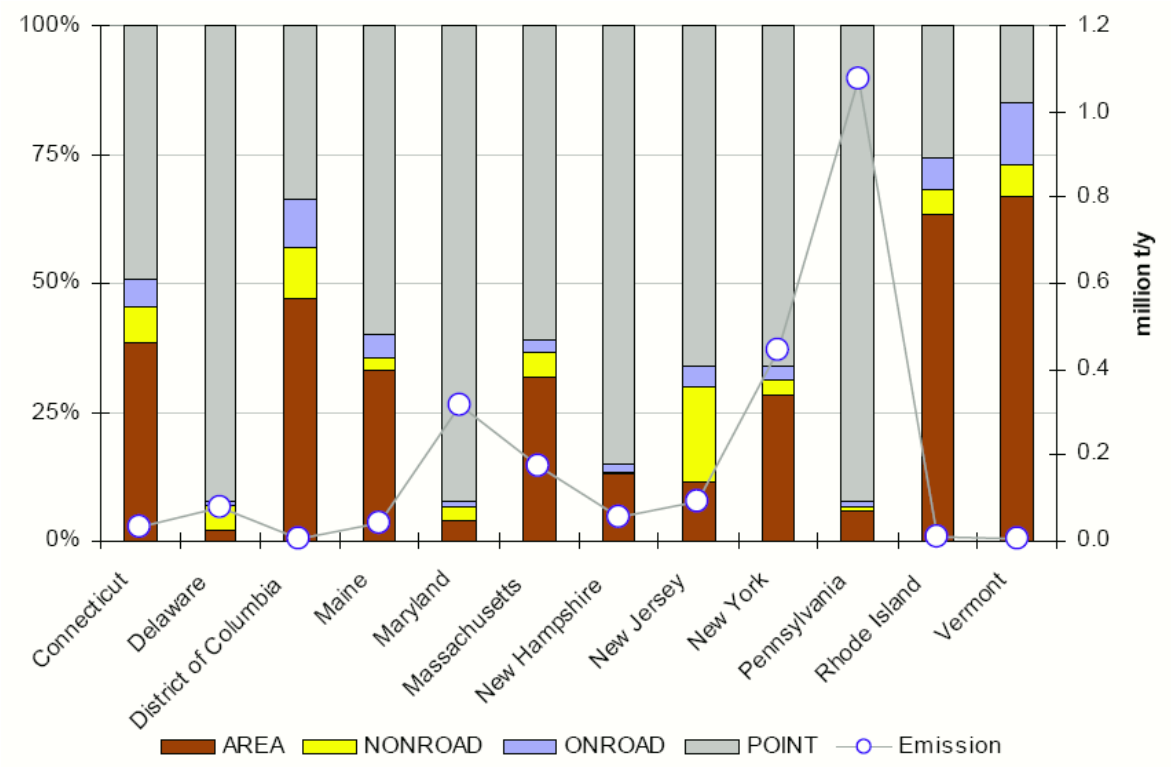
Figure 8.6 shows SO_2 emission trends in the MANE-VU states extracted from the NEI database for the years 1996, 1999, and the 2002 MANE-VU inventory (EPA, 2005). Most of the states (with the exception of Maryland) show declines in 2002 annual SO_2 emissions compared with 1996 emissions. While some states show an increase in emissions in 1999 followed by a decline in 2002, others show consistent declines throughout the entire period.

Figure 8.6 Trends in Annual Sulfur Dioxide (SO_2) Emissions, by State



The upward trend in emissions after 1996 in several states probably reflects electricity demand growth during the late 1990s combined with the availability of banked emission allowances resulting from initial over-compliance with control requirements in Phase 1 of EPA's Acid Rain Program. This situation led to relatively low market prices for allowances later in the decade and encouraged utilities to purchase allowances rather than implement new controls as electricity output expanded. The observed decline in SO_2 emissions in 2002 can be attributed to implementation of Phase 2 of the Acid Rain program, which in 2000 further reduced allowable emissions and extended emission limits to a greater number of power plants.

Figure 8.7 2002 Sulfur Dioxide (SO_2) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (106 tpy)



The bar graph in Figure 8.7 displays the percentage contributions from different emission source categories to annual SO_2 emissions in the MANE-VU states in 2002. The chart shows that point sources – consisting mainly of stationary combustion sources for generating electricity, industrial power, and heat – dominate SO_2 emissions in the region. Smaller stationary combustion sources, referred to collectively as areas sources, are another important source category in the MANE-VU states. These include smaller industrial, commercial, and institutional boilers as well as residential heating sources. By contrast, on-road and non-road mobile sources make a relatively minor contribution to overall SO_2 emissions in the region (NESCAUM, 2001a).

8.3.2 Volatile Organic Compounds (VOC)

Existing emissions inventories generally refer to volatile organic compounds (VOCs) as hydrocarbons whose volatility in the atmosphere makes them particularly important to ozone formation. From a regional haze perspective, there is less concern with the volatile organic gases emitted directly to the atmosphere than with the secondary organic aerosols (SOAs) that VOCs form after undergoing condensation and oxidation. Thus the VOC inventory category is of interest primarily because of the organic matter component of $PM_{2.5}$.

Particle phase organic matter is present in the atmosphere as thousands of complex mixtures composed primarily of organic carbon, oxygen and hydrogen. These organic compounds may

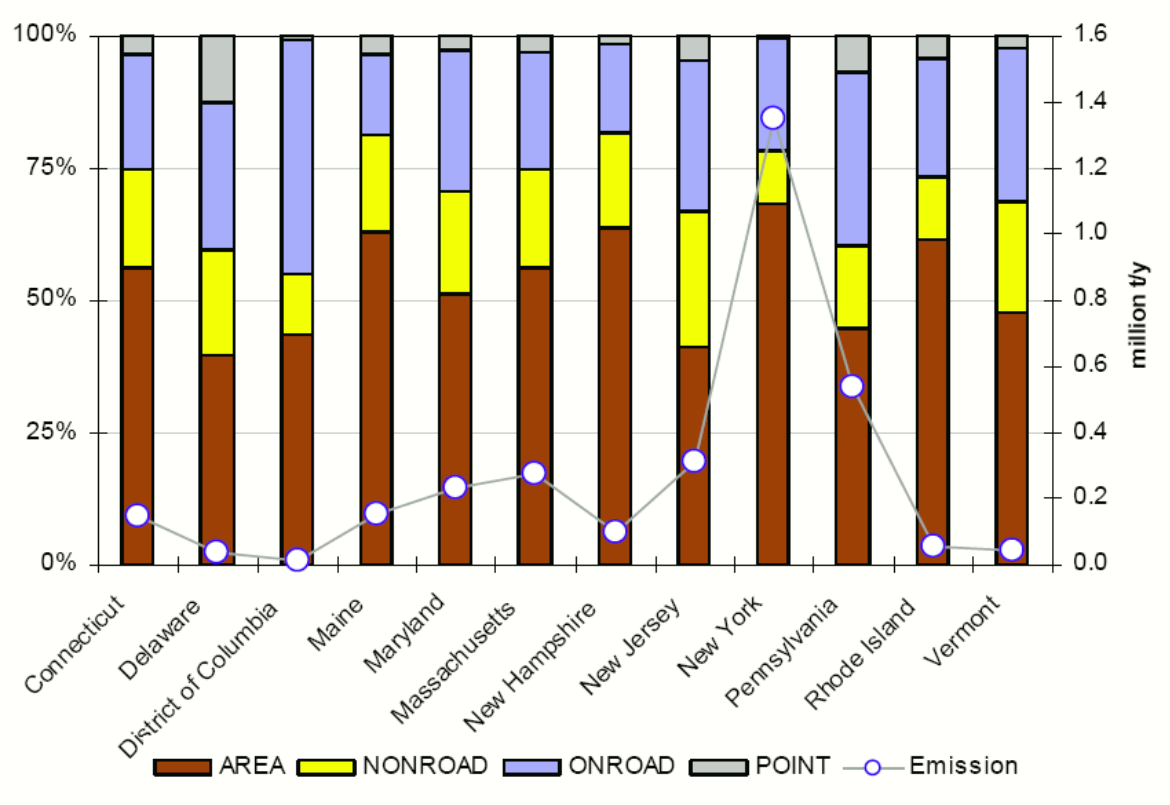
be emitted directly from emission sources as components of primary PM or that may form in the atmosphere as secondary pollutants. After sulfate, organic matter generally accounts for the next largest share of fine particle mass and particle-related light extinction at northeastern Class I sites. The organic matter present at Class I areas includes a mix of pollutants originating from anthropogenic sources such as gasoline and diesel motor vehicles, biogenic hydrocarbons emitted by vegetation, and wood smoke from natural or anthropogenic fires. Recent efforts to cut back on manmade organic carbon emissions have been undertaken mainly for the purpose of reducing summertime ozone formation in urban centers. Future efforts to make further reductions in organic carbon emissions may be driven by programs that address fine particles and visibility.

Understanding the source regions and transport dynamics for organic matter in MANE-VU and nearby Class I areas is likely to be more complex than for sulfate. This complexity derives from the large number and diversity of organic carbon species, the wide variation in their transport characteristics, and the fact that a given species may undergo numerous complex chemical reactions in the atmosphere. Thus, the organic carbon contribution to visibility impairment at most Class I areas in the region is likely to include manmade pollution from nearby sources, manmade pollution transported from a distance, and biogenic emissions – especially terpenes from coniferous forests.

As shown in Figure 8.8, the VOC inventory is dominated by mobile and area sources. On-road mobile sources of VOCs include evaporative emissions from transportation fuels and exhaust emissions from gasoline passenger vehicles and diesel-powered, heavy-duty vehicles. VOC emissions may also originate from a variety of area sources (including those that use organic solvents, architectural coatings, and dry cleaning fluids) as well as from some point sources (e.g., industrial facilities and petroleum refineries).

Biogenic VOCs may play an important role within the rural settings typical of Class I areas. The oxidation of hydrocarbon molecules containing seven or more carbon atoms is generally the most significant pathway for the formation of light-scattering organic aerosol particles (Odum et al., 1997). Smaller reactive hydrocarbons that may contribute significantly to urban smog (ozone) are less likely to play a direct role in organic aerosol formation, although it is noted that high ozone levels can have an indirect effect on visibility by promoting the oxidation of other available hydrocarbons, including biogenic emissions (NESCAUM, 2001a). In short, further work is needed to characterize the organic carbon contribution to regional haze in the MANE-VU states and to develop emissions inventories that will be of greater value for visibility planning purposes.

Figure 8.8 2002 Volatile Organic Carbon (VOC) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (106 tpy)

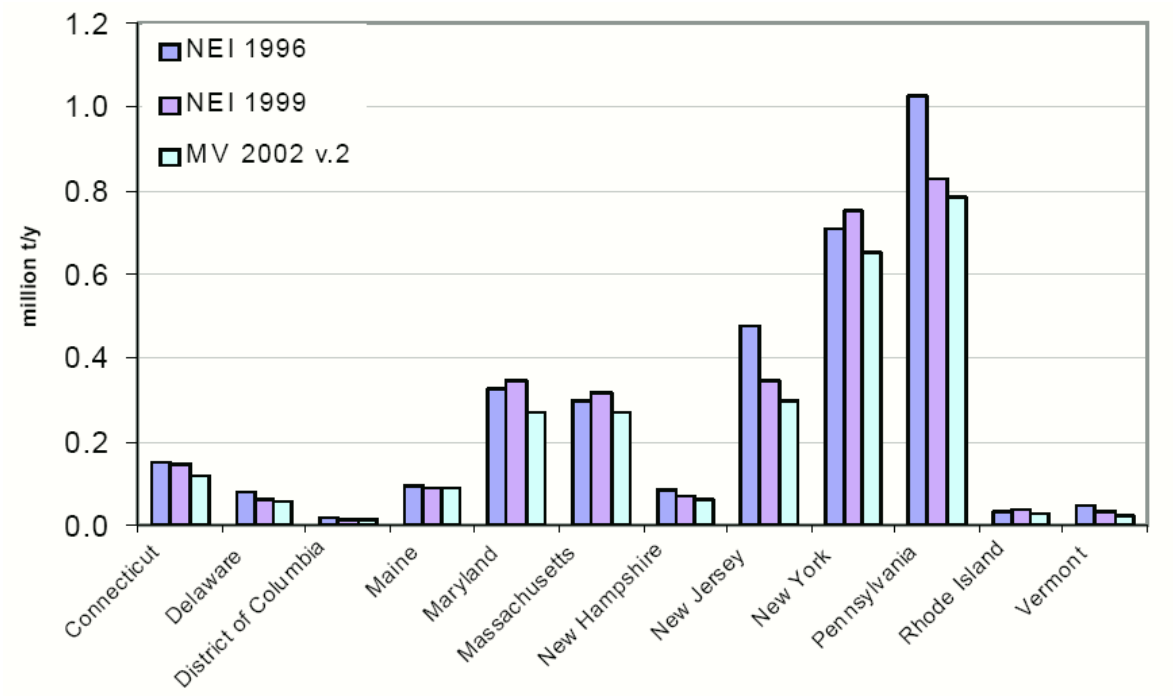


8.3.3 Oxides of Nitrogen (NO_X)

NO_X emissions contribute to visibility impairment in the eastern U.S. by forming light-scattering nitrate particles. Nitrate generally accounts for a substantially smaller fraction of fine particle mass and related light extinction than sulfate and organic carbon at northeastern Class I areas. Notably, nitrate may play a more important role in urban settings and in the wintertime. In addition, NO_X may have an indirect effect on summertime visibility by virtue of its role in the formation of ozone, which in turn promotes the formation of secondary organic aerosols (NESCAUM, 2001a).

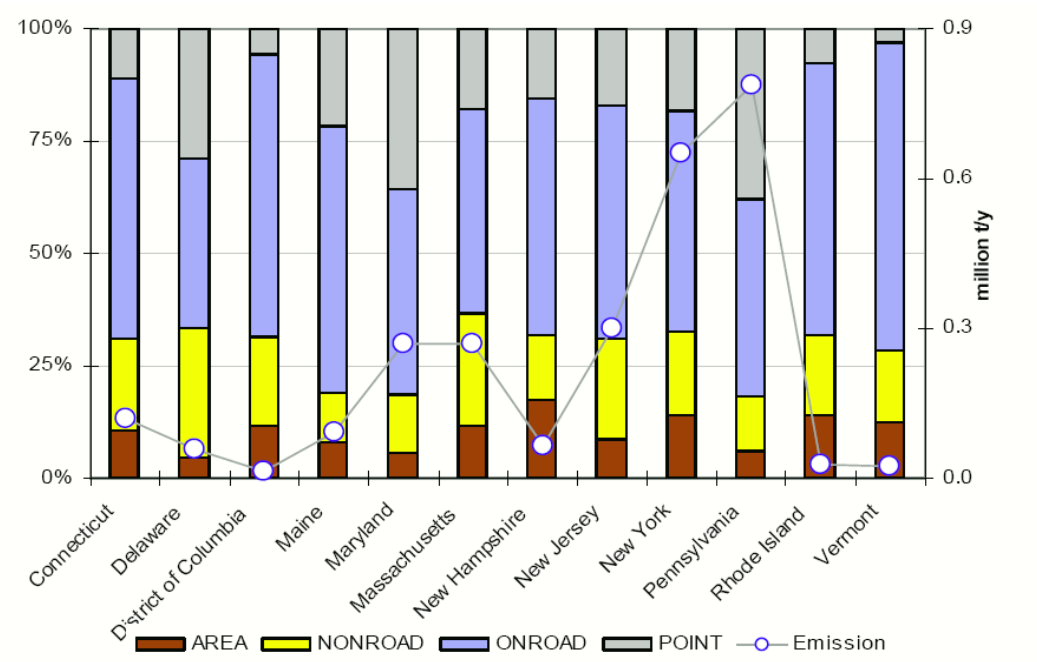
Since 1980, nationwide emissions of NO_X from all sources have shown little change. In fact, emissions increased by 2 percent between 1989 and 1998 (EPA, 2000a). This increase is most likely due to industrial sources and the transportation sector, as power plant combustion sources have implemented emission reductions during the same time period. Figure 8.9 shows NO_X emissions in 1996, 1999, and 2002 for each state in the MANE-VU region. Most states experienced steadily declining NO_X emissions between the two outer years. The exceptions were Massachusetts, Maryland, New York, and Rhode Island, where NO_X emissions increased from 1996 to 1999 before declining to below-1996 levels in 2002.

Figure 8.9 Trends in Annual Nitrogen Oxide (NO_X) Emissions, by State



Power plants and mobile sources generally dominate state and national NO_X emissions inventories. Nationally, power plants account for more than one-quarter of all NO_X emissions, amounting to over six million tons annually. The electric sector plays an even larger role in parts of the industrial Midwest, where power plants contribute significantly to NO_X emissions. By contrast, mobile sources dominate the NO_X inventories for more urbanized MANE-VU states, as shown in Figure 8.10.

Figure 8.10 2002 Nitrogen Oxide (NO_X) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (106 tpy)



In these states, on-road mobile sources (i.e., highway vehicles) represent the largest NO_X source category. Emissions from non-road (i.e., off-highway) mobile sources, primarily diesel-powered engines, also make up a substantial fraction of the inventory.

While there are fewer uncertainties associated with NO_X emissions than with other key haze-related pollutants (especially primary fine particulate and ammonia emissions), further efforts could improve the quality of current NO_X emission inventories in a number of areas (NESCAUM, 2001a). Specifically, better information on the contribution of area and non-road mobile sources may be of most interest in the context of regional haze planning. Available emission estimation methodologies are weaker for these types of sources than for the large stationary combustion sources. Moreover, because NO_X emissions must mix with ammonia to participate in secondary ammonium nitrate particle formation, emissions that occur over large areas at the surface may be more efficient in secondary fine particulate formation than concentrated emissions from isolated tall stacks (Duyzer, 1994).

8.3.4 Primary Particulate Matter (PM_{10} and $PM_{2.5}$)

Directly emitted, or "primary," particles (as distinct from secondary particles that form in the atmosphere through chemical reactions involving precursor pollutants such as SO_2 and NO_X) can also contribute to regional haze. For regulatory purposes, a distinction is made between particulate matter (PM) with an aerodynamic diameter less than or equal to 10 micrometers (PM_{10}) and smaller particles with an aerodynamic diameter less than or equal to 2.5 micrometers ($PM_{2.5}$).

Figures 8.11 and 8.12 show PM_{10} and $PM_{2.5}$ emissions, respectively, for the MANE-VU states for the years 1996, 1999, and 2002. Note that the inventory values for PM_{10} are drawn from the 2002 NEI. Most states show a steady decline in annual PM_{10} emissions over this time period. By contrast, emission trends for primary $PM_{2.5}$ are more variable.

Crustal sources are significant contributors of primary PM emissions. This category includes fugitive dust emissions from construction activities, paved and unpaved roads, and agricultural tilling. Typically, monitors estimate PM_{10} emissions from these types of sources by measuring the horizontal flux of particulate mass at a fixed downwind sampling location within perhaps 10 meters of a road or field. Comparisons between estimated emission rates for fine particles using these types of measurement techniques and observed concentrations of crustal matter in the ambient air at downwind receptor sites suggest that physical or chemical processes remove a significant fraction of crustal material relatively quickly. As a result, it rarely entrains into layers of the atmosphere where it can be transported to downwind receptor locations. Because of this discrepancy between estimated emissions and observed ambient concentrations, modelers typically reduce estimates of total $PM_{2.5}$ emissions from all crustal sources by applying a factor of 0.15 to 0.25 to the total $PM_{2.5}$ emissions before including them in modeling analyses.

Figure 8.11 Trends in Primary Coarse Particle (PM_{10}) Emissions, by State

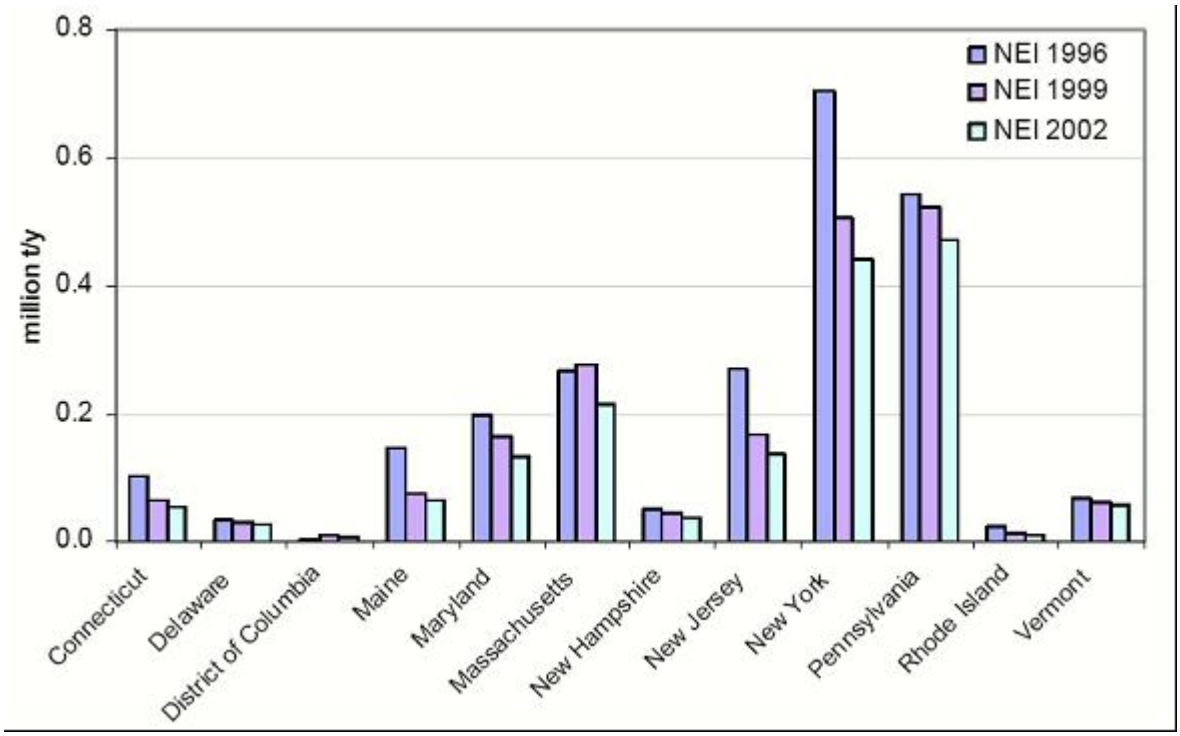
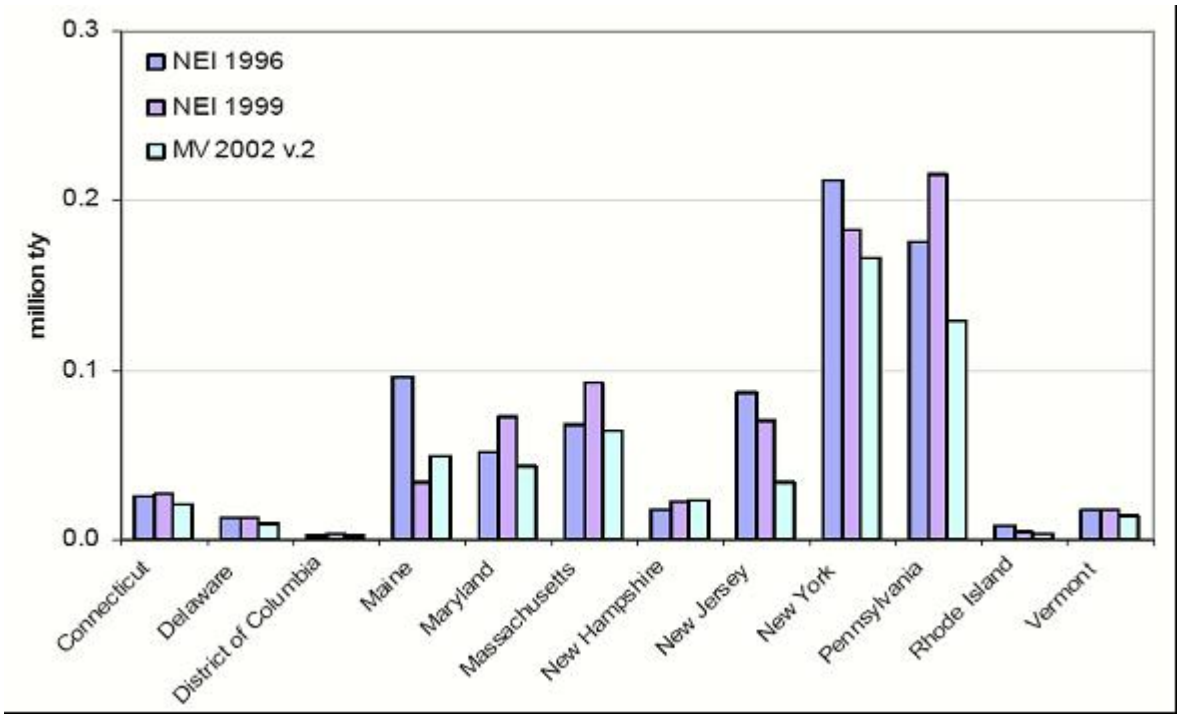


Figure 8.12 Trends in Primary Fine Particle ($PM_{2.5}$) Emissions, by State



From a regional haze perspective, crustal material generally does not play a major role. On the 20 percent best visibility days during the baseline period (2000-2004), crustal PM accounted for six to eleven percent of particle-related light extinction at MANE-VU Class I sites. On the 20 percent worst visibility days, however, crustal material generally plays a much smaller role than other haze-forming pollutants, contributing only two to three percent of light extinction, Moreover, the crustal fraction includes materials of natural origin, such as soil or sea salt, that is not targeted under the Regional Haze Rule. Of course, the crustal fraction can be influenced by construction, agricultural practices, and road maintenance (including wintertime salting). Thus, to the extent that these types of activities are found to affect visibility at Northeastern Class I areas, control measures targeted at crustal material may prove beneficial.

Experience from the western United States, where the crustal component has played a more significant role in overall particulate and regional haze levels, may be applicable to the extent that it is relevant to the situation in the eastern states. In addition, a few areas in the Northeast, such as New Haven, Connecticut, and Presque Isle, Maine, have had some experience with the control of dust and road-salt stemming from regulatory obligations related to their past non-attainment status with respect to the NAAQS for PM_{10}.
Current emissions inventories for the entire MANE-VU area indicate that residential wood combustion represents 25 percent of primary fine particle emissions in the region. This finding implies that rural sources can play an important role as well as contributions from the region's many populous urban areas. An important consideration in this regard is that residential wood combustion occurs mainly in the winter months, while wild fires as well as managed or prescribed burning activities occur largely in other seasons. The latter category includes agricultural field-burning, prescribed burning of forested areas, and miscellaneous burning activities such as construction waste burning. Particulate emissions from many of these sources can be managed by limiting allowed burning activities to times when favorable meteorological conditions can efficiently disperse the emissions.

Many sections of the relatively high elevation of the Lye Brook Wilderness Area - and the Lye Brook IMPROVE monitor - are likely to be frequently above the mixed layer during the winter when (lower elevation) residential wood burning emissions are greatest. Thus winter wood smoke may be less of an important contributor to haze at Lye Brook than it is as a contributor to high winter $PM_{2.5}$ concentrations in more populated, lower elevation mountain valley locations. In a receptor modeling analysis conducted for MANE-VU by Battelle Labs using the Positive Matrix Factorization (PMF) model, Coutant et al (2002) identified a "biomass combustion" (wood smoke) source at Lye Brook (based on 1991 to 1999 IMPROVE data). The PMF-modeled wood smoke source accounted for nearly 1/3 of the average fine mass at Lye Brook, although its contribution was proportionately larger on the cleanest days than on the haziest days. Its average concentration was higher in the summer than in winter, consistent with forest fires rather than residential wood combustion.

Figure 8.13, taken from the MANE-VU Contribution Assessment, shows the trajectory-based incremental probability field for the highest concentrations of Lye Brook PMF wood smoke source. Note that it includes a Canadian area in eastern Ontario and western Quebec which has been periodically associated with lightening-induced forest fires.

Figure 8.13 Upwind Incremental Probability for LYBR PMF Wood Smoke Source

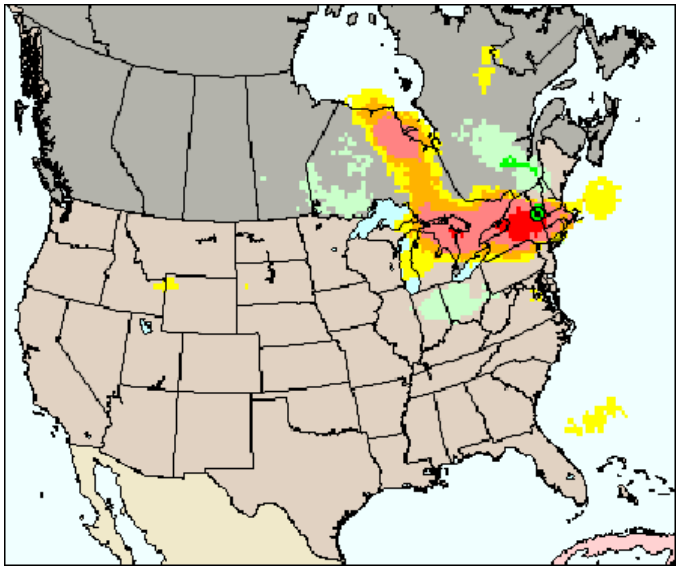
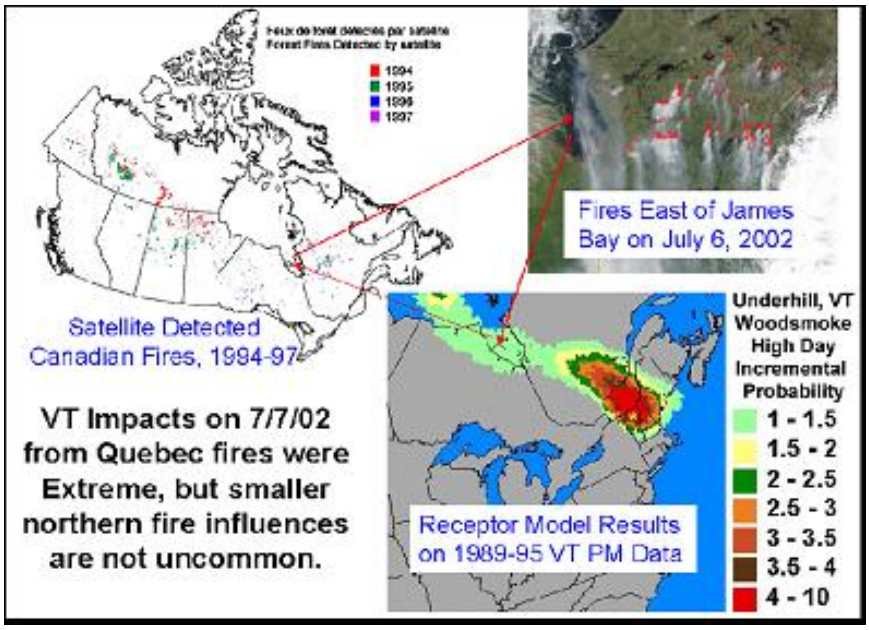


Figure 8.14 shows a similar incremental probability field for a wood smoke source identified by Unmix receptor modeling of 1989-1995 IMPROVE-like data from Underhill, VT reported by Poirot et al., (2001), along with the location of satellite-detected Canadian fires between 1994 and 1997, and the locations of the massive July, 2002 Quebec fires.

Figure 8.14 Incremental probability for 1989-1995 Underhill VT wood smoke compared with Canadian forest fire locations



While there are occasionally large Canadian wild fire impacts at Lye Brook, these infrequent natural sources are not subject to regulatory controls. There are also relatively minor impacts from prescribed burning on visibility in MANE-VU class I areas. MANE-VU's "Technical Support Document on Agricultural and Forestry Smoke Management in the MANE-VU Region," September 1, 2006 (Attachment S), concluded that fire from land management activities was not a major contributor to regional haze in MANE-VU Class I Areas, and that the majority of emissions from fires were from residential wood combustion. As the costs of home heating fuels continue to rise, residential wood burning is likely to become a more important source of $PM_{2.5}$ concentrations and visibility impairment in the future.

Figures 8.15 and 8.16 show that area sources dominate primary PM emissions. (The NEI inventory categorizes residential wood combustion and some other combustion sources as area sources.) The relative contribution of point sources is larger in the primary $PM_{2.5}$ inventory than in the primary PM_{10} inventory because the crustal component of particulate emissions (consisting mainly of larger, or coarse, particles) contributes more to overall PM_{10} levels than to $PM_{2.5}$ levels. At the same time, pollution control equipment commonly installed at large point sources is usually more efficient at capturing coarse particle emissions, than it is at capturing fine particles and their gaseous precursors.

Figure 8.15 2002 Primary Coarse Particle (PM_{10}) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (10_6 tpy)

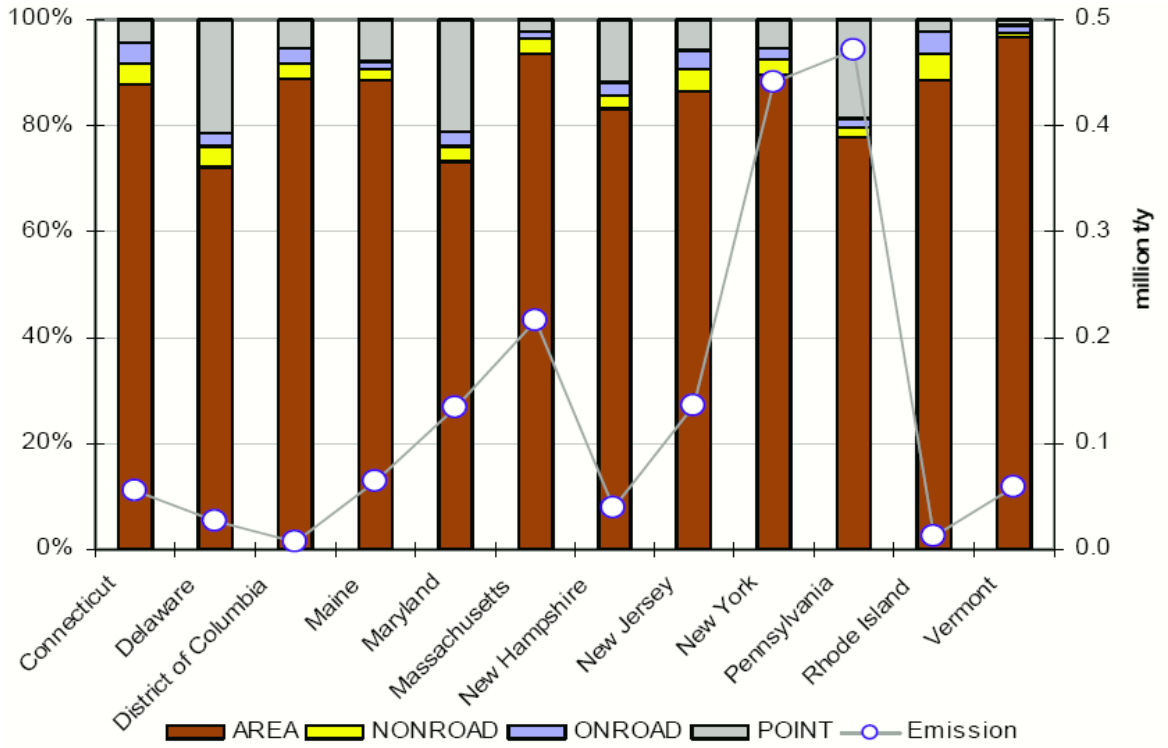
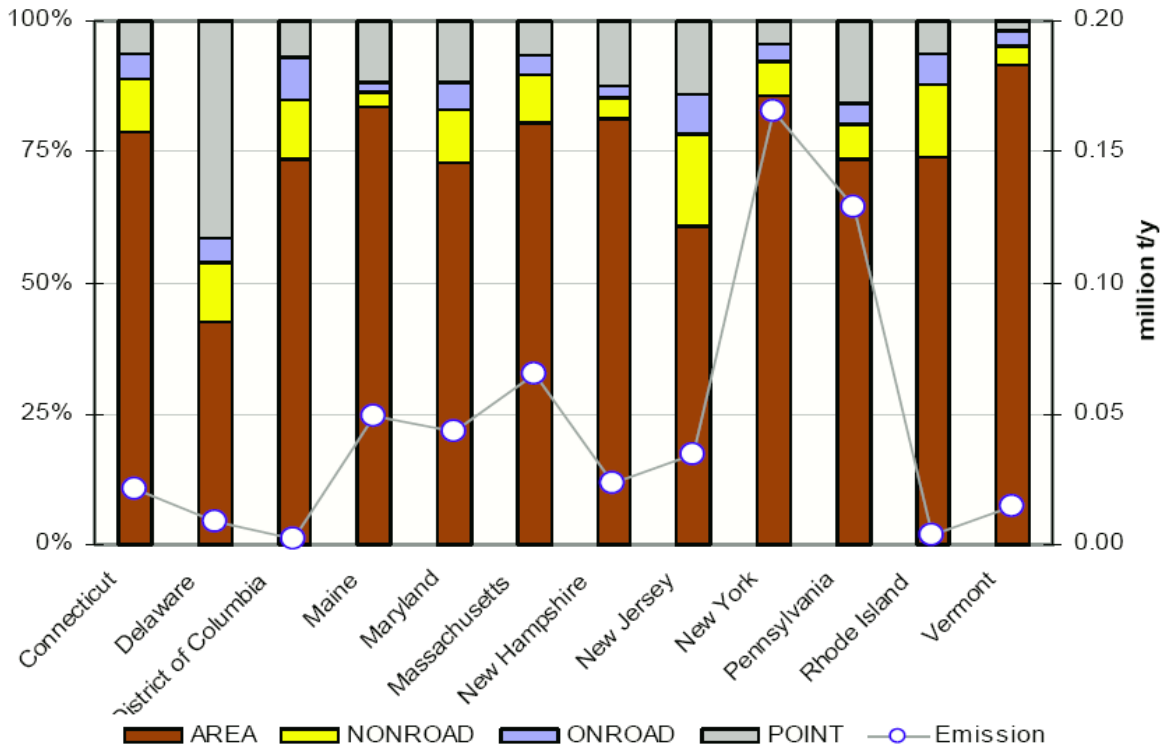


Figure 8.16 2002 Primary Fine Particle ($PM_{2.5}$) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (10_6 tpy)



8.3.5 Ammonia Emissions (NH_3)

Because ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3) are significant contributors to atmospheric light scattering and fine particle mass, knowledge of ammonia emission sources is important to the development of effective regional haze reduction strategies. According to 1998 estimates, livestock agriculture and fertilizer use accounted for approximately 86 percent of all US ammonia emissions to the atmosphere (EPA, 2000b). However, improved ammonia inventory data are needed as inputs to the photochemical models used to simulate fine particle formation and transport in the eastern United States. States were not required to include ammonia in their emissions data collection efforts until fairly recently (see the Consolidated Emissions Reporting Rule, 67 CFR 39602, June 10, 2002). Therefore, emissions data for ammonia do not exist at the same level of detail or reliability as exists for other pollutants.

Ammonium ion (formed from ammonia emissions to the atmosphere) is an important constituent of airborne particulate matter, typically accounting for 10–20 percent of total fine particle mass. Reductions in ammonium ion concentrations can be instrumental to controlling regional haze because such reductions can yield proportionately greater reductions in fine particle mass. Ansari and Pandis (1998) showed that a one $\mu g/m^3$ reduction in ammonium ion could result in up to a four $\mu g/m^3$ reduction in fine particulate matter. Decision makers,

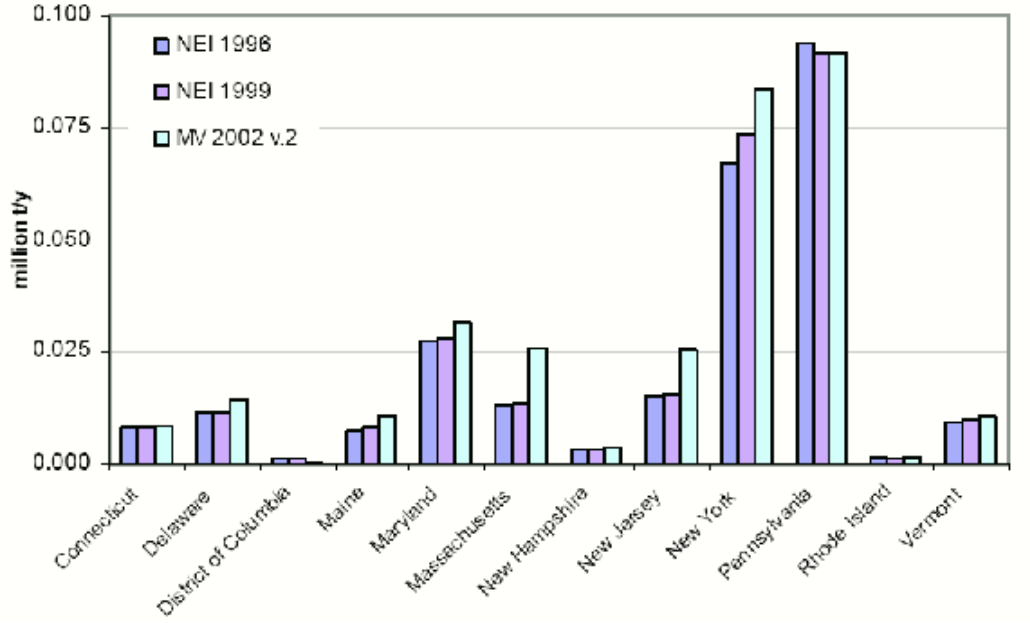
however, must weigh the benefits of ammonia reduction against the significant role it plays in neutralizing acidic aerosol.*

To address the need for improved ammonia inventories, MARAMA, NESCAUM, and EPA funded researchers at Carnegie Mellon University (CMU) in Pittsburgh to develop a regional ammonia inventory (Davidson et al., 1999). This study focused on three issues with respect to current emission estimates: 1) a wide range of ammonia emission factors, 2) inadequate temporal and spatial resolution of ammonia emissions estimates, and 3) a lack of standardized ammonia source categories.

The CMU project established an inventory framework with source categories, emission factors, and activity data that are readily accessible to the user. With this framework, users can obtain data in a variety of formats† and can make updates easily, allowing additional ammonia sources to be added or emission factors to be replaced as better information becomes available (Strader et al., 2000; NESCAUM, 2001b).

Figures 8.17 and 8.18 show that estimated ammonia emissions held fairly stable across the 1996, 1999, and 2002 inventories for MANE-VU states, with some increases observed for Massachusetts, New Jersey, and New York.

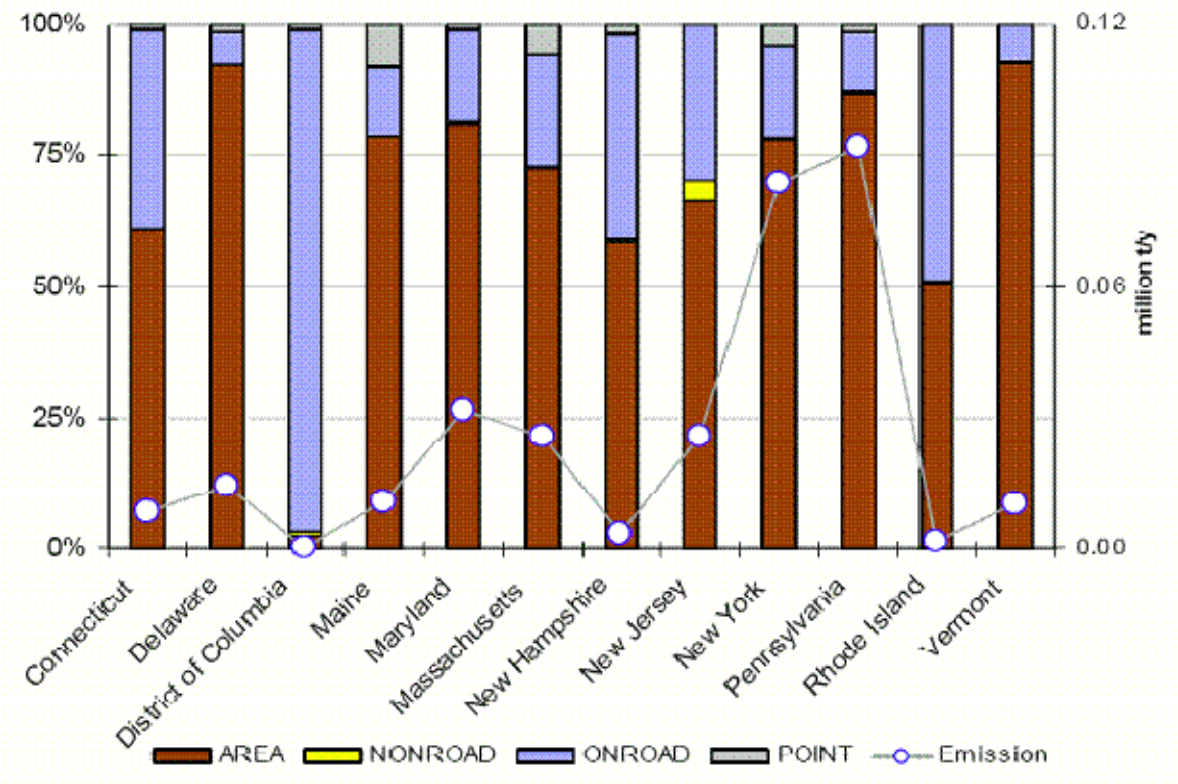
Figure 8.17 Trends in Ammonia (NH_3) Emissions, by State



* SO_2 reacts in the atmosphere to form sulfuric acid (H_2SO_4). Ammonia can partially or fully neutralize this strong acid to form ammonium bisulfate or ammonium sulfate. If planners focus future control strategies on ammonia and do not achieve corresponding SO_2 reductions, fine particles formed in the atmosphere will be substantially more acidic than those presently observed.

† For example, the user will have the flexibility to choose the temporal resolution of the output emissions data or to spatially attribute emissions based on land-use data.

Figure 8.18 2002 Ammonia (NH_3) Emissions, by State Bar Graph = Percentage Fractions of Four Source Categories Line Graph = Total Annual Emissions (10_6 tpy)



Area and on-road mobile sources dominate the ammonia inventory data. Specifically, emissions from agricultural sources and livestock production account for the largest share of estimated ammonia emissions in the MANE-VU region, except in the District of Columbia. The two other sources contributing significant emissions are wastewater treatment systems and gasoline exhaust from highway vehicles.

8.4 References for Section 8

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9. Best Available Retrofit Technology (BART)

In the Regional Haze Rule, EPA included provisions designed specifically to reduce emissions of visibility-impairing pollutants from large sources that, because of their age, were exempted from new source performance standards (NSPS) established under the Clean Air Act. These provisions, known as Best Available Retrofit Technology, or BART, are located at 40 CFR 51.308(e).

The BART requirements pertain to large facilities in each of 26 source categories that meet certain criteria, including industrial boilers, pulp and paper mills, cement kilns, and other large stationary sources. The BART program applies to units installed and operated between 1962 and 1977 with the potential to emit more than 250 tons per year of a visibility-impairing pollutant. Each BART-eligible unit must undergo a case-by-case analysis to determine whether new emission restrictions are appropriate to limit the unit's impact on visibility at Class I areas.

Under this part of the Regional Haze rule, Vermont is required to submit an implementation plan containing emission limitations representing Best Available Retrofit Technology and schedules for compliance with BART for each BART-eligible source that may reasonably be anticipated to cause or contribute to any impairment of visibility in any mandatory Class I area. The BART provisions of the Regional Haze Rule require states to develop an inventory of sources within each state that would be eligible for BART controls. The rule also:

- Outlines methods to determine whether a source is "reasonably anticipated to cause or contribute to haze,"
- Defines the methodology for conducting BART control analysis,
- Provides presumptive limits for electricity generating units (EGUs) larger than 750 Megawatts, and
- Provides a justification for the use of the Clean Air Interstate Rule (CAIR) as meeting BART requirements for CAIR-affected electrical generating units (EGUs). (Note: Vermont (along with many other states) has always held that CAIR requirements are not source-specific and therefore should not, in the general case, be considered equivalent to BART requirements, which *are* source-specific.)

Beyond the specific elements listed above, EPA has allowed the states a great deal of flexibility in implementing the BART program. Because of the collective importance of BART sources to the management of regional haze, the MANE-VU Board decided, in June 2004, that a BART determination would be made by the member states for each BART-eligible source, without exception. However, as indicated in the MANE-VU Reports "Assessment of Control Technology Options for BART-Eligible Sources" (Attachment V), and "Five-Factor Analysis on BART-Eligible Sources" (Attachment T), there are **no** BART-eligible sources in Vermont.

Many facilities in the MANE-VU region are relatively small emission sources with potential emissions exceeding the BART applicability threshold of 250 tons per year of haze-causing pollutants but whose actual emissions are well below 250 tons in any year. Some of these

facilities may have accepted an enforceable permit limitation restricting their emissions to less than 250 tons per year. Any otherwise BART-eligible facility may be allowed to "cap-out" of BART by accepting enforceable permit limits. In addition, some BART-eligible facilities may have permanently shut down. Because there are no BART-eligible sources in Vermont, **no** BART-eligible facilities capped out or permanently shut down to avoid BART in Vermont.

As provided in 40 CFR 51.308(e)(1)(ii)(C) of the Regional Haze Rule, a state is not required to make a BART determination for either SO_2 or NO_X if a BART-eligible source has the potential to emit less than 40 tons per year of these pollutants, or for PM_{10} if a BART-eligible source emits less than 15 tons per year of this pollutant. In Vermont **no** BART-eligible sources have been exempted from the BART determination process.

9.1 Bart-Eligible EGUs and the Role of CAIR

The BART-eligible EGUs in MANE-VU (and in the Midwest RPO and VISTAS regions) represent the largest potential for emission reductions among the various BART-eligible source categories. The population of BART-eligible EGUs within the MANE-VU domain was geographically divided into three groups.

- *CAIR states (year-round)*: EGUs in states eligible to participate in the (CAIR) program on a year-round basis (Delaware, District of Columbia, Maryland, New Jersey, New York, and Pennsylvania, for SO_2 and NO_X);
- *CAIR states (seasonal)*: EGUs in states eligible to participate in the seasonal CAIR program only (Connecticut and Massachusetts, for summertime NO_X); and
- *Non-CAIR states*: EGUs in states not eligible to participate in the CAIR annual or seasonal programs (Maine, New Hampshire, Rhode Island, and Vermont).

Under 40 CFR 51.308(e)(4), EPA established that a state's participation in the CAIR program will satisfy BART requirements for BART-eligible EGUs that are also subject to CAIR. This provision could affect all BART-eligible EGUs in Pennsylvania, Delaware, Maryland, New Jersey, New York, the District of Columbia, and those EGUs located in Connecticut and Massachusetts that are also included in the CAIR program, but only with respect to their emissions of ozone-season NO_X.

The original purpose of BART was to require source-specific controls on BART-eligible units. Vermont has always maintained that the location of BART-eligible EGUs and their impacts on visibility in Class I areas should be addressed as the BART rule intended. MANE-VU assessments have determined that allowing EGUs with the largest impacts on Class I areas to purchase allowances under the CAIR emissions trading program will produce less visibility benefit than intended by the BART rule. Accordingly, MANE-VU developed a targeted EGU strategy in order to recapture some of the lost benefit. (The targeted EGU strategy is discussed at length in Sections 10 and 11).

10. Reasonable Progress Goals

40 CFR 51.308(d)(1) of the Regional Haze Rule requires that Vermont establish reasonable progress goals (RPGs) toward achieving natural visibility conditions for the Lye Brook Wilderness Area. On June 1, 2007, the U.S. Environmental Protection Agency (EPA) released final guidance to be used by states in setting reasonable progress goals. The goals must provide for visibility improvement on the days of greatest visibility impairment and ensure no visibility degradation on the days of least visibility impairment for the duration of the State Implementation Plan (SIP) period.

As provided in 40 CFR 51.308 (d)(1)(iv), the state must consult with other states in the setting of reasonable progress goals. The rule states:

> "In developing each reasonable progress goal, the State must consult with those States which may reasonably be anticipated to cause or contribute to visibility impairment in the mandatory Class I Federal area. In any situation in which the State cannot agree with another such State or group of States that a goal provides for reasonable progress, the State must describe in its submittal the actions taken to resolve the disagreement. In reviewing the State's implementation plan submittal, the Administrator will take this information into account in determining whether the State's goal for visibility improvement provides for reasonable progress towards natural visibility condition."

Vermont consulted with states found to contribute to visibility impairment at Lye Brook. In addition, Vermont worked closely with the other MANE-VU states to ensure consistency of approach in setting reasonable progress goals. **Accordingly, Vermont agrees with the reasonable progress goals established by Maine, New Hampshire, and New Jersey.** A description of the consultation process is found in Section 3.0, Regional Planning and Consultation.

The Regional Haze Rule also requires each Class I state to consider four factors in setting reasonable progress goals: cost, time needed for compliance, energy and non-air quality environmental impacts, and remaining useful life. In addition, the state must show that it considered the uniform rate of improvement and the emission reduction measures needed to achieve it for the period covered by the implementation plan. If the state proposes a rate of progress slower than the uniform rate of progress, the state must assess the number of years it would take to attain natural conditions if visibility improvement continues at the rate proposed.

10.1 Calculation of Uniform Rate of Progress

As a benchmark to aid in developing reasonable progress goals, MANE-VU compared baseline visibility conditions to natural visibility conditions at each MANE-VU Class I area. The difference between baseline and natural visibility conditions for the 20 percent worst days was used to determine the uniform rate of progress that would be needed during each implementation period in order to attain natural visibility conditions by 2064. Table 10.1 presents baseline visibility, natural visibility, and required uniform rate of progress for each

MANE-VU Class I area. Visibility values are expressed in deciviews (dv), where each single-unit deciview decrease would represent a barely perceptible improvement in visibility.

Table 10.1 Uniform Rate of Progress Calculation (all values in deciviews)

Class I Area	2000-2004 Baseline Visibility (20% Worst Days)	Natural Visibility (20% Worst Days)	Total Improvement Needed by 2018	Total Improvement Needed by 2064	Uniform Annual Rate of Improvement
Acadia National Park	22.9	12.4	2.4	10.5	0.174
Moosehorn Wilderness and Roosevelt Campobello International Park	21.7	12.0	2.3	9.7	0.162
Great Gulf Wilderness and Presidential Range - Dry River Wilderness	22.8	12.0	2.5	10.8	0.180
Lye Brook Wilderness	24.5	11.7	3.0	12.8	0.212
Brigantine Wilderness	29.0	12.2	3.9	16.8	0.280

Note: Both natural conditions and baseline visibility for the 5-year period from 2000 through 2004 were calculated in conformance with an alternative method recommended by the IMPROVE Steering Committee.*

The reasonable progress goals established for MANE-VU's Class I Areas, described later in Subsection 10.3, are expected to provide visibility improvements in excess of the uniform rates of progress shown above.

10.2 Identification of (Additional) Reasonable Control Measures

Vermont and the other MANE-VU states have identified specific emission control measures – beyond those which individual states or RPOs had already made commitments to implement – that would be reasonable to undertake as part of a concerted strategy to mitigate regional haze. The proposed additional control measures were incorporated into the regional strategy adopted by MANE-VU on June 20, 2007, to meet the reasonable progress goals established in this SIP. The basic elements of this strategy are described in the Vermont/MANE-VU "Ask" (see Part 3.2.2 in Section 3.0, Regional Planning and Consultation). States targeted for coordinated actions toward achieving these goals include all of the MANE-VU states plus Georgia, Illinois, Indiana, Kentucky, Michigan, North Carolina, Ohio, South Carolina, Tennessee, Virginia, West Virginia and Wisconsin.†

In addition to including proposed emission controls in the eastern United States, MANE-VU determined that it was reasonable to include anticipated emission reductions in Canada in the modeling used to set reasonable progress goals. This determination was based on evaluations

* "Baseline and Natural Visibility Conditions, Considerations and Proposed Approach to the Calculation of Baseline and Natural Visibility Conditions at MANE-VU Class I Areas," NESCAUM, December 2006.

† Independently from other MANE-VU modeling and assessments, Vermont CALPUFF modeling identified Wisconsin as a significant contributor to visibility impairment at the Lye Brook Wilderness Class I Area (See Section 3.2.1).

conducted before and during the consultation process (see description of relevant consultations in Part 3.2.1). Specifically, the modeling accounts for six coal-burning electric generating units (EGUs) in Canada having a combined output of 6,500 MW that are scheduled to be shut down and replaced by nine natural gas turbine units equipped with selective catalytic reduction (SCR) by 2018.

The process of identifying reasonable measures and setting reasonable progress goals is described in the subsections which follow. Further elaboration on the reasonable measures which make up the Vermont/MANE-VU long-term strategy is provided in Section 11.0 of this SIP. Under this plan, the affected states will have a maximum of 10 years to implement reasonable and cost-effective control measures to reduce primarily SO_2 and NO_X emissions. For a description of how proposed emission control measures were modeled to estimate resulting visibility improvements, see Subsection 10.4, Visibility Effects of (Additional) Reasonable Control Measures.

10.2.1 Rationale for Determining Reasonable Controls

40 CFR 51.308(d)(1)(i)(A) of EPA's Regional Haze Rule requires that, in establishing reasonable progress goals for each Class I area, the state must consider the costs of compliance, the time necessary for compliance, the energy and non-air quality environmental impacts of compliance, and the remaining useful life of any potentially affected sources. The SIP must include a demonstration showing how these factors were taken into consideration in setting the RPGs. These factors are sometimes termed the "four statutory factors," since their consideration is required by the Clean Air Act.

Focus on SO_2: MANE-VU conducted a Contribution Assessment (Attachment B) and developed a conceptual model that showed the dominant contributor to visibility impairment at all MANE-VU Class I areas during all seasons in the base year was particulate sulfate formed from emissions of SO_2. While other pollutants, including organic carbon, will need to be addressed in order to achieve the national visibility goals, MANE-VU's contribution assessment suggested that an early emphasis on SO_2 would yield the greatest near-term benefit. Therefore, it is reasonable to conclude that the additional measures considered in setting reasonable progress goals require reductions in SO_2 emissions.

Contributing Sources: The MANE-VU Contribution Assessment indicates that emissions from within MANE-VU in 2002 were responsible for approximately 25 percent of the sulfate at MANE-VU Class I Areas. Sources in the Midwest and Southeast regions were responsible for about 15 to 25 percent each. Point sources dominated the inventory of SO_2 emissions. Therefore, MANE-VU's long-term strategy includes additional measures to control sources of SO_2 both within the MANE-VU region and in other states that were determined to contribute to regional haze at MANE-VU Class I Areas.

The Contribution Assessment documented the source categories most responsible for visibility degradation at MANE-VU Class I Areas. As described in Section 11, Long-Term Strategy, there was a collaborative effort between the Ozone Transport Commission and MANE-VU to evaluate a large number of potential control measures. Several measures that would reduce SO_2 emissions were identified for further study.

These efforts led to production of the MANE-VU report by MACTEC Federal Programs, Inc., "Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I Areas," Final, July 9, 2007, otherwise known as the Reasonable Progress Report (Attachment U). This report provides an analysis of the four statutory factors for five major source categories: electrical generating units (EGUs); industrial, commercial, and institutional (ICI) boilers; cement and lime kilns; heating oil combustion; and residential wood combustion. Table 10.2 summarizes the results of MANE-VU's four-factor analysis for the source categories considered.

Table 10.2 Summary of Results from Four-Factor Analysis of Different Source Categories

Source Category	Primary Regional Haze Pollutant	Control Measure(s)	Average Cost in 2006 dollars (per ton of pollutant reduction)	Compliance Timeframe	Energy and Non-Air Quality Environmental Impacts	Remaining Useful Life
Electric Generating Units	SO_2	Switch to a low-sulfur coal (generally <1% sulfur); switch to natural gas (virtually 0% sulfur); coal cleaning; flue gas desulfurization (FGD), including wet, spray-dry, or dry.	$775-$1,690 based on IPM® v.2.1.9 * $170-$5,700 based on available literature	2-3 years following SIP submittal	Fuel supply issues, possible permitting issues, reduced electricity production capacity, wastewater issues	50 years or more
Industrial, Commercial, Institutional Boilers	SO_2	Switch to a low-sulfur coal (generally <1% sulfur); switch to natural gas (virtually 0% sulfur); switch to a lower-sulfur oil; coal cleaning; combustion controls; flue gas desulfurization (FGD), including wet, spray-dry, or dry.	$130-$11,000 based on available literature; dependent on size.	2-3 years following SIP submittal	Fuel supply issues, potential permitting issues, control device energy requirements, wastewater issues	10-30 years
Cement and Lime Kilns	SO_2	Fuel switching; flue gas desulfurization (FGD), including wet, spray-dry, or dry; advanced flue gas desulfurization (FGD).	$1,900-$73,000 based on available literature; dependent on size.	2-3 years following SIP submittal	Control device energy requirements, wastewater issues	10-30 years
Heating Oil	SO_2	Switch to lower-sulfur fuel (varies by state)	$550-$750 based on available literature; high degree of uncertainty with this cost estimate	Currently feasible; capacity issues may influence timeframe for implementation of new fuel standards	Increased furnace/boiler efficiency, reduced furnace/boiler maintenance requirements	18-25 years
Residential Wood Combustion	PM	State implementation of NSPS, ban on resale of uncertified devices, installer training certification or inspection program, pellet stoves, EPA Phase II certified RWC devices, retrofit requirement, accelerated changeover requirement or inducement	$0-$10,000 based on available literature	Several years, depending on mechanism for emission reductions	Increased efficiency of combustion device, reduced greenhouse gas emissions	10-15 years

* Integrated Planning Model® CAIR versus CAIR plus analysis conducted for MARAMA/MANE-VU by ICF Consulting, L.L.C.

The MANE-VU states reviewed the four-factor analyses presented in the Reasonable Progress Report, consulted with one another about possible control measures, and concluded by adopting the statements known as the MANE-VU Ask. These statements identify the control measures that would be pursued toward improving visibility in the region. The following discussions focus on the four basic control strategies chosen by MANE-VU and included in the modeling to establish the reasonable progress goals:

1. Best Available Retrofit Technology (BART),
2. Low-sulfur fuel oil requirements,
3. Emission reductions from specific EGUs, and
4. Additional measures determined to be reasonable.

10.2.2 Best Available Retrofit Technology Controls

The MANE-VU states have identified approximately 100 BART-eligible sources in the region. Most of these facilities are already controlling emissions in response to other federal or state air programs or are likely to install emission controls under new programs. (Previously, EPA had determined that CAIR fulfilled the BART requirement for all EGUs in participating CAIR states.) A complete compilation of BART-eligible sources in the MANE-VU region is available in Appendix A of MANE-VU's "Assessment of Control Technology Options for BART-Eligible Sources," March 2005, also known as the BART Report (Attachment V).

To assess the benefits of implementing BART in the MANE-VU region, NESCAUM estimated emission reductions for twelve BART-eligible sources in MANE-VU states that would probably be controlled as a result of BART requirements alone. These sources include one EGU and eleven non-EGUs. The affected sources were identified by a survey of states' staff members, who furnished data on the potential control technologies and expected control levels for these sources under BART implementation. The twelve sources are listed in Table 10.3 along with their 2002 baseline and 2018 estimated emissions. Information on these sources was incorporated into the 2018 emissions inventory projections that were used in the modeling to set reasonable progress goals.

***Best Available Retrofit Technology is Reasonable*:** BART controls are part of the strategy for improving visibility at MANE-VU Class I Areas. MANE-VU prepared reports to provide states with information about available control technologies (e.g., MANE-VU's BART Report referenced above), estimated cost ranges, and other factors associated with those controls. The reasonable progress goals established in this regional haze SIP assume that states whose emissions affect Class I areas in Vermont and elsewhere in MANE-VU will make determinations demonstrating the reasonableness of BART controls for sources in their states.

Table 10.3 Estimated Emissions from BART-Eligible Facilities in MANE-VU States (Facilities Likely to be Controlled as a Result of BART Alone)

State	Facility Name	Unit Name	SCC Code	Plant ID (MANE-VU Inventory)	Point ID (MANE-VU Inventory)	Facility Type	2002 SO_2 Emissions (tons)	2018 SO_2 Emissions (tons)
MD	EastAlco Aluminum	28	30300101	021-0005	28	Metal Production	1,506	1,356
MD	Eastalco Aluminum	29	30300101	021-0005	29	Metal Production	1,506	1,356
MD	Lehigh Portland Cement	39	30500606	013-0012	39	Portland Cement	9	8
MD	Lehigh Portland Cement	16	30500915	021-0003	16	Portland Cement	1,321	1,189
MD	Lehigh Portland Cement	17	30500915	021-0003	17	Portland Cement	9,76	8,78
MD	Westvaco Fine Papers	2	10200212	001-0011	2	Paper and Pulp	8,923	1,338
ME	Wyman Station	Boiler 3	10100401	2300500135	004	EGU	616	308
ME	SAPPI Somerset	Power Boiler 1	10200799	2302500027	001	Paper and Pulp	2,884	1,442
ME	Verso Androscoggin LLC	Power Boiler 1	10200401	2300700021	001	Paper and Pulp	2,964*	1,482
ME	Verso Androscoggin LLC	Power Boiler 2	10200401	2300700021	002	Paper and Pulp	3,086*	1,543
NY	Kodak Park Division	U00015	10200203	8261400205	U00015	Chemical Manufacturer	23,798	14,216
NY	Lafarge Building Materials, Inc	41000	30500706	4012400001	041000	Portland Cement	14,800	4,440

Note: Many additional sources in MANE-VU are BART-eligible but are expected to be controlled as a result of other emission reduction programs (e.g., state-specific multi-pollutant programs, CAIR-successor legislation, etc.).

*Data for 1999 baseline year.

10.2.3 Low-Sulfur Fuel Strategy

The MANE-VU region, especially the Northeast, is heavily reliant on distillate oil for home space heating, with more than 4 million gallons used, according to 2006 estimates from the Energy Information Administration*. Likewise, the heavier residual oils are widely used by non-EGU sources and, to a lesser extent, the EGU sector. The sulfur content of distillate fuels currently averages above 2,000 ppm (0.2 percent). Although the sulfur content of residual oils varies by source and region, it can exceed 2.0 percent. Combustion of distillate and residual fuel in the MANE-VU states resulted in SO_2 emissions totaling approximately 380,000 tons in 2002.

As the second component of MANE-VU's long-term strategy, the member states agreed to pursue measures that would require the sale and use of fuel oils having reduced sulfur content. This strategy would be implemented in two phases:

* U.S. Department of Energy, EIA, Table F3a, at http://www.eia.doe.gov/emeu/states/sep_fuel/html/fuel_use_df.html

- Phase 1 would require reducing the sulfur content in distillate (#1 and # 2) fuel oils from current levels of 2,000 to 2,300 ppm (0.20 to 0.23 percent) to a maximum of 500 ppm (0.05 percent) by weight. It would also restrict the sale of heavier blends of residual (# 4, #5, and # 6) fuel oils that have sulfur content greater than 2,500 ppm (0.25 percent) and 5,000 ppm (0.5 percent) by weight, respectively.
- Phase 2 would require further reducing the sulfur content of the distillate fraction from 500 ppm (0.05 percent) to 15 ppm (0.015 percent) while keeping the sulfur limits on residual oils at first-phase levels.

The two phases are to be introduced in sequence with slightly different timing for an inner zone of MANE-VU states* and the remainder of MANE-VU states. While all MANE-VU states have agreed to pursue implementation of both phases to full effect by the end of 2018, it is possible that not every state can make a firm commitment to these measures today. States are expected to review the situation by the time of the first regional haze SIP progress report in 2012 and to seek alternate, equivalent reductions if necessary.

Reductions in sulfur dioxide emissions will occur as a direct consequence of the low-sulfur fuel strategy. For both phases combined, it is estimated that SO_2 emissions in the MANE-VU region will decline from 2002 levels by 168,222 tons per year for combustion of light distillates and by 42,875 tons per year for combustion of the heavier fuels. Together, these reductions represent a 35 percent decrease in the projected 2018 SO_2 emissions inventory for non-EGU sources in the region.

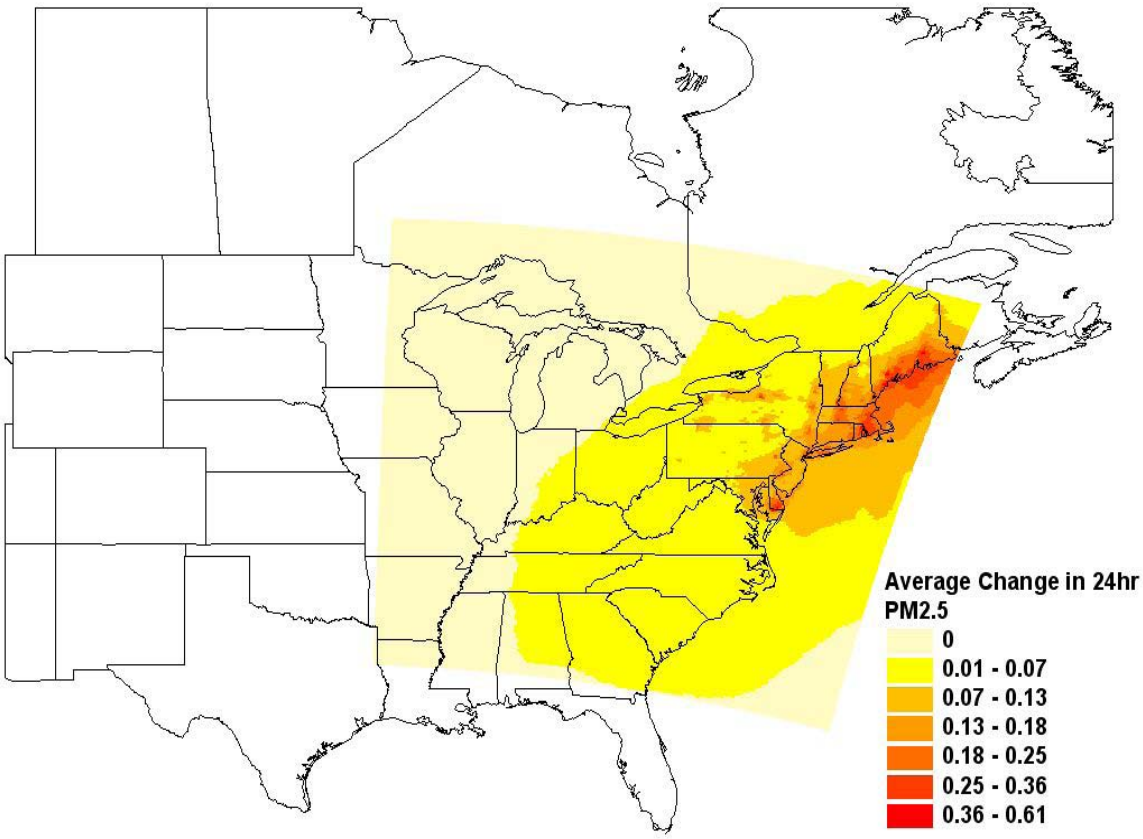
NESCAUM analyzed the two program phases separately for MANE-VU, but it is the combined benefit of implementing both phases that is relevant to the question of visibility improvement by 2018. To estimate the effects of the low-sulfur fuel strategy, MANE-VU applied the expected sulfur dioxide emission reductions to all non-EGU sources burning #1, #2, #4, #5, or #6 fuel oil. These emission reductions would result directly from the lowering of fuel sulfur content from original levels to 0.015 percent for #1 and #2 oil, to 0.25 percent for #4 oil, and to 0.5 percent for #5 and #6 oil.

The reduction in SO_2 emissions by 2018 will yield corresponding reductions in sulfate aerosol, the main culprit in fine-particle pollution and regional haze. The full benefit of MANE-VU-s low-sulfur fuel strategy is represented in Figure 10.1, which displays the estimated average reductions in 24-hr $PM_{2.5}$ concentration as calculated by the CMAQ model for the combined first and second phases of the program.

Low-Sulfur Fuel Oil Requirements are Reasonable: The MANE-VU Contribution Assessment documented source apportionment analyses that linked visibility impairment in MANE-VU Class I Areas with SO_2 emissions from sources burning fuel oil. The reasonable assumption underlying the low-sulfur fuel oil strategy is that refiners can, by 2018, produce home heating and fuel oils that contain 50 percent less sulfur for the heavier grades (#4 and #6 residual oil), and 75 to 99.25 percent less sulfur in #2 fuel oil (also known as home heating oil, distillate, or diesel fuel) at an acceptably small increase in price to the consumer.

* The inner zone includes New Jersey, Delaware, New York City, and possibly portions of eastern Pennsylvania.

Figure 10.1 Average Change in 24-hr $PM_{2.5}$ Due to Low-Sulfur Fuel Strategy (Phases I and 2 Combined) Relative to OTB/OTW (values in $\mu g/m^3$)



***Four-Factor Analysis – Low-Sulfur Fuel Oil Strategy*:** The MANE-VU Reasonable Progress Report discussed the four factors as they apply to low-sulfur fuel use for ICI boilers and residential heating systems. MANE-VU's Reasonable Progress Report identified switching to a lower-sulfur fuel oil as an available SO_2 control option that would achieve 50 to 90 percent reductions in SO_2 emissions from ICI Boilers. The report also noted that home heating oil use generates an estimated 100,000 tons of SO_2 emissions in the Northeast each year and that SO_2 emissions would decline in proportion to reductions in fuel sulfur content. The following discussion summarizes information concerning the four factors for the low-sulfur fuel strategy.

***1) Low-Sulfur Fuel Oil Strategy – Costs of Compliance*:** The MANE-VU Reasonable Progress report noted that because of requirements for motor vehicle fuels, refineries have already performed the capital investments required for the production of low-sulfur diesel (LSD) and ultra-low sulfur diesel (ULSD). The report estimated a cost per ton of SO_2 removed by switching to lower-sulfur fuel would range from $554 to $734 per ton (converted from 2001 to 2006 dollars using a conversion factor of 1.1383). In some seasons and some locations, low-sulfur diesel is actually cheaper than regular diesel fuel. (See Chapter 8 of the MANE-VU Reasonable Progress Report.)

The sulfur content of #4 and #6 fuels can also be cost-effectively reduced. Residual oil is essentially a byproduct of the refining process and is produced in several grades that can be blended to meet a specified fuel sulfur content limit. New York Harbor residual fuel prices for the week ending March 21, 2008, ranged from a low of $71.38 a barrel for 2.0 and 2.2 percent sulfur fuel to a high of $91.38 per barrel for 0.3 percent sulfur fuel*.

While the costs of achieving the projected emissions reductions with the low-sulfur fuel strategy are somewhat uncertain, they are believed to be reasonable in comparison with the costs of controlling other sectors. Some MANE-VU states are proceeding with low-sulfur oil requirements much sooner than 2018; however, all of the MANE-VU states concur that a low-sulfur oil strategy is both reasonable and achievable within the MANE-VU region by no later than 2018. MANE-VU has concluded that the cost of requiring the use of lower-sulfur fuels is reasonable.

2) Low-Sulfur Fuel Oil Strategy – Time Necessary for Compliance: MANE-VU's Reasonable Progress Report indicated that furnaces and boilers would not have to be retrofit and would not require expensive control technologies to burn ULSD distillate fuel oil. Therefore, the time necessary for compliance would be determined by the availability of the fuel.

The MANE-VU Reasonable Progress Report notes that, on a national scale, more ULSD is produced than both LSD and high-sulfur fuel, and concludes that the United States has the infrastructure to produce adequate stocks of these fuels. NESCAUM's report, "Low Sulfur Heating Oil in the Northeast States: An Overview of Benefits, Costs, and Implementation Issues," December 2005 (Attachment W) observes that the federal rules for heavy duty highway diesel fuel are flexible, so that if there is a shortage of 15 ppm fuel, the 15 to 500 ppm fuel could be used to relieve the shortage. With this flexibility, the report concludes that the likelihood of a fuel shortage in the short term due to use of ULSD for heating oil is diminished. The volatile nature of heating supply and demand presents unique challenges to the fuel oil industry. The success of a low-sulfur fuel oil program is predicated on meeting these challenges. The Northeast states are assessing a variety of business strategies and regulatory approaches that could be used to minimize any potential adverse supply and price impacts that could result from a regional 500 ppm sulfur standard for heating oil. Suppliers can increase pre-season reserves of low-sulfur product. Blending domestically produced biodiesel into heating oil offers opportunity to reduce imports, stabilize supplies and minimize supply-related price spikes.

Potential supply disruptions and price spikes for residual fuels are a particular concern for several northern MANE-VU states. Maine, New Hampshire, and Massachusetts receive a significant percentage of their residual fuel supplies from offshore sources during the winter months, when barge traffic from New York Harbor is interrupted because of severe weather. At these times, residual oil is often imported directly from foreign sources (e.g., Venezuela and Russia), and stakeholders have expressed concerns that the supply of low-sulfur residual fuels may be insufficient to satisfy demand during these periods. While the potential for

* During this same period, low-pour (low-temperature, reduced viscosity) residual fuel oil with a 0.5 percent sulfur content sold for $80.83 per barrel. Residual oil with a fuel sulfur content limit of 0.7 percent and 1.0 percent traded at $75.13 and $72.63, respectively.

disruptions in the supply of residual fuels is greater than that for distillate oil, these disruptions would affect only a limited number of states during extreme weather events.

MANE-VU has identified several mechanisms that could be implemented to address disruptions, including seasonal averaging and emergency waivers. A seasonal averaging approach would reduce potential supply constraints by allowing the use of higher-sulfur fuel during periods of peak demand (and limited supply), and then requiring the increased sulfur content of these fuels to be offset through the use of a lower-sulfur fuel at other times. This approach would provide regulatory certainty and greater flexibility during the winter months when fuel supplies may be subject to weather-related disruptions, but at a cost of increased recordkeeping and compliance monitoring. Since many states already have statutory authority to waive fuel sulfur limits in an emergency, states could also utilize their discretionary powers to address short-term supply disruptions.

The strategy adopted by Vermont and the other MANE-VU states proposes to phase in the required use of lower-sulfur fuels over the next 10 years, providing adequate time for full implementation.

***3) Low-Sulfur Fuel Oil Strategy – Energy and Non-Air Quality Environmental Impacts of Compliance*:** According to MANE-VU's Reasonable Progress Report, reducing the sulfur content of fuel oil would have a variety of beneficial consequences for boilers and furnaces using this fuel. Low-sulfur distillate fuel is cleaner burning and emits less particulate matter, thereby reducing the rate of fouling of heating units and allowing longer time intervals between cleanings. The MANE-VU report cites a study by the New York State Energy Research and Development Authority (NYSERDA) that showed that boiler deposits are reduced by a factor of two by lowering the fuel sulfur content from 1,400 ppm to 500 ppm. The use of low-sulfur oil could extend the useful life of a source by reducing the maintenance required because low-sulfur oil is less damaging to the combustion equipment. The report also notes that decreasing sulfur levels in fuel would enable manufacturers to develop more efficient furnaces and boilers by using more advanced condensing equipment that recovers energy normally lost to the heating of water vapor in the exhaust gases.

Furthermore, SO_2 controls would have beneficial environmental impacts by reducing acid deposition and helping to decrease ambient concentrations of $PM_{2.5}$. Reductions in $PM_{2.5}$ resulting from use of low-sulfur fuels could help nonattainment areas meet health-based National Ambient Air Quality Standards.

***4) Low-Sulfur Fuel Oil Strategy – Remaining Useful Life of Any Potentially Affected Sources*:** Residential furnaces and boilers have finite life spans, but they do not need to be replaced to burn low- or ultra-low-sulfur fuel oil. The Energy Research Center estimates that the average life expectancy of a residential heating oil boiler is 20-25 years. As noted above, use of low-sulfur fuel is less damaging to equipment and could therefore extend the useful life of an oil-fired residential furnace or boiler.

Available information on the remaining useful life of ICI boilers indicates a wide range of life expectancies, depending on unit size, capacity factor, and level of maintenance performed.

(Capacity factor is defined as the actual amount of energy a boiler generates in one year divided by the total amount it could generate if it ran full time at full capacity.) The typical life expectancy of an ICI boiler ranges from 10 years to more than 30 years. As in the case of residential units, use of lower-sulfur fuels could extend the life span of an ICI boiler.

10.2.4 Targeted EGU Strategy for SO_2 Reduction

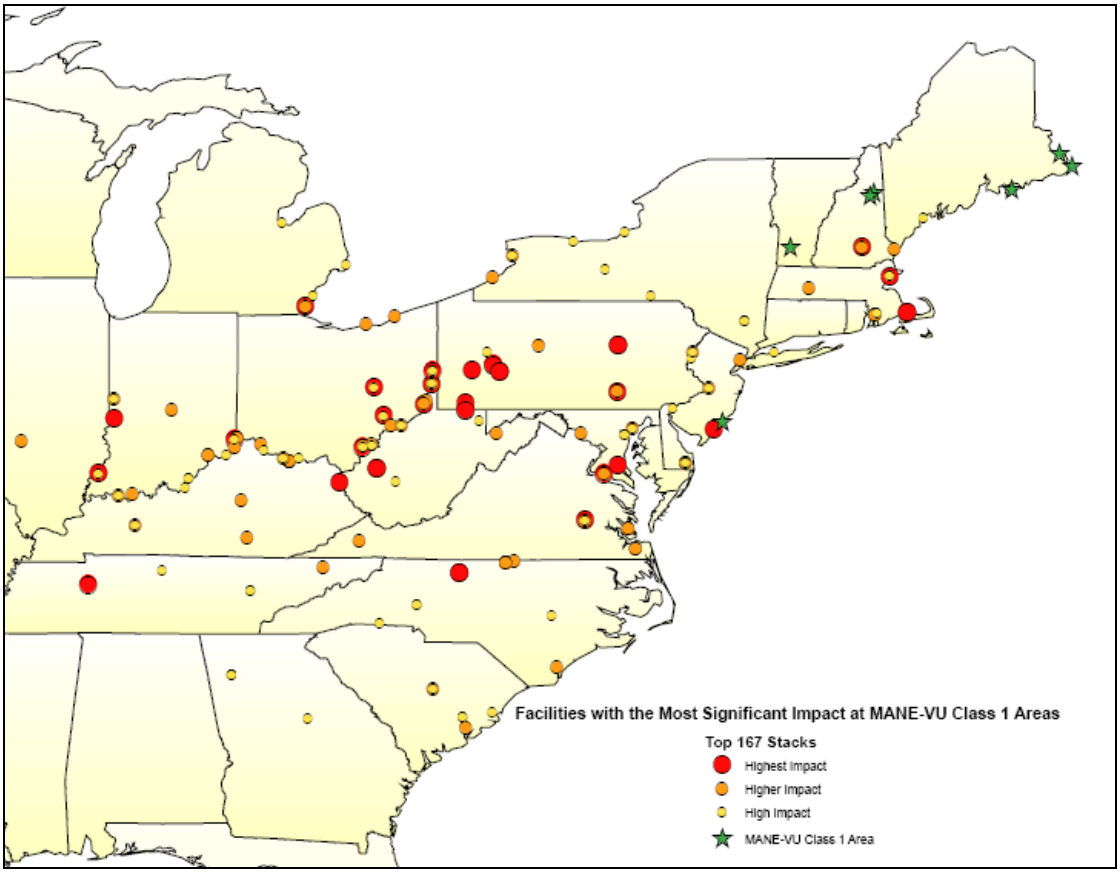
Electrical generating units (EGUs) are the single largest sector contributing to visibility impairment at MANE-VU's Class I Areas. SO_2 emissions from power plants continue to dominate the emissions inventory. Sulfate formed through atmospheric processes from SO_2 emissions are responsible for over half the mass and approximately 70-80 percent of visibility extinction on the days of worst visibility (see NESCAUM's Contribution Assessment, Attachment B).

To ensure that EGU control measures are targeted at those units having the greatest impact on visibility at MANE-VU Class I Areas, a modeling analysis was conducted to identify the individual sources responsible for the highest contributions to visibility degradation. Accordingly, MANE-VU developed lists of the 100 EGU emission points (stacks) having the largest impacts at each MANE-VU Class I Area during 2002. The combined list for all seven MANE-VU Class I Areas identified a total of 167 distinct emission points. These 167 stacks are spread across the Northeast, Southeast, and Midwest (Figure 10.2).

After consultations with its member states and with other RPOs, MANE-VU requested a 90-percent reduction in SO_2 emissions from the top 167 stacks by no later than 2018 (see the MANE-VU "Ask"). NESCAUM's preliminary modeling for MANE-VU showed that SO_2 emission reductions of this magnitude from the targeted facilities would produce substantial improvements in ambient 24-hour $PM_{2.5}$ concentrations. Assuming a control level equal to 10 percent of the 2002 baseline emissions (i.e., 90-percent emission reduction), NESCAUM used CMAQ to model sulfate concentrations in 2018 after implementation of controls. The modeled sulfate values were then converted to estimates of $PM_{2.5}$ concentration. Figure 10.3 displays the predicted average change in 24-hr $PM_{2.5}$.

The map illustrates the reductions in fine-particle pollution in the Eastern U.S. that would result from implementation of the targeted EGU strategy for SO_2. Improvements in $PM_{2.5}$ levels would occur throughout the MANE-VU region and portions of the VISTAS and MRPO regions, especially along the Ohio River Valley.

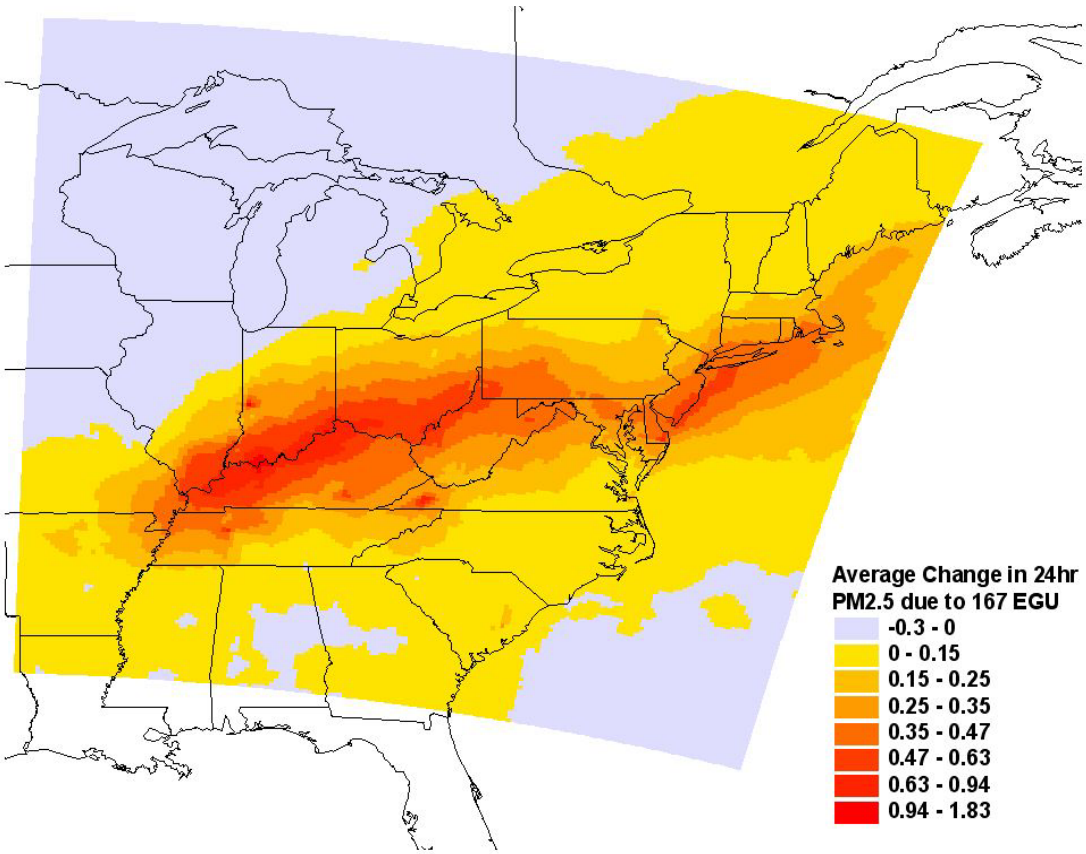
Figure 10.2 Location of 167 EGU Stacks Contributing the Most to Visibility Impairment at MANE-VU Class I Areas



Note: Some facilities have more than one stack.

Although the reductions would be both advantageous and potentially large, MANE-VU determined, after further consultation with affected states, that it was unreasonable to expect that the full 90-percent reduction in SO_2 emissions would be achieved by 2018. Therefore, additional modeling was conducted to assess the more realistic scenario in which emissions would be controlled by the individual facilities and/or states to levels already projected to take place by that date. At some facilities, the actual emission reductions are anticipated to be greater or less than the 90 percent benchmark. For details, see Alpine Geophysics' report for MARAMA entitled, "Documentation of 2018 Emissions from Electric Generating Units in the Eastern United States for MANE-VU's Regional Haze Modeling, Revised Final Draft," April 28, 2008 (Attachment G).

Figure 10.3 Preliminary Estimate of Average Change in 24-hr $PM_{2.5}$ Resulting from a 90-Percent Reduction in SO_2 Emissions from the Top 167 EGU Stacks Affecting MANE-VU Class I Areas



***Targeted EGU SO_2 Reduction Strategy Controls are Reasonable*:** MANE-VU identified specific EGU stacks that were significant contributors to visibility degradation at MANE-VU Class I Areas in 2002 based on CALPUFF modeling analyses documented in the Contribution Assessment. MANE-VU obtained information about existing and planned controls on emissions from those stacks. These analyses and information on proposed EGU controls are presented in MANE-VU's Reasonable Progress Report and the Contribution Assessment as well as in Section 6.0, Emissions Inventory, and Section 11.0, Long-Term Strategy section of this SIP.

Based on information gathered from the states and regional planning organizations, MANE-VU anticipated that emissions from many of the targeted EGU stacks will be subject to EPA's Clean Air Interstate Rule (CAIR). However, because CAIR is a cap-and-trade program that has been remanded to EPA, it is not possible to predict with certainty which of the 167 stacks will be controlled under CAIR (or its replacement) in 2018.

***Four-Factor Analysis – Targeted EGU SO_2 Reduction Strategy*:** The following discussion addresses each of the four factors with respect to the strategy of controlling specific EGUs. Information is taken primarily from the MANE-VU Reasonable Progress Report (Attachment U) and MANE-VU BART Report (Attachment V).

***1) Targeted EGU SO_2 Reduction Strategy – Costs of Compliance*:** Technologies to control the precursors of regional haze are commercially available today. Because EGUs are the most significant stationary source of SO_2, NO_X, and PM, they have been subject to extensive federal and state regulations to control all three pollutants. The technical feasibility of control technologies has been successfully proven for a substantial number of small (e.g., 100 MW) to very large (over 1,000 MW) boilers burning different types of coal. Over the last few years, the cost data clearly indicate that many technologies provide substantial and cost-effective emission reductions.

Both wet and dry scrubbers are in wide commercial use in the U.S. for controlling SO_2 emissions from coal-fired power plants. The capital costs for new or retrofit wet or dry scrubbers are higher than the capital costs for NO_X and PM controls. Capital costs for scrubbers ranged from $180/kW for large units (greater than 600 MW) to as high as $350/kW for small units (200 to 300 MW). (See pages 2-22 through 2-25 of the BART Report, Attachment V). However, the last few years have seen a general trend of declining capital costs attributable to vendor competition and technology maturation. Also, the cost-effectiveness (in dollars per ton of emissions removed) is very attractive because the high sulfur content of the coal burned results in very large amounts of SO_2 removed by the control devices. The typical cost is in the range of 200 to 500 dollars per ton of SO_2 removed, although the cost rises steeply for small units burning lower-sulfur coal and operating at low capacity factors. For any plant, overall cost-effectiveness depends mainly on the baseline pre-controlled SO_2 emission rate (or fuel sulfur content), size and capacity factor of the unit, and capital costs of flue gas desulfurization (generally ranging from $150 to $200/kW).

The MANE-VU Reasonable Progress Report reviewed options for controlling coal-fired EGU boilers, including switching to lower-sulfur coal, switching to natural gas, coal cleaning, and flue gas desulfurization (FGD). The most effective control option (but not necessarily appropriate for all installations) is FGD, which can achieve up to 95 percent reduction in SO_2 emissions. The costs of different technologies vary considerably among units and were estimated to range from as low as $170/ton to as high as $5,700/ton. Table 10.4 summarizes the estimated costs of controlling SO_2 emissions, expressed in dollars per ton of SO_2 removed.

To predict future emissions and further evaluate the costs of emission controls for electric generating units, MANE-VU and other RPOs have followed the example of the US Environmental Protection Agency (EPA) in using the Integrated Planning Model (IPM®), an integrated economic and emissions model for EGUs. This model projects electricity supplies based on various assumptions while at the same time developing least-cost solutions to electrical generating needs within specified emissions targets. IPM also provides estimates of the costs of complying with various policy requirements.

Table 10.4 Estimated Cost Ranges for SO_2 Control Options for Coal-Fired EGU Boilers (2006 dollars per ton of SO_2 removed)

Technology	Description	Performance	Cost Range (2006 dollars/ton of SO_2 Reduced)
Switch to a Low Sulfur Coal (generally <1% sulfur)	Replace high-sulfur bituminous coal combustion with lower-sulfur coal	50-80% reduction in SO_2 emissions by switching to a lower-sulfur coal	Potential reduction in coal costs, but possibly offset by expensive retrofits and loss of boiler efficiency
Switch to natural gas (virtually 0% sulfur)	Replace coal combustion with natural gas	Virtually eliminate SO_2 emissions by switching to natural gas	Unknown – cost of switch is currently uneconomical due to price of natural gas
Coal Cleaning	Coal is washed to remove some of the sulfur and ash prior to combustion	20-25% reduction in SO_2 emissions	2-15% increase in fuel costs based on current prices of coal
Flue Gas Desulfurization (FGD) – Wet	SO_2 is removed from flue gas by dissolving it in a lime or limestone slurry. (Other alkaline chemicals are sometimes used)	30-95%+ reduction in SO_2 emissions	$570-$5,700 for EGUs <1,200 MW $330-$570 for EGUs >1,200 MW
Flue Gas Desulfurization (FGD) – Spray Dry	A fine mist containing lime or other suitable sorbent is injected directly into flue gas	60-95%+ reduction in SO_2 emissions	$570-$4,550 for EGUs <600 MW $170-$340 for EGUs >600 MW
Flue Gas Desulfurization (FGD) –Dry	Powdered lime or other suitable sorbent is injected directly into flue gas	40-60% reduction in SO_2 emissions	$250-$850 for EGUs ~300 MW

Table references:
1. EIA website accessed on 2/20/07: http://www.eia.doe.gov/cneaf/coal/page/coalnews/coalmar.html
2. EIA website accessed on 2/20/07: http://www.eia.doe.gov/cneaf/coal/page/acr/table31.html
3. STAPPA-ALAPCO. *Controlling Fine Particulate Matter Under the Clean Air Act: A Menu of Options*; March 2006.

EPA developed IPM version 2.1.9 and used this model to evaluate the impacts of CAIR and the Clean Air Mercury Rule (CAMR). (Note that CAMR was vacated by the federal courts and is no longer in effect.) Recently, EPA updated their input data and developed IPM v.3.0. However, because of time constraints, all MANE-VU runs were based on EPA IPM v.2.1.9 with changes made to the input assumptions.

The RPOs collaborated with one another to update the inputs to IPM v.2.1.9 using more current data on the EGUs and more realistic fuel prices. The resulting IPM run is called VISTAS PC_1f. This IPM run serves as the basis for regional air quality modeling for ozone and haze SIPs in MANE-VU and the OTC.

MANE-VU, through MARAMA, contracted with the consulting firm ICF Resources, L.L.C. to prepare two new IPM runs, as documented in "Comparison of CAIR and CAIR Plus Proposal using the Integrated Planning Model (IPM®)," Final Draft Report, May 30, 2007 (Attachment X). The first run, known as the MARAMA CAIR Base Case run (also known as MARAMA_5c), was based on the VISTAS PC_1f run and underlying EPA IPM v.2.1.9 with some updated information on fuel prices, control constraints, etc. The second run, called the MARAMA CAIR Plus run (also known as MARAMA_4c), was similarly based on VISTAS

PC_1f run and the underlying EPA IPM v.2.1.9. The MARAMA CAIR Plus run included updated information used in the VISTAS run but assumed lower NO_X emission caps and higher SO_2 retirement ratios.

Based on the modeling results, MANE-VU estimates that the marginal cost of SO_2 emission reductions (the cost of reducing one additional ton of emissions) ranges from $640/ton in 2008 to $1,392/ton in 2018 (see Table 6, "Allowance Prices (Marginal Costs) of Emissions Reductions…," in Attachment X).

Costs will vary for individual plants to reduce emissions by 90 percent, as recommended in the Vermont/MANE-VU Ask. However, this strategy provides states with flexibility to pursue controls on specific sources as appropriate and to control emissions from alternative sources, if necessary, to meet the 90 percent target established in the Ask.

Given the importance of SO_2 emissions from specific EGUs to visibility impairment in MANE-VU Class I Areas, the MANE-VU Commissioners, after weighing all factors – the availability of technology to reduce emissions, the estimated costs of controls, the costs of alternative measures, the flexibility to achieve alternative reductions if necessary, etc. – concluded that the costs of the targeted EGU strategy are reasonable. Vermont agrees with this conclusion.

***2) Targeted EGU SO_2 Reduction Strategy – Time Necessary for Compliance*:** MANE-VU's Reasonable Progress Report indicates that, generally, sources are given a 2- to 4-year phase-in period to comply with new rules. Under Phase I of the NO_X SIP call, EPA provided a compliance date of about 3½ years from the SIP submittal date. Most MACT standards allow a 3-year compliance period. Under Phase II of the NO_X SIP Call, EPA provided for 2-year compliance period from the SIP submittal date. Vermont concludes that there is more than sufficient time between 2008 and 2018 for affected states to adopt requirements and for affected sources to install necessary controls.

***3) Targeted EGU SO_2 Reduction Strategy – Energy and Non-Air Quality Environmental Impacts of Compliance*:** The MANE-VU Reasonable Progress Report identified several energy and non-air quality impacts from additional EGU controls. Large-scale fuel switching could potentially impact fuel supplies. Flue gas desulfurization systems may generate wastewater and sludge (which is sometimes recycled as a useful byproduct). On the other hand, SO_2, NO_X, and ammonia controls would have beneficial environmental impacts by reducing acid deposition and nitrogen deposition to water bodies and natural land areas. Emission reductions for these pollutants would also produce decreases in ambient levels of $PM_{2.5}$ and result in corresponding health benefits. Similarly, mercury emissions may be reduced by the addition of controls for other pollutants. Vermont concludes that the energy and non-air quality impacts of additional EGU controls are reasonable.

***4) Targeted EGU SO_2 Reduction Strategy – Remaining Useful Life of Any Potentially Affected Sources*:** As noted in the MANE-VU Reasonable Progress Report, remaining useful life estimates of EGU boilers indicate a wide range of operating lifetimes, depending on unit size, capacity factor, and level of maintenance performed. Typical life expectancies range to 50 years or more. Additionally, implementation of air pollution regulations over the years has

necessitated emission control retrofits that have increased the expected life spans of many EGUs. The lifetime of an EGU may be extended through repair, re-powering, or other strategies if the unit is more economical to run than to replace with power from other sources. Extending facility lifetime may be particularly likely for a unit serving an area with limited transmission capacity to bring in other power.

10.2.5 Non-EGU SO_2 Emissions Reduction Strategy for Non-MANE-VU States

In addition to the measures described above (i.e., BART, low-sulfur fuel, and targeted EGU controls), Vermont asked states in neighboring regional planning organizations to consider further non-EGU emission reductions comparable to those achieved by MANE-VU states through application of MANE-VU's low-sulfur fuel strategy. Previous modeling indicated that the MANE-VU low-sulfur fuel strategy would achieve a greater than 28- percent reduction in non-EGU SO_2 emissions by 2018. After consultation with other states and consideration of comments received, MANE-VU decided to include, in the latest modeling for the VISTAS and MRPO regions, implementation of control measures capable of achieving SO_2 emission reductions equivalent to MANE-VU's 28-percent reduction in non-EGU SO_2 emissions in 2018.

To model the effects of this strategy on visibility at MANE-VU Class I Areas, MANE-VU had to make reasonable assumptions about where the requested emission reductions would occur in the VISTAS and MRPO states without knowing precisely how those reductions would be realized. As a way to represent approximately a 28-percent reduction in non-EGU SO_2 emissions, the following reductions were modeled:

- For control measures in VISTAS and MRPO states:
  - Coal-fired ICI boilers: SO_2 emissions were reduced by 60 percent.
  - Oil-fired ICI boilers: SO_2 emissions were reduced by 75 percent.
  - ICI boilers lacking fuel specification: SO_2 emissions were reduced by 50 percent.
- For additional controls *only* in the VISTAS states: SO_2 emissions from other oil-fired area sources were reduced by 75 percent (based on the same SCCs identified in MANE-VU's oil strategies list).

This modeling scenario represents just one example of realistic strategies that states outside of MANE-VU could employ to meet the non-EGU SO_2 emissions reductions requested by MANE-VU.

Vermont acknowledges that a number of non-MANE-VU states have not included, or may not include, the requested 28-percent reduction in non-EGU SO_2 emissions in their State Implementation Plans at the present time. Vermont expects these states to revisit the MANE-VU Ask in the course of future regional haze SIP revisions and to make commitments to this request where feasible. Vermont will continue to monitor other states' actions with respect to regional haze planning. In time, actual reductions could turn out to be greater or less than the MANE-VU Ask. If necessary, Vermont will adjust its reasonable progress goals and long-

term strategy at a later date to be consistent with programs implemented by the non-MANE-VU states. Any such adjustments would be incorporated into Vermont's first regional haze SIP revision in 2012.

***Non-EGU SO_2 Emission Reduction Measures Outside MANE-VU are Reasonable*:** After EGUs, ICI boilers are the next largest class of SO_2 emitters. ICI boilers are thus a logical choice among non-EGU sources for consideration of additional SO_2 control measures.

***ICI Boiler Control Options*:** Air pollution reduction and control technologies for ICI boilers have advanced substantially over the past 25 years. However, according to a 1998 survey of industrial boilers by EPA (2004), only 2 percent of gas-fired boilers and 3 percent of oil-fired boilers had installed any kind of air pollution control device. A larger percentage of coal-fired boilers had installed air pollution controls: specifically, 47 percent had installed some type of control device, mainly to control particulate matter (PM). Post-combustion SO_2 controls were used by less than one percent of industrial boilers in 1998, with the exception of boilers firing petroleum coke (2 percent of boilers using this fuel had acid scrubbers). A small percentage of industrial boilers had combustion controls in place in 1998, although additional low-NO_X firing systems may have been installed since that date.

Almost all SO_2 emission control technologies fall into the category of reducing SO_2 after its formation as opposed to minimizing its formation during combustion. The method of SO_2 control appropriate for any individual ICI boiler is dependent upon the type of boiler, type of fuel, capacity utilization, and the types and staging of other air pollution control devices. However, cost-effective emission reduction technologies for SO_2 are available and are effective in reducing emissions from the exhaust gas stream of ICI boilers. Post-combustion SO_2 control is accomplished by reacting the SO_2 in the gas with a reagent (usually calcium- or sodium-based) and removing the resulting product (a sulfate/sulfite) for disposal or commercial use, depending on the particular technology. SO_2 reduction technologies are commonly referred to as flue gas desulfurization (FGD) and are usually described in terms of the process conditions (wet versus dry), byproduct utilization (throwaway versus saleable) and reagent utilization (once-through versus regenerable).

The exceptions to the nearly universal use of post-combustion controls are found in fuel switching, coal cleaning, and fluidized bed boilers, in which limestone is added to the fuel in the combustion chamber. Both pre- and post-combustion SO_2 emission control alternatives for ICI boilers are outlined in Table 10.5. Further description of these technology options is available in Chapter 4 of the MANE-VU Reasonable Progress Report (Attachment U).

The SO_2 removal efficiency of these controls varies from 20 to 99+ percent depending on the fuel type and control technology. For coal-fired boilers, options include switching to low-sulfur coal, coal cleaning, wet FGD, dry FGD, and spray dryers. The overall SO_2 reductions vary from a low of 20 to 25 percent for fuel switching to a high of 60 to 95 percent for wet FGD and spray dry FGD. The majority of control strategies, however, are capable of achieving a 60 percent or greater reduction. Thus, assuming that coal-fired ICI boilers adopt varying levels of controls, with most choosing a 50- to 70- percent reduction strategy and fewer choosing either the 20-percent or the 90-percent reduction strategy, the region-wide average would be likely to fall in the vicinity of a 60- percent reduction in SO_2 emissions. This assumption is validated by data showing that wet FGD systems represent 85 percent of

the FGD systems in use in the United States and that these systems have an average SO_2 removal efficiency of 78 percent. MANE-VU's modeling of a 60-percent reduction in SO_2 emission from coal-fired ICI boilers is therefore reasonable.

Table 10.5 Available SO_2 Control Options for ICI Boilers

Technology	Description	Applicability	Performance
Switch to a Low Sulfur Coal (generally <1% sulfur)	Replace high-sulfur bituminous coal combustion with lower-sulfur coal	Potential control measure for all coal-fired ICIs currently using coal with high sulfur content	50-80% reduction in SO_2 emissions by switching to a lower-sulfur coal
Switch to Natural Gas (virtually 0% sulfur)	Replace coal combustion with natural gas	Potential control measure for all coal-fired ICIs	Virtually eliminate SO_2 emissions by switching to natural gas
Switch to a Lower Sulfur Oil	Replace higher-sulfur residual oil with lower-sulfur distillate oil. Alternatively, replace medium sulfur distillate oil with ultra-low sulfur distillate oil	Potential control measure for all oil-fired ICIs currently using higher sulfur content residual or distillate oils	50-80% reduction in SO_2 emissions by switching to a lower-sulfur oil
Coal Cleaning	Coal is washed to remove some of the sulfur and ash prior to combustion	Potential control measure for all coal-fired ICI boilers	20-25% reduction in SO_2 emissions
Combustion Control	A reactive material, such as limestone or bi-carbonate, is introduced into the combustion chamber along with the fuel	Applicable to pulverized coal-fired boilers and circulating fluidized bed boilers	40%-85% reductions in SO_2 emissions
Flue Gas Desulfurization (FGD) - Wet	SO_2 is removed from flue gas by dissolving it in a lime or limestone slurry. (Other alkaline chemical are sometimes used)	Applicable to all coal-fired ICI boilers	30-95%+ reduction in SO_2 emissions
Flue Gas Desulfurization (FGD) - Spray Dry	A fine mist containing lime or other suitable sorbent is injected directly into flue gas	Applicable primarily for boilers currently firing low to medium sulfur fuels	60-95%+ reduction in SO_2 emissions
Flue Gas Desulfurization (FGD) - Dry	Powdered lime or other suitable sorbent is injected directly into flue gas	Applicable primarily for boilers currently firing low to medium sulfur fuels	40-60% reduction in SO_2 emissions

For oil-fired boilers, options include switching to a lower-sulfur fuel (e.g., oil or natural gas), dry FGD, and spray dryers. The overall SO_2 reductions vary from a low of 40 to 60 percent for dry FGD to a high of 60 to 95 percent for spray dry FGD. For comparison, the MANE-VU low-sulfur fuel strategy assumes a 50- to 90- percent reduction in SO_2 emissions from oil-fired ICI boilers. Assuming a normal distribution of control strategies chosen by the sources, MANE-VU's modeling of an average 75-percent reduction in SO_2 emission from oil-fired ICI boilers is reasonable.

For ICI boilers in which a fuel was not specified, a 50-percent reduction in SO_2 emissions was assumed. ICI boilers in this category include those outside the MANE-VU region for which the current inventory did not specify the type of fuel burned. Because a response from the MRPO was not received, this assumption also encompasses some of the uncertainty regarding

the implementation of MANE-VU's non-EGU Ask. Given the paucity of data, a lower reduction in SO_2 emissions (50 percent) was assumed for this category than for coal- or oil-fired ICI boilers. Implementation of one or more of the suggested SO_2 control options to achieve, on average, a 50-percent reduction in SO_2 emissions at these sources is a reasonable assumption.

For emissions from other area oil-combustion sources in the VISTAS region, an SO_2 reduction of 75 percent was assumed. This reduction is equal to the reduction that would result from implementing the MANE-VU low-sulfur fuel strategy for this sector. The four-factor analysis for the low-sulfur fuel strategy was described in Part 10.2.3 of this section.

***Four-Factor Analysis – Non-EGU SO_2 Emission Reduction Measures Outside MANE-VU*:** Based on the survey of available technologies outlined above and the four-factor analyses summarized below, MANE-VU concludes that each of the strategies assumed for modeling purposes to meet the Vermont/MANE-VU Ask of a 28-percent reduction in non-EGU SO_2 emissions is reasonable. States should have no difficulty in meeting this benchmark in light of the control efficiencies that are attainable at reasonable costs with retrofit technologies that are available for ICI boilers today.

***1) Non-EGU SO_2 Emission Reduction Measures outside MANE-VU – Costs of Compliance*:** Industrial boilers have a wider range of sizes than EGUs and often operate over a wider range of capacities. Thus, cost estimates for the same technologies will generally span a relatively larger range, and costs for an individual boiler will depend on the capacity of the boiler and typical operating conditions. In general, cost-effectiveness increases as boiler size and capacity factor (a measure of boiler utilization) increases.

MANE-VU's Reasonable Progress Report (Attachment U) provides emission control cost estimates for ICI boilers in the range of $130 to $11,000 per ton of SO_2 removed, a very wide spread due to the variability of sources and control options in this category. All costs presented below for emission controls on ICI boilers are borrowed from this report. Dollar amounts originated from EPA publications cited in the report and are restated in 2006 dollars using appropriate adjustment factors found at www.inflationdata.com.

◊ ***Cost of Fuel Switching*:** Although fuel switching can be a very effective means of controlling SO_2 emissions (reductions of 50 to 99.9 percent are possible), burning low-sulfur fuel may not be technically feasible or economically practical as an SO_2 control option for every coal-fired boiler. Factors impacting applicability include the characteristics of the plant and the particular type of fuel change being considered. Additionally, switching to a lower-sulfur coal can affect fuel handling systems, boiler performance, PM control effectiveness, and ash handling systems. Oil-fired boilers switching to a lower-sulfur fuel of the same grade (e.g., switching from #6 fuel oil at 2.0% S to #6 fuel oil at 0.5% S) do not typically encounter these issues. (See Part 10.2.3 for a discussion of the costs and issues associated with switching to low-sulfur fuel oil.)

The costs of coal fuel switching, including substitution or blending with a low-sulfur coal, can be attributed to two main factors: the cost of low-sulfur coal compared to higher-sulfur coal (including consideration of the coal's heating value), and the cost of necessary boiler or coal-

handling equipment modifications. Many plants will be able to switch from high-sulfur to low-sulfur bituminous coal without serious difficulty, but switching from bituminous to sub-bituminous coal may require potentially significant investments and modifications to an existing plant. Even if a lower-sulfur fuel is available, it may not be cost competitive if it must be supplied in small quantities or transported long distances from the supplier. It also may be more cost-effective to burn a higher-sulfur fuel supplied by nearby suppliers and to use a post-combustion control device.

Switching from coal combustion to natural gas combustion virtually eliminates SO_2 emissions. It is technically feasible to switch from coal to natural gas, but it is currently uneconomical to consider this option for large ICI boilers because of the fuel quantity necessary and the price of natural gas. Natural gas is roughly seven times the price of coal in terms of heating value (price per million Btus).

◊ ***Cost of Coal Cleaning*:** The World Bank, an organization which assists with economic and technological needs in developing countries, reports that the cost of physically cleaning coal varies from $1 to $10 per ton of coal cleaned, depending on the coal quality, the cleaning process used, and the degree of cleaning desired. In most cases, the costs were found to be between $1 and $5 per ton of coal cleaned. Coal cleaning typically results in a 20- to 25-percent reduction in SO_2 emissions and increases the heating value of the fuel by a small amount.

◊ ***Cost of Combustion Controls***: Dry sorbent injection (DSI) systems have lower capital and operation costs than post-combustion FGD systems because of the simplicity of the DSI design, lower water use needs, and smaller land area requirements. Table 10.6 presents the estimated costs of adding DSI-based SO_2 emission controls to ICI boilers for different boiler sizes, fuel types, and capacity factors.

Table 10.6 Estimated Costs of Dry Sorbent Injection (DSI) for ICI Boilers (2006 dollars)

Fuel	SO_2 Reduction (%)	Capacity Factor (%)	Cost-Effectiveness ($/ton of SO_2 removed)		
			100 MMBtu/hr	250 MMBTU/hr	1,000 MMBTU/hr
2%-Sulfur Coal	40	14	4,686	3,793	2,979
		50	1,312	1,062	834
		83	772	624	490
3.43%-Sulfur Coal	40	14	2,732	2,212	1,737
		50	765	619	486
		83	450	364	286
2%-Sulfur Coal	85	14	2,205	1,786	1,402
		50	617	500	392
		83	363	294	231
3.43%-Sulfur Coal	40	14	1,286	1,040	818
		50	360	291	229
		83	212	171	134

***Cost of FGD*:** Installation of post-combustion SO_2 controls in the form of FGD has several impacts on facility operations, maintenance, and waste handling procedures. FGD systems generally require substantial land area for construction of the absorber towers, sorbent tanks, and waste handling equipment. Facility costs therefore depend on cost and availability of space for construction of the FGD system. In addition, significant quantities of waste material may be generated that require disposal. The costs may be mitigated, however, by utilization of a forced oxidation FGD process that produces commercial-grade gypsum, which may be sold as a raw material for other commercial processes.

Table 10.7 presents the total estimated cost-per-ton of adding FGD-based SO_2 emission controls to ICI boilers for different boiler sizes, fuel types, and capacity factors. There is no indication that these cost data include possible revenues from gypsum sales, which would partially offset the costs of FGD controls. Carbon dioxide is also emitted as a byproduct of FGD; therefore, the impacts of increased carbon emissions associated with this technology would need to be considered. CO_2 emissions will become more of an issue in the future if they are limited under climate change mitigation strategies. Given the uncertainty of such future strategies, costs related to increased carbon emissions from FGD cannot yet be assessed.

MANE-VU's request for a 28-percent reduction in non-EGU SO_2 emissions allows states flexibility in determining which sources to control, so that the most cost-effective control measures can be adopted and implemented over the next 10 years. Given the wide range of control options and costs available for this purpose, MANE-VU has concluded that the request for a 28-percent reduction in non-EGU SO_2 emissions is reasonable. Vermont concurs with this conclusion.

Table 10.7 Estimated Costs of Flue Gas Desulfurization for ICI Boilers (2006 dollars)

Fuel	Technology	SO_2 Reduction (%)	Capacity Factor (%)	Cost-Effectiveness ($/ton of SO_2 removed)		
				100 MMBtu/hr	250 MMBTU/hr	1,000 MMBTU/hr
High-Sulfur Coal	FGD (dry)	40	14	3,781	2,637	1,817
			50	1,379	1,059	828
			83	1,006	814	676
Lower-Sulfur Coal	FGD (dry)	40	14	4,571	3,150	2,119
			50	1,605	1,207	928
			83	1,147	906	744
Coal	FGD (spray dry)	85	14	4,183	2,786	1,601
			50	1,290	899	567
			83	843	607	407
High-Sulfur Coal	FGD (spray dry)	85	14	3,642	2,890	1,909
			50	1,116	875	601
			83	709	563	398
Lower-Sulfur Coal	FGD (wet)	40	14	4,797	3,693	2,426
			50	1,415	1,106	751
			83	892	705	492
Oil	FGD (wet)	40	14	10,843	8,325	5,424
			50	2,269	1,765	1,184
			83	1,371	1,079	740

***2) Non-EGU SO_2 Emission Reduction Measures outside MANE-VU – Time Necessary for Compliance*:** For pre- and post-combustion SO_2 emission controls, engineering and construction lead times will vary between 2 and 5 years, depending on the size of the facility and specific control technology selected. Generally, sources are given a 2- to 4- year phase-in period to comply with new rules, as previously described, and states generally have a 2-year period for compliance with RACT rules.

For the purposes of this review, it is assumed that a 2-year period after SIP submittal is adequate for pre-combustion controls (fuel switching or cleaning), and a 3-year period is adequate for the installation of post-combustion controls. MANE-VU has therefore concluded that there is sufficient time between 2008 and 2018 for affected states to adopt emission control requirements and for affected sources to install the necessary controls to meet MANE-VU's requested SO_2 emission reductions from non-EGU sources. Vermont concurs with this conclusion.

***3) Non-EGU SO_2 Emission Reduction Measures Outside MANE-VU – Energy and Non-Air Quality Environmental Impacts of Compliance*:** The primary energy impact of pre- or post-combustion control alternatives is a potential increase in electricity usage. Fuel switching and cleaning do not significantly affect the efficiency of the boiler itself, but require additional energy to clean or blend coal. FGD systems typically operate with high-pressure drops across the control equipment and therefore consume significant amounts of electricity to operate blowers and circulation pumps. In addition, some combinations of FGD technology and plant configuration may require flue gas reheating to prevent physical damage to equipment, resulting in higher fuel usage.

The primary non-air environmental impacts of fuel switching derive from transportation of the fuel. Secondary environmental impacts derive from waste disposal and material handling operations (e.g. fugitive dust). For FGD systems, the generation of wastewater and sludge from the SO_2 removal process is a consideration. Wastewater from the FGD systems will increase sulfate, metals, and solids loading at the receiving wastewater treatment facility, resulting in potential impacts to operating cost, energy requirements, and effluent water quality. Processing of the wastewater sludge can require energy for stabilization and/or dewatering, and transporting the dewatered sludge to a landfill has additional environmental implications.

Fuel switching to a low-sulfur distillate fuel oil has a variety of beneficial consequences for ICI boilers. Low-sulfur distillate fuel is cleaner burning and emits less particulate matter, which reduces the rate of fouling of heating units substantially and permits longer time intervals between cleanings. According to a study conducted by NYSERDA (reference 10 in Attachment W), boiler deposits are reduced by a factor of two by lowering the fuel sulfur content from 1,400 ppm to 500 ppm. These reductions in buildup of deposits result in longer service intervals between cleanings.

Reducing SO_2 emissions from ICI boilers would have positive environmental and health impacts. SO_2 controls would reduce acid deposition, helping to preserve aquatic life, forests, and crops as well as buildings and sculptures made of acid-sensitive materials. These

emission reductions would also help to decrease ambient levels of $PM_{2.5}$, a significant contributor to premature morbidity and illness in individuals with heart or lung conditions.

MANE-VU has concluded that the energy and non-air environmental impacts of controlling SO_2 emissions from ICI boilers are justified in light of the beneficial impacts on regional haze, fine particulate air pollution, acid rain, and equipment operation, as described above. Vermont concurs with this conclusion.

***4) Non-EGU SO_2 Emission Reduction Measures Outside MANE-VU – Remaining Useful Life of Any Potentially Affected Sources*:** Available information for remaining useful life estimates of ICI boilers indicates a wide range of life expectancies, depending on unit size, capacity factor, and level of maintenance performed. Typical life spans range from about 10 years to over 30 years. However, the remaining useful life of a specific source is highly variable; and older units are not likely to be retrofitted with expensive emission controls. Given the typical range of life expectancies of ICI boilers, the technical options available, and the flexibility that non-MANE-VU states would have to meet the Ask, MANE-VU has concluded that a 28-percent reduction in non-EGU SO_2 emissions is reasonable. Vermont concurs with this conclusion.

10.3 Reasonable Progress Goals for Class I Areas in the State

As required under 40 CFR 51.308(d)(1), this regional haze SIP establishes reasonable progress goals (RPGs) for the Lye Brook Wilderness in Vermont for the 10-year period of the implementation plan ending in 2018. These RPGs are determined from modeling based on implementation of the proposed reasonable measures included in MANE-VU's long-term strategy. Table 10.8 provides a summary of the reasonable progress goals, in deciviews, for the Lye Brook Wilderness.

Table 10.8 Reasonable Progress Goals for Lye Brook Wilderness (in deciviews)

Visibility Condition	Natural Visibility	2000-2004 Baseline Visibility	RPG (Visibility Expected by 2018)	Visibility Improvement Expected by 2018
20 Percent Worst Days (Average)	11.7	24.4	20.9	3.5
20 Percent Best Days (Average)	2.8	6.4	5.5	0.9

Both natural conditions and baseline visibility for the 5-year period from 2000 through 2004 were calculated in conformance with an alternative method recommended by the IMPROVE Steering Committee. (See Attachment J, "Baseline and Natural Visibility Conditions: Considerations and Proposed Approach to the Calculation of Baseline and Natural Visibility Conditions at MANE-VU Class I Areas," December 2006.) Future progress toward the 2018 visibility target will be calculated in a nationally consistent manner based on 5-year averages in accordance with EPA's "Guidance for Tracking Progress Under the Regional Haze Rule"

(EPA-454/B-03-004, September 2003) with adjustments for the alternative method as recommended by the IMPROVE Steering Committee.

40 CFR 51.308(d)(1)(vi) requires that reasonable progress goals represent at least the visibility improvement expected from implementation of other Clean Air Act programs during the applicable planning period. The modeling that formed the basis for reasonable progress goals for MANE-VU Class I Areas included estimation of the effects of all other programs required by the Clean Air Act. MANE-VU's modeling also included the specific control measure assumptions described previously in Subsection 10.2. Additional information may be found in Section 6.0, Emissions Inventory, and Section 11.0, Long-Term Strategy, as well as in the documentation for the MANE-VU modeling.

In setting the reasonable progress goals to improve visibility at MANE-VU Class I Areas, Vermont recognizes that contributing states will have flexibility to submit SIP revisions and implement various control measures to meet these goals between now and 2018. The overall approach to reducing and preventing emissions that contribute to regional haze allows each state up to 10 years to implement reasonable SO_2 and NO_X control measures as appropriate and necessary.

10.4 Visibility Effects of (Additional) Reasonable Control Measures

MANE-VU's evaluations included modeling to estimate the effects on visibility of the Vermont/MANE-VU Ask. The results of this work are summarized below.

NESCAUM performed preliminary modeling as described in the report entitled "MANE-VU Modeling for Reasonable Progress Goals, Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G). NESCAUM also conducted more recent, revised modeling to assess the effects of all haze reduction strategies combined. The latter modeling is described in NESCAUM's "2018 Visibility Projections," May 13, 2008 (Attachment O).

The NESCAUM modeling demonstrates that significant visibility benefits will accrue from implementation of the additional reasonable control measures described in Subsection 10.2, above. Figures 10.4 and 10.5 describe the results of this modeling. In the first of the two figures, the light yellow bars represent expected visibility at MANE-VU Class I Areas in 2018. Comparison of these values with the 2018 "glide slope" values (the plum-colored bars) shows that all areas are expected to experience visibility improvements that meet or exceed the uniform rate of progress calculated for each area. The second figure shows that, for the 20 percent of days having best visibility, expected visibility in 2018 will be better than it is today at all locations.

While the MANE-VU states agree that these modeled 2018 visibility changes result from required and reasonable control measures, it should be noted that source-specific VISTAS and MRPO RPOs projected 2018 emissions are similar to but different from those requested in the MANE-VU Ask, and consequently the future impacts on Lye Brook visibility may be different from what has been projected here. See sections 3.2, and 10.2 for additional detail.

In conclusion, the reasonable control measures proposed by Vermont and the other MANE-VU states are found to be consistent with the stated national goals of preventing further visibility degradation while making measurable progress toward achieving natural visibility conditions in national parks and wilderness areas by 2064.

Figure 10.4 Demonstration of Required and Reasonable Visibility Progress for 20 Percent Worst Visibility Days

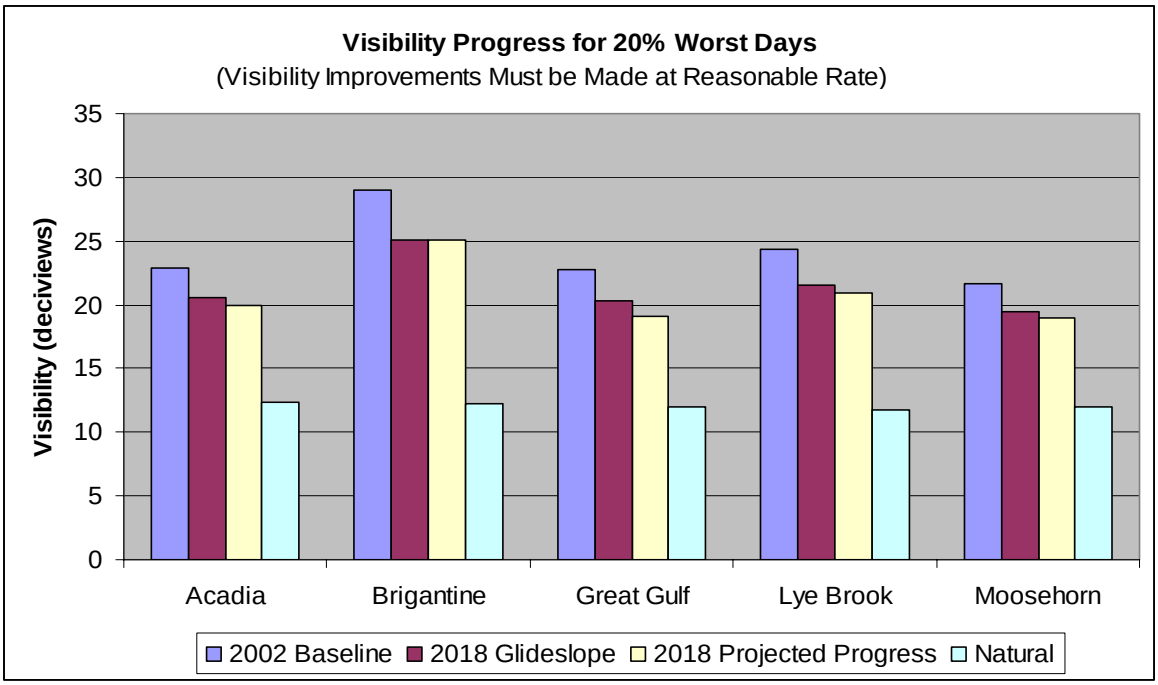
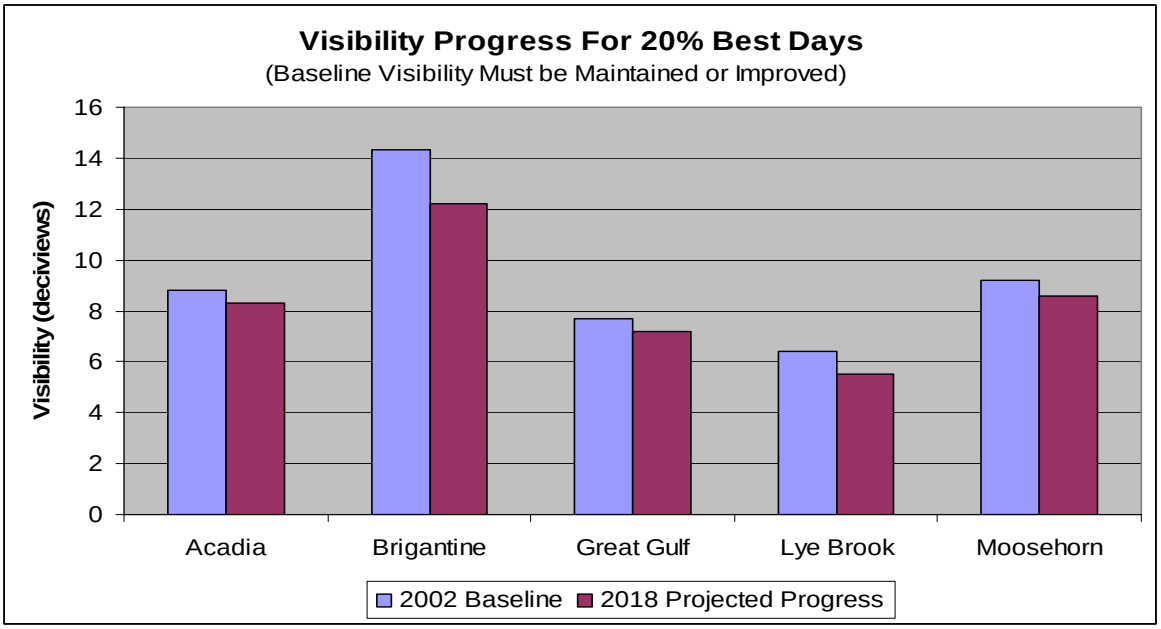


Figure 10.5 Demonstration of Required Maintenance or Improvement of Visibility for 20 Percent Best Visibility Days



10.5 References for Section 10

U.S. Environmental Protection Agency, *National Emission Standards for Hazardous Air Pollutants for Industrial/ Commercial/Institutional Boilers and Process Heaters*, http://cascade.epa.gov/RightSite/dk_public_collection_detail.htm?ObjectType=dk_docket_collection&cid=OAR-2002-0058&ShowList=items&Action=view (Accessed Feb. 25, 2004)

11. Long-Term Strategy

40 CFR 51.308(d)(3) of the Regional Haze Rule requires each state listed in 40 CFR 51.300(b)(3) to submit a long-term strategy that addresses regional haze visibility impairment for all mandatory Class I federal areas within and outside the state that may be affected by emissions from within the state. There are seven designated Class 1 areas within the MANE-VU region: Lye Brook Wilderness, Great Gulf Wilderness, Presidential Range - Dry River Wilderness, Acadia National Park, Moosehorn Wilderness, Roosevelt Campobello International Park, and Brigantine Wilderness. As presented in Section 3.0, Regional Planning and Consultation, Vermont consulted with other states to develop the coordinated emission management strategies contained in this SIP. The following describes how Vermont meets the long-term strategy requirements of the Regional Haze Rule.

Vermont's long-term strategy includes enforceable emission limitations, compliance schedules, and other measures necessary to achieve the reasonable progress goals described in Section 10.0. Additional measures may be reasonable to adopt at a later date after further consideration and review. In developing this long-term strategy, Vermont also considered the requirements of the Clean Air Act, Section 110 (a)(2)(D)(i)(II), pertaining to interstate and international transport of pollutants. More specifically, Section 110 (a)(2)(D)(i)(II) requires states to include provisions in their implementation plans to prohibit any source or activity from emitting air pollutants in amounts that would interfere with another state's ability to prevent significant deterioration of air quality and visibility. The long-term strategy presented herein is designed to protect visibility in Vermont as well as areas downwind from Vermont. As noted in Chapter 2 of this SIP, Vermont emissions contributed less than half of 1 percent of annual average sulfate in any class I area outside of VT.

11.1 Overview of Strategy Development Process

The regional strategy development process identified reasonable measures that would reduce emissions contributing to visibility impairment at Class I areas by 2018 or earlier. The process of identifying potential emission reduction measures and the technical basis for the long-term strategy are discussed in this section. As a MANE-VU member and participant, Vermont supported several technical analyses undertaken to assist the MANE-VU states in deciding which regional haze control measures to pursue. These analyses are documented in the following reports:

- NESCAUM, "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States," August 2006, otherwise known as the Contribution Assessment (Attachment B).
- ICF Resources, L.L.C., "Comparison of CAIR and CAIR Plus Proposal Using the Integrated Planning Model®," Final Draft Report, May 30, 2007, otherwise known as the CAIR Plus Report (Attachment X);
- MACTEC Federal Programs, Inc., "Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I Areas," Final, July 9, 2007, otherwise known as the Reasonable Progress Report (Attachment U);

- NESCAUM, "Five-Factor Analysis of BART-Eligible Sources: Survey of Options for Conducting BART Determinations," June 1, 2007 (Attachment T); and
- NESCAUM, "Assessment of Control Technology Options for BART-Eligible Sources: Steam Electric Boilers, Industrial Boilers, Cement Plants and Paper and Pulp Facilities," March 2005, otherwise known as the BART Report (Attachment V).

MANE-VU reviewed a wide range of potential control measures aimed at reducing regional haze by the 2018 milestone. The process of choosing a set of control measures started in late 2005. OTC selected a contracting firm to assist with the analysis of ozone and regional haze control measure options and provided the contractor with a master list of some 900 potential control measures based on experience and previous state implementation plan work. With the help of an internal OTC Control Measures Workgroup, the contractor narrowed the list of regional haze control measures for further consideration by MANE-VU.

MANE-VU then developed an interim short list of possible control measures for regional haze. The identified control measures can be divided into three general categories:

- Beyond- CAIR sulfate reductions and related control measures targeted at specific electrical generating units (EGUs) in the eastern United States,
- Low-sulfur heating oil for industrial, commercial, institutional (ICI) boilers and residential sources (i.e., boilers and furnaces), and
- Emission controls on ICI boilers (both coal- and oil-fired); lime and cement kilns; residential wood stoves; and outdoor burning (including outdoor wood boilers).

The next step was to further refine this list, with the aid of several of the reports named above. The CAIR Plus Report documents MANE-VU's assessment of the costs of CAIR and provides a cost analysis for additional SO_2 and NO_X controls at power plants in the eastern United States. The Reasonable Progress Report documents the assessment of control measures for EGUs and the other source categories selected for analysis. Further analysis is provided in the second of the two NESCAUM documents referenced above pertaining to Best Available Retrofit Technology (BART) controls.

The beyond-CAIR strategy for EGUs rose to the top of the list because the Contribution Assessment showed that EGU sulfur emissions have, by far, the largest impact on visibility in the MANE-VU Class I Areas. Similarly, a low-sulfur oil strategy gained traction after a NESCAUM-initiated conference with refiners and fuel-oil suppliers concluded that such a strategy could realistically be implemented within the next 10 years. Thus, the low-sulfur heating oil option for the residential and commercial sectors and the control measures option for the oil-fired ICI boiler sector merged into an overall strategy requiring the use of low-sulfur oil. Under this strategy, low-sulfur oil would be required for all residential and commercial heating units and all ICI boilers burning #2, #4, or #6 fuel oils.

During MANE-VU's internal consultation meeting in March 2007, member states reviewed the interim list of control measures to make additional refinements. States determined, for example, that there may be too few coal-fired ICI boilers in MANE-VU for these sources to be included in a regional strategy, but that they could be covered in programs adopted by

individual states. The member states also decided that lime and cement kilns, of which there are few in the MANE-VU region, are most likely to be handled via the BART determination process. Residential wood burning and outdoor wood-fired boilers remained on the list for those states where localized visibility impacts are a consideration even though emissions from these sources are primarily organic carbon and direct particulate matter. Finally, it was decided that the issue of outdoor wood-fired boilers should be examined further on a state-by-state basis because of concerns related to enforcement and penetration of existing state regulations.

11.2 Technical Basis for Strategy Development

40 CFR 51.308(d)(3)(iii) requires Vermont to document the technical basis for the state's apportionment of emission reductions necessary to meet reasonable progress goals in each Class I area affected by Vermont's emissions. Vermont relied on technical analyses developed by MANE-VU to demonstrate that Vermont's emission reductions, when coordinated with those of other states and tribes, are sufficient to achieve reasonable progress goals in Class I areas located in Vermont and in other Class I areas affected by emissions originating in Vermont.

The emission reductions necessary to meet reasonable progress goals in Class I areas affected by Vermont and other MANE-VU states are described in the following documents:

- NESCAUM, "Baseline and Natural Background Visibility Conditions: Considerations and Proposed Approach to the Calculation of Baseline and Natural Background Visibility Conditions at MANE-VU Class I Areas," December 2006 (Attachment J);
- NESCAUM, "The Nature of the Fine Particle and Regional Haze Air Quality Problems in the MANE-VU Region: A Conceptual Description," Final, November 2, 2006 (Attachment Y);
- NESCAUM, "Contributions to Regional Haze in the Northeast and Mid-Atlantic United States," August 2006, otherwise known as the Contribution Assessment (Attachment B).
- ICF Resources, L.L.C., "Comparison of CAIR and CAIR Plus Proposal Using the Integrated Planning Model®," Final Draft Report, May 30, 2007, otherwise known as the CAIR Plus Report (Attachment X);
- MACTEC Federal Programs, Inc., "Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I Areas," Final, July 9, 2007, otherwise known as the Reasonable Progress Report (Attachment U);
- NESCAUM, "Five-Factor Analysis of BART-Eligible Sources: Survey of Options for Conducting BART Determinations," June 1, 2007 (Attachment T);
- NESCAUM, "Assessment of Control Technology Options for BART-Eligible Sources: Steam Electric Boilers, Industrial Boilers, Cement Plants and Paper and Pulp Facilities," March 2005, otherwise known as the BART Report (Attachment V);

- NESCAUM, "MANE-VU Modeling for Reasonable Progress Goals: Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G); and
- NESCAUM, "2018 Visibility Projections," May 13, 2008 (Attachment O).

As described in Subsection 11.1, above, Vermont worked with other members of the Ozone Transport Commission and MANE-VU to evaluate a large number of potential emission reduction strategies covering a wide range of sources of SO_2 and other pollutants contributing to regional haze. 40 CFR 51.308(d)(3)(v) requires states to consider several factors in developing their long-term strategies. Operating within this framework and using available information about emissions and potential impacts, the MANE-VU Reasonable Progress Workgroup selected the following source categories for detailed analysis:

- Coal and oil-fired electric generating units (EGUs);
- Point and area source ICI boilers;
- Cement kilns and lime kilns;
- Sources capable of using low-sulfur heating oil; and
- Residential wood combustion and open burning.

These efforts led to the selection of the emission reduction strategies presented in this SIP.

11.3 Existing Commitments to Reduce Emissions

40 CFR Section 51.308(d)(3)(v)(A) requires Vermont to consider emission reductions from ongoing pollution control programs. In developing its long-term strategy, Vermont considered air pollution programs being implemented between the 2002 baseline year and 2018. The emission reduction programs described in Parts 11.3.1, 11.3.2, and 11.3.3, below, represent commitments already made by Vermont and other states to implement air pollution control measures for EGU point sources, non-EGU point sources, and area sources, respectively. These control measures are the very same measures that were included in the 2018 emissions inventory and used in the modeling. While these control measures were not designed expressly for the purpose of improving visibility, the pollutants they control include those that contribute to visibility impairment in MANE-VU Class I Areas.

MANE-VU's 2018 beyond-on-the-way (BOTW) emissions inventory accounts for emission controls already in place as well as emission controls that are not yet finalized but are likely to achieve additional emission reductions by 2018. The BOTW inventory was developed based on the MANE-VU 2002 Version 3.0 inventory and the MANE-VU 2018 on-the-books/on-the-way (OTB/OTW) inventory. Inventories used for other RPOs reflect anticipated emissions controls that will be in place by 2018. The inventory is termed BOTW because it includes control measures that were developed for ozone SIPs that were not yet on the books in some states. For some states, BOTW also included controls that were under consideration for regional haze SIPs that have not yet been adopted. More information may be found in the following documents:

- MACTEC Federal Programs, Inc., "Development of Emissions Projections for 2009, 2012, and 2018 for NonEGU Point, Area, and Nonroad Sources in the MANE-VU Region," Final Report, February 28, 2007, otherwise known as the Emission Projections Report (Attachment L);
- Alpine Geophysics, LLC, "Documentation of 2018 Emissions from Electric Generating Units in the Eastern United States for MANE-VU's Regional Haze Modeling, Revised Final Draft, April 28, 2008 (Attachment G);
- NESCAUM, "MANE-VU Modeling for Reasonable Progress Goals: Model Performance Evaluation, Pollution Apportionment, and Control Measure Benefits," February 7, 2008 (Attachment G); and
- NESCAUM, "2018 Visibility Projections," May 13, 2008 (Attachment O).

11.3.1 Controls on EGUs Expected by 2018

The following EGU emission reduction programs were included in the modeling used to develop the reasonable progress goals. These programs represent the greatest opportunities for reducing SO_2 emissions and their resulting particulate matter sulfate impacts at Class I areas in the MANE-VU region and serve as the starting point for MANE-VU's long-term strategy to mitigate regional haze. For Vermont's Class I area in particular, because of the very large percentage of visibility impairing sulfate impacts at that area caused by sulfur oxide emissions originating outside Vermont, it is important that EGU SO_2 emission reduction programs of at least the scope identified here be implemented during this first 10-year planning period. Vermont does not have sulfur oxide emitting EGUs in-state and therefore has no regulatory authority of its own to require control of individual EGU SO_2 emissions that contribute to haze impacts in Vermont.

***Clean Air Interstate Rule (CAIR)*:** As promulgated, this major federal rule would have imposed permanent emissions caps on sulfur dioxide (SO_2) and nitrogen oxides (NO_X) in the eastern United States by 2015. When fully effective, CAIR would have reduced SO_2 emissions in the CAIR region by up to 70 percent. To predict future emissions from EGUs after implementation of CAIR, MANE-VU used the Integrated Planning Model (IPM)*. Adjustments to the IPM output were made to provide a more accurate representation of anticipated controls at specific EGU sources as documented in the Alpine Geophysics report listed above. In making these adjustments, emission controls originating from the following state and regional programs were considered:

***Connecticut EGU Regulations*:** Connecticut adopted the following regulations governing EGU emissions:

* The IPM model runs also anticipated the implementation of EPA's Clean Air Mercury Rule (CAMR), which was recently vacated by the courts. However, MANE-VU believes that the adjustments made to the predicted SO_2 emissions from electric generating units (EGUs) will have a larger effect on the air quality modeling analysis conducted for this SIP than will the vacatur of the CAMR rule. The emission adjustments were based on states' comments on the actual levels of SO_2 controls expected to be installed in response to state-specific regulations and EPA's CAIR rule. MANE-VU believes these adjustments improve the reliability of both the emissions inventory and modeling results.

- *Regulations of Connecticut State Agencies (RCSA), section 22a-174-19a*, limiting the SO_2 emission rate to 0.33 lb/MMBtu for fossil-fuel-fired EGUs greater than 15 MW that are also Title IV sources (effective, 2007).
- *RCSA, section 22a-174-22*, limiting the non-ozone seasonal NO_X emission rate to 0.15 lb/MMBtu for fossil-fuel-fired EGUs greater than 15 MW (effective, 2007).
- *RCSA, section 22a-199*, limiting the mercury (Hg) emission rate to 0.0000006 lb/MMBtu for all coal-fired EGUs or alternatively coal-fired EGUs can meet a 90% Hg emission reduction (effective, 2008).

***Delaware EGU Regulations*:** Delaware adopted the following regulations governing EGU emissions:

- *Reg. 1144, Control of Stationary Generator Emissions*, requiring emission controls for SO_2, PM, VOC, and NO_X state-wide, effective January 2006.
- *Reg. 1146, Electric Generating Unit (EGU) Multi-Pollutant Regulation,* requiring SO_2 and NO_X emission controls state-wide, effective December 2007. SO_2 reductions will be more than regulation specifies
- *Reg. 1148, Control of Stationary Combustion Turbine Electric Generating Unit Emissions*, requiring SO_2, NO_X, and $PM_{2.5}$ emission controls state-wide, effective January 2007.

Delaware estimates that these regulations will result in the following emission reductions for affected units: SO_2 emissions of 32,630 tons in 2002 will decline to 8,137 tons in 2018 (a 75-percent reduction); NO_X emissions of 8,735tons in 2002 will decline to 3,740 tons in 2018 (a 57-percent reduction). Also, Delaware anticipates the following reductions resulting from the consent decree with Valero Refinery Delaware City, DE (formerly Motiva, Valero Enterprises): SO_2 emissions of 29,747 tons in 2002 will decline to 608 tons in 2018 (a 98-percent reduction); NO_X emissions in 1,022 in 2002 will decline to 102 tons in 2018 (a 90-percent reduction).

***Maine EGU Regulations*:** *Chapter 145, NO_X Control Program*, limits the NO_X emission rate to 0.22 lb/MMBtu for fossil-fuel-fired units greater than 25 MW built before 1995 with a heat input capacity between 250 and 750 MMBtu/hr, and also limits the NO_X emission rate to 0.15 lb/MMBtu for fossil-fuel-fired units greater than 25 MW built before 1995 with a heat input capacity greater than 750 MMBtu/hr (effective, 2007).

***Massachusetts EGU Regulations*:** Based on the Massachusetts Department of Environmental Protection's 310 CMR 7.29, *Emissions Standards for Power Plants,* adopted in 2001, six of the largest fossil-fuel-fired power plants in Massachusetts must comply with emissions limitations for NO_X, SO_2, Hg, and CO_2. These regulations will achieve an approximately 50-percent reduction in NO_X emissions and a 50- to 75-percent reduction in SO_2 emissions. Depending on the compliance paths selected, the affected facilities will meet the output-based NO_X and SO_2 standards between 2004 and 2008. This regulation also limits the six grandfathered EGUs to a CO_2 emission rate of 1,800 lb/MWh.

***New Hampshire EGU Regulations*:** New Hampshire adopted the following regulations governing EGU emissions:

- *Chapter Env-A 2900, Multiple Pollutant Annual Budget Trading and Banking Program*, capping NO_X emissions at 3,644 tons per year, SO_2 emissions at 7,289 tons per year, and CO_2 emissions at 5,425,866 tons CO_2 per year for all existing fossil-fuel-fired steam units by December 31, 2006.
- *Chapter Env-A 3200*, *NO_X Budget Trading Program*, limiting ozone season NO_X emissions on all fossil-fuel-fired EGUs greater than 15 MW to 0.15 lb/MMBtu, effective November 2, 2007.

***New Jersey New Source Review Settlement Agreements*:** The New Jersey settlement agreement with PSEG required the following actions for specific EGUs:

- *Bergen Unit #2*: Repower to combined cycle by December 31, 2002.
- *Hudson Unit #2*: Install dry FGD or approved alternative technology by Dec. 31, 2006, to control SO_2 emissions and operate the control technology at all times the unit operates to limit SO_2 emissions to 0.15 lb/MMBtu; install SCR or approved alternative technology by May 1, 2007, to control NO_X emissions and operate the control technology year-round to limit NO_X emissions to 0.1 lb/MMBtu; and install a baghouse or approved alternative technology by May 1, 2007, to control and limit PM emissions to 0.015 lb PM/MMBtu.
- *Mercer Unit #1*: Install dry FGD or approved alternative technology by Dec. 31, 2010, to control SO_2 emissions and operate the control technology at all times the unit operates to limit SO_2 emissions to 0.15 lb/MMBtu; and install SCR or approved alternative technology by 2005 to control NO_X emissions and operate the control technology during ozone season only in 2005 and year-round by May 1, 2006, to limit NO_X emissions to 0.13 lb/MMBtu.
- *Mercer Unit #2*: Install dry FGD or approved alternative technology by Dec. 31, 2012, to control SO_2 emissions and operate the control technology at all times the unit operates to limit SO_2 emissions to 0.15 lb/MMBtu; and install SCR or approved alternative technology by 2004 to control NO_X emissions and operate the control technology during ozone season only in 2004 and year-round by May 1, 2006, to limit NO_X emissions to 0.13 lb/MMBtu.

The New Jersey settlement also requires that units operating an FGD use coal having a monthly average sulfur content no greater than 2 percent.

***New York EGU Regulations*:** New York adopted the following regulations governing EGU emissions:

- *Title 6 NYCRR Parts 237, Acid Deposition Reduction NO_X Budget Trading Program*, limits NO_X emissions on all fossil-fuel-fired EGUs greater than 25 MW to a non-ozone season cap of 39,908 tons in 2007.

- *Title 6 NYCRR Parts 238, Acid Deposition Reduction SO_2 Budget Trading Program*, limits SO_2 emissions from all fossil-fuel-fired EGUs greater than 25 MW to an annual cap of 197,046 tons per year starting in 2007 and an annual cap of 131,364 tons per year starting in 2008.

***North Carolina Clean Smokestacks Act*:** Enacted in 2002, this legislation requires that coal-fired EGUs achieve a 77-percent cut in NO_X emissions by 2009 and a 73-percent cut in sulfur dioxide SO_2 emissions by 2013. This act also established annual caps on both SO_2 and NO_X emissions for the two primary utility companies in North Carolina, Duke Energy and Progress Energy. These reductions must be made in North Carolina, and allowances are not saleable.

***Consent Agreements in the VISTAS region*:** The effects of the following consent agreements in the VISTAS states were reflected in the emissions inventories used for those states:

- *Santee Cooper*: A 2004 consent agreement calls for Santee Cooper in South Carolina to install and commence operation of continuous emission control equipment for $PM/SO_2/NO_X$ emissions; comply with system-wide annual $PM/SO_2/NO_X$ emissions limits; agree not to buy, sell, or trade SO_2/NO_X allowances allocated to Santee Cooper System as a result of this agreement; and to comply with emission unit limits of this agreement.
- *TECO*: Under a settlement agreement, by 2008, Tampa Electric in the state of Florida will install permanent emission control equipment to meet stringent pollution limits; implement a series of interim pollution reduction measures to reduce emissions while the permanent controls are designed and installed; and retire pollution emission allowances that Tampa Electric or others could use, or sell to others, to emit additional NO_X, SO_2, and PM.
- *VEPCO*: Virginia Electric and Power Co. agreed to spend $1.2 billion by 2013 to eliminate 237,000 tons of SO_2 and NO_X emissions each year from eight coal-fired electricity generating plants in Virginia and West Virginia.
- *Gulf Power 7*: A 2002 agreement calls for Gulf Power to upgrade its operation to cut NO_X emission rates by 61 percent at its Crist 7 generating plant by 2007 with major reductions beginning in early 2005. The Crist plant is a significant source of NO_X emissions in the Pensacola, Florida, area.

11.3.2 Controls on Non-EGU Point Sources Expected by 2018

For non-EGU sources within MANE-VU, Vermont relied on MANE-VU's Version 3.0 Emission Inventory for 2002. MACTEC conducted an analysis of various control measures as documented in the Emission Projections Report (Attachment L). Control factors were applied to the 2018 MANE-VU inventory for non-EGUs to represent the following national, regional, or state control measures:

- NO_X SIP Call Phase I (NO_X Budget Trading Program) (except ME, NH, VT);
- NO_X SIP Call Phase II (except ME, NH, VT);
- NO_X RACT in 1-hour Ozone SIPs (already included in the 2002 inventory);
- NO_X OTC 2001 Model Rule for ICI Boilers;
- 2-, 4-, 7-, and 10-year MACT Standards;
- Combustion Turbine and RICE MACT (NO_X co-benefits were not included and assumed to be small);
- Industrial Boiler/Process Heater MACT*; and
- Refinery Enforcement Initiative (Fluid catalytic cracking units and fluid coking units, process heaters and boilers, flare gas recovery, leak detection and repair, and benzene (wastewater)).

In addition, states provided control measure information about specific non-EGU sources or regulatory programs in their states. MANE-VU used the state-specific data to the extent it was available. For example, several states developed additional control measures in the course of their planning efforts to reduce ozone within the Ozone Transport Region (OTR). These control measures were included by MANE-VU in the inventories used for regional haze modeling. (The affected states may or may not have committed to adopting these measures in their ozone SIPs.) For specific states, the ozone-reduction strategies included in the modeling would reduce NO_X emissions from the following non-EGU point sources:

- Asphalt production plants in Connecticut, New Jersey, New York, and the District of Columbia;
- Cement kilns in Maine, Maryland, New York, and Pennsylvania; and
- Glass and fiberglass furnaces in Maryland, Massachusetts, New Jersey, New York, and Pennsylvania.

For other regions, MANE-VU used emission inventory data developed by the RPOs for those regions, including VISTAS's Base G2, MRPO's Base K, and CenRAP's emissions inventory. Non-EGU source controls incorporated into the modeling include those required under the following consent agreements as reflected in the VISTAS inventory:

* The inventory was prepared before the MACT for Industrial Boilers and Process Heaters was vacated. Control efficiency was assumed to be 4 percent for SO_2 and 40 percent for PM. The overall effects of including these reductions in the inventory are estimated to be minimal.

- *Dupont*: A 2007 agreement calls for E. I. Dupont Nemours & Co.'s James River plant to install dual absorption pollution control equipment by September 1, 2009, resulting in SO_2 emission reductions of approximately 1,000 tons annually. The James River plant is a non-EGU located in the state of Virginia.
- *Stone Container*: A 2004 agreement calls for the West Point Paper Mill in Virginia owned by Smurfit/Stone Container to control SO_2 emissions from its #8 Power Boiler by using a wet scrubber. This control device should result in reductions of over 3,500 tons of SO_2 in 2018.

11.3.3 Controls on Area Sources Expected by 2018

For area sources within MANE-VU, Vermont relied on MANE-VU's Version 3.0 Emissions Inventory for 2002. In general, MANE-VU developed the 2018 inventory for area sources by applying growth and control factors to the 2002 Version 3.0 inventory. Area source control factors were developed for the following national or regional control measures:

- The Ozone Transport Commission's VOC Model Rules, in OTC states where appropriate (for consumer products, architectural and industrial maintenance coatings, portable fuel containers, mobile equipment repair and refinishing, and solvent cleaning);
- Stage I vapor recovery systems at vehicle refueling stations in Vermont and Stage II vapor recovery systems at Vermont vehicle refueling stations any gasoline dispensing facility with an annual gasoline throughput of 400,000 gallons or more;
- New Jersey post-2002 area source controls; and
- Residential woodstove NSPS.

The following additional control measures were included in the 2018 analysis to reduce NO_X and VOC emissions for the following area source categories for some (identified) states:

- NO_X control measures for combustion of coal; natural gas; and #2, #4, and #6 fuel oils (CT, NJ, and NY only);
- VOC control measures for adhesives and sealants (all MANE-VU states except New Jersey* and VT);
- VOC control measures for emulsified and cutback asphalt paving (all MANE-VU states except ME and VT);
- VOC control measures for consumer products (all MANE-VU states except VT); and
- VOC control measures for portable fuel containers (all MANE-VU states except VT).

As noted above, inventory data for other regions were obtained from those regions' RPOs.

* New Jersey's emission reductions from control measures for adhesives and sealants apply only to area sources. No reductions for point sources (SCC 4-02-0007-xx) were included to avoid inventory double-counting.

Some of the area-source control measures listed above may have been developed by states for the primary purpose of reducing ozone within the Ozone Transport Region (OTR) – see Part 11.3.2 for information on other measures included in states' ozone SIPs.

11.3.4 Controls on Mobile Sources Expected by 2018

For the on-road mobile source emission inventory, Vermont relied on MANE-VU's Version 3.0 emission inventory, which included the following emission control measures for Vermont:

- Vermont's Low Emission Vehicle Regulations, which incorporate by reference California's emissions standards for motor vehicles;
- An enhanced motor vehicle emissions inspection and maintenance (IM) program including an anti-tampering inspection for 1995 and older vehicles, and an on-board diagnostics (OBD) inspection for 1996 and newer vehicles.
- Federal On-Board Refueling Vapor Recovery (ORVR) Rule;
- Federal Heavy-Duty Diesel Engine Emission Standards for Trucks and Buses; and
- Federal Emission Standards for Large Industrial Spark-Ignition Engines and Recreational Vehicles.

Similar programs in other MANE-VU states were included in the on-road mobile source emission inventory, where applicable. The last three items listed above are federal programs, briefly described here:

***On-Board Refueling Vapor Recovery (ORVR) Rule*:** The 1990 Clean Air Act (CAA) Amendments contain provisions that require passenger cars to capture refueling emissions. In 1994, EPA published the ORVR Rule establishing standards for refueling emissions controls for passenger cars and light trucks. The onboard controls were required to be phased in for all new car production by 2000 and for all light trucks by 2006. The rule established a refueling emission standard of 0.20 grams per gallon of dispensed fuel, which was expected to yield a 95 percent reduction of VOC emissions over uncontrolled levels. The CAA authorizes EPA to allow state and local agencies that are not in the ozone transport region (OTR) to phase out Stage II programs, even in the worst nonattainment areas, once EPA has determined that onboard systems are in widespread use. Additional requirements apply under section 184(b)(2) of the CAA to states in the OTR.

***Heavy-Duty Diesel Engine Emission Standards for Trucks and Buses*:** EPA set a PM emissions standard of 0.01 grams per brake-horsepower-hour (g/bhp-hr) for new heavy-duty diesel engines in trucks and buses, to take full effect in the 2007 model year. This rule also includes standards for NO_X and non-methane hydrocarbons (NMHC) of 0.20 g/bhp-hr and 0.14 g/bhp-hr, respectively. These NO_X and NMHC standards will be phased in together between 2007 and 2010. Sulfur in diesel fuel must be lowered to enable modern pollution-control technology to be effective on the trucks and buses that use this fuel. EPA will require a

97-percent reduction in the sulfur content of highway diesel fuel from its current level of 500 parts per million (low-sulfur diesel) to 15 parts per million (ultra-low sulfur diesel).

***Emission Standards for Large Industrial Spark-Ignition Engines and Recreational Vehicles*:** EPA has adopted new standards for emissions of NO_X, hydrocarbons (HC), and carbon monoxide (CO) from several groups of previously unregulated non-road engines. Included are large industrial spark-ignition engines and recreational vehicles. The affected spark-ignition engines are those powered by gasoline, liquid propane, or compressed natural gas rated over 19 kilowatts (kW) (25 horsepower). These engines are used in commercial and industrial applications, including forklifts, electric generators, airport baggage transport vehicles, and a variety of farm and construction applications. Non-road recreational vehicles include snowmobiles, off-highway motorcycles, and all-terrain vehicles. These rules were initially effective in 2004 and will be fully phased-in by 2012.

11.3.5 Controls on Non-Road Sources Expected by 2018

For non-road emission sources, Vermont used Version 3.0 of the MANE-VU 2002 Emissions Inventory. Because the NONROAD Model used to develop the non-road source emissions did not include aircraft, commercial marine vessels, and locomotives, MANE-VU's contractor, MACTEC, developed the inventory for these sources. Non-road mobile source emissions for the 2018 emission inventory were calculated with EPA's NONROAD2005 emissions model as incorporated into the NMIM2005 (National Mobile Inventory Model) database. The NONROAD model accounts for emissions benefits associated with federal non-road emission control requirements such as the following:

- "Control of Air Pollution: Determination of Significance for Nonroad Sources and Emissions Standards for New Nonroad Compression Ignition Engines at or above 37 Kilowatts," 59 FR 31306, June 17, 1994.
- "Control of Emissions of Air Pollution from Nonroad Diesel Engines," 63 FR 56967, October 23, 1998.
- "Control of Emissions from Nonroad Large Spark-Ignition Engines and Recreational Engines (Marine and Land-Based)," Final Rule, 67 FR 68241, November 8, 2002.
- "Control of Emissions of Air Pollution from Nonroad Diesel Engines and Fuel," Final Rule, April, 2004.

As noted above, inventory data for other regions were obtained from those regions' RPOs.

11.4 Additional Reasonable Measures

As required under 40 CFR 51.308(d)(1)(i)(A), Vermont and the other MANE-VU states applied four-factor analysis to potential control measures for the purpose of establishing reasonable progress goals (see Subsection 10.2 for detailed description). Reasonable measures include those that the affected states have already committed themselves to implementing, as described in Subsection 11.3, above. In addition, the MANE-VU states have identified other control measures that were found to be reasonable and were included in

the modeling that was used to set reasonable progress goals. (These additional measures surpass the "beyond-on-the-way" emission controls and inventories.) All of the control measures – those embodied in the states' commitments to existing or planned programs and the additional reasonable control measures described below – comprise the long-term strategy for improving visibility at MANE-VU Class I Areas.

Specifically, the Vermont/MANE-VU long-term strategy relies on the following additional measures to reduce pollutants that cause regional haze.

- Timely implementation of BART requirements in all states with BART eligible sources.

- A low-sulfur fuel oil strategy in the inner-zone MANE-VU states (New Jersey, New York, Delaware, and Pennsylvania, or portions thereof) to reduce the sulfur content of:
  - #2 distillate oil to 0.05 percent (500 ppm) sulfur, by weight, by no later than 2012;
  - #4 residual oil to 0.25 percent sulfur, by weight, by no later than 2012;
  - #6 residual oil to 0.3-0.5 percent sulfur, by weight, by no later than 2012;
  - Further reduction of the sulfur content of distillate oil to 15 ppm by 2016.

- A low-sulfur fuel oil strategy in the outer-zone MANE-VU states (the remainder of the MANE-VU region) to reduce the sulfur content of:
  - #2 distillate oil to 0.05 percent (500 ppm) sulfur, by weight, by no later than 2014;
  - #4 residual oil to 0.25-0.50 percent sulfur, by weight, by no later than 2018;
  - #6 residual oil to 0.5 percent sulfur or less, by weight, by no later than 2018;
  - Further reduction of the sulfur content of distillate oil to 15 ppm by 2018, contingent on supply and availability.

- A 90-percent or greater reduction in sulfur dioxide (SO_2) emissions from each of the EGUs identified by MANE-VU as reasonably anticipated to cause or contribute to impairment of visibility in any mandatory Class I area in the MANE-VU region. (This requirement affects 167 point sources, or stacks, at EGU facilities in the eastern United States.) If it is infeasible to achieve this level of SO_2 reductions from specific EGUs, equivalent alternative measures will be pursued in the affected states.

- Continued evaluation of other control measures, including energy efficiency, alternative clean fuels, other measures to reduce SO_2 and nitrogen oxide (NO_X) emissions from all coal-burning facilities by 2018, and new source performance standards for wood combustion.

This suite of additional control measures are those that the MANE-VU states have agreed to pursue for the purpose of mitigating regional haze. The corollary is that the MANE-VU Class I states (Maine, New Hampshire, Vermont, and New Jersey) are asking states outside the MANE-VU region that contribute to visibility impairment inside the region to pursue similar measures. The control measures that non-MANE-VU states choose to pursue may be directed

toward the same emission source sectors identified by MANE-VU for its own emission reductions, or they may be equivalent measures targeting other source sectors. Under MANE-VU's long-term strategy, states will be allowed up to ten years to pursue adoption and implementation of proposed control measures. While some measures that states pursue may not represent enforceable commitments immediately, they may become enforceable in the future as new laws are passed, rules are written, and facility permits are issued.

11.4.1 BART

Vermont has no BART-eligible sources. However, Vermont considers the implementation of the BART provisions of the Regional Haze Rule (40 CFR 51.308(e)) – in other MANE-VU states and in other upwind RPOs - as one of the important reasonable strategies included in this SIP. For electrical generating units, EPA determined that CAIR fulfilled BART requirements for this sector. Although CAIR has been remanded to EPA, Vermont assumes that EPA will either promulgate an interstate rule to replace CAIR that will achieve EGU emissions reductions of a magnitude as least as large as would have been required under CAIR, or will require specific emissions controls on all BART-eligible EGU sources if an alternative interstate rule is not promulgated.

To assess the benefits of implementing BART controls for MANE-VU's non-EGU sectors, NESCAUM included in the final 2018 CMAQ modeling analysis anticipated emission reductions for the region's BART-eligible facilities, as described previously in Part 10.2.2 of this SIP. It is anticipated that twelve units at eight BART-eligible sources in MANE-VU would be controlled as a result of BART requirements alone (see Table 10.3).

Note that additional emission reductions will occur at many other BART-eligible facilities within MANE-VU as a result of controls achieved by other programs that serve as BART but are not specifically identified as such (e.g., RACT control measures). While not specifically identified as being attributable to BART, these additional emission reductions were fully accounted for in the 2018 CMAQ modeling.

Further visibility benefits are likely to result from installation of new emission controls at BART-eligible facilities located in neighboring RPOs. However, the MANE-VU modeling did not account for BART controls in other RPOs and, consequently, did not include visibility improvements at MANE-VU Class I Areas that would be likely to accrue from such measures.

11.4.2 Low-Sulfur Oil Strategy

The important assumption underlying MANE-VU's low-sulfur fuel oil strategy is that refiners can, by 2018, produce sufficient quantities of home heating and other fuel oils with lower sulfur content than current fuel supplies at only a small increase in price to the end user. The expected reductions in sulfur content range from 50 percent for the heavier grades (#4 and #6 residual) to a minimum of 75 percent and maximum of 99.25 percent for #2 fuel oil (also known as home heating oil, distillate, or diesel fuel). As much as three-fourths of the total sulfur reductions achieved by this strategy will come from using low-sulfur #2 distillate for space heating in the residential and commercial sectors. The costs of these emissions reductions are estimated at $550 to $750 per ton, as documented in the MANE-VU

Reasonable Progress Report. While the costs of the low-sulfur fuel oil strategy remain somewhat uncertain, they appear to be reasonable when measured against the costs of controlling other sectors.
Currently there are logistical issues in supplying large quantities of low-sulfur oils to the PADD1B (northern New England region). This oil is supplied by PADD1A and barged into the region in quantities that allow for blending with high-sulfur fuels to produce 1-percent sulfur fuels. Current capacities are limited by Federal restrictions that prevent large ships from transferring fuels between two U.S. ports. The states of this region intend to build full capacity for 0.5-percent-sulfur #6 fuel oil by 2018.

The MANE-VU states agree that a low-sulfur oil strategy is reasonable to pursue in the next ten years. Vermont will review the details of this strategy in five years, coincident with Vermont's first regional haze SIP progress report, to ascertain that requiring the use of low-sulfur fuel remains viable for implementation by 2018.

11.4.3 Targeted EGU Strategy

MANE-VU has identified emissions from the top 167 EGU emission points that contribute the most to visibility impairment at MANE-VU Class I Areas (see Figure 10.2). Controlling emissions from these contributing facilities is crucial to mitigating haze pollution in wilderness areas and national parks of the Northeast states.

MANE-VU's agreed regional approach for the EGU source sector is to pursue a 90-percent control level on SO_2 emissions from the 167 identified stacks by 2018. MANE-VU has concluded that pursuing this level of sulfur reduction is both reasonable and cost-effective. Even though current wet scrubber technology can achieve sulfur reductions greater than 95 percent, an overall 90-percent sulfur reduction level would include the effects of lower average reduction rates from dry scrubbing technology, consistent with historical experience. The costs of SO_2 emission reductions will vary by unit. MANE-VU's Reasonable Progress Report (Attachment U) summarizes the available control methods and costs, which range from $170 to $5,700 per ton (2006 dollars), depending on site-specific factors such as size of unit, combustion technology used, and type of fuel burned.

Several other states within and outside the MANE-VU region have implemented state-specific EGU emission reduction programs that will help MANE-VU meet visibility improvement goals. Many of the state programs that will contribute to meeting the targeted EGU strategy are identified in Part 11.3.1 of this section. Listed below are other state programs not previously identified that will also contribute to meeting this strategy. These other programs may yield additional benefits by controlling emissions at certain EGUs not listed among the top 167 EGU stacks. The listed programs represent existing commitments by the states and, as such, were included in MANE-VU's most recent modeling.

***Maryland Healthy Air Act*:** Maryland adopted the following requirements governing EGU emissions:

- For NO_X:
  - Phase I (2009) sets unit-specific annual caps totaling 20,216 tons and ozone-

season caps totaling 8,900 tons.

  - Phase II (2012) sets unit-specific annual caps totaling 16,667 tons and ozone-season caps totaling 7,337 tons.

- For SO_2:
  - Phase I (2010) sets unit-specific annual caps totaling 48,818 tons.
  - Phase II (2013) sets unit-specific annual caps totaling 37,235 tons.
- For mercury:
  - Phase I (2010) requires a 12-month-rolling-average minimum removal efficiency of 80 percent.
  - Phase II (2013) requires a 12-month-rolling-average minimum removal efficiency of 90 percent.

The specific EGUs included are: Brandon Shores (Units 1 and 2), C.P. Crane (Units 1 and 2), Chalk Point (Units 1, and 2), Dickerson (Units 1, 2, and 3), H.A. Wagner (Units 2 and 3) Morgantown (Units 1 and 2), and R. Paul Smith (Units 3 and 4). No out-of-state trading of emission allowances, no inter-company trading of allowances, and no banking of allowances from year to year were included in the analyses.

***New Jersey Mercury MACT Rule*:** Under this rule all coal-fired EGUs in New Jersey will have a mercury removal efficiency of 90 percent. (Some SO_2 reductions may occur as a co-benefit of mercury emission controls.)

New Hampshire RSA 125-O, Multiple Pollutant Reduction Program:

- *Merrimack Station Unit MK-1:* 8,799 tons (90%) SO_2 reduction by 2013.
- *Merrimack Station Unit MK-21:* 18,812 tons (90%) SO_2 reduction by 2013.
- *Newington Station Unit NT-1:* 2,613 tons (50%) SO_2 reduction by 2018

***Consent Agreements in the VISTAS region*:** The following consent agreements in the VISTAS states were reflected in the emissions inventories used for those states:

- *East Kentucky Power Cooperative*: A July 2, 2007, consent agreement between EPA and East Kentucky Power Cooperative (EKPC) requires the utility to reduce its SO_2 emissions by 54,000 tons per year and its NO_X emissions by 8,000 tons per year, by installing and operating selective catalytic reduction (SCR) technology; low-NO_X burners, and PM and mercury continuous emissions monitors at the utility's Spurlock, Dale, and Cooper Plants. According to the EPA, total emissions from the plants will decrease between 50 and 75 percent from 2005 levels. As with all federal consent decrees, EKPC is precluded from using reductions required under other programs such as CAIR to meet the reduction requirements of the consent decree. EKPC is expected to spend $654 million to install pollution controls.
- *American Electric Power*: Under this agreement, American Electric Power (AEP) will spend $4.6 billion dollars for emission controls at sixteen plants located in Indiana,

Kentucky, Ohio, Virginia, and West Virginia. These control measures will eliminate 72,000 tons of NO_X emissions each year by 2016 and 174,000 tons of SO_2 emissions each year by 2018 from the affected facilities.

11.5 Source Retirement and Replacement Schedules

40 CFR Section 51.308(d)(3)(v)(D) of the Regional Haze Rule requires Vermont to consider source retirement and replacement schedules in developing reasonable progress goals. Source retirement and replacement were considered in developing the 2018 emissions inventory described previously in Subsection 10.3, Reasonable Progress Goals for Class I Areas in the State. See also Table B-5 in the Emission Projections Report (Attachment L).

11.6 Measures to Mitigate the Impacts of Construction Activities

40 CFR 51.308(d)(3)(v)(B) of the Regional Haze Rule requires Vermont to consider measures to mitigate the impacts of construction activities on regional haze. MANE-VU's consideration of control measures for construction activities is documented in "Technical Support Document on Measures to Mitigate the Visibility Impacts of Construction Activities in the MANE-VU Region," Draft, October 20, 2006," (Attachment Z).

MANE-VU's Contribution Assessment (Attachment B) found that, from a regional haze perspective, crustal material generally does not play a major role. On the 20 percent best-visibility days during the 2000-2004 baseline period, crustal material accounted for 6 to 11 percent of particle-related light extinction at MANE-VU Class I Areas. On the 20 percent worst-visibility days, however, the ratio was reduced to 2 to 3 percent. Furthermore, the crustal fraction is largely made up of pollutants of natural origin (e.g., soil or sea salt) that are not targeted under the Regional Haze Rule. Nevertheless, the crustal fraction at any given location can be heavily influenced by the proximity of construction activities; and construction activities occurring in the immediate vicinity of MANE-VU Class I Areas could have a noticeable effect on visibility.

For this regional haze SIP, Vermont considered additional measures to mitigate the impacts of construction activities but decided to defer evaluation of further controls. Future deliberations on potential control measures for construction activities and their possible implementation will be documented in the first regional haze SIP progress report in 2012.

11.7 Agricultural and Forestry Smoke Management

40 CFR 51.308(d)(3)(v)(E) requires Vermont to consider smoke management techniques related to agricultural and forestry management in developing the long-term strategy. MANE-VU's analysis of smoke management in the context of regional haze is documented in "Technical Support Document on Agricultural and Forestry Smoke Management in the MANE-VU Region, September 1, 2006," (Attachment S).

As that report notes, fires used for resource benefits are of far less significance to the total inventory of fine-particle pollutant emissions than other sources of wood smoke in the region.

The largest MANE-VU wood smoke source categories, with respect to $PM_{2.5}$ emissions, are residential wood combustion (73 percent); open burning (15 percent); and industrial, commercial, and institutional wood combustion (9 percent). Unwanted fires involving buildings and wild lands make up only a minor fraction of wood burning emissions and cannot be reasonably addressed in a SIP. Fires that are covered under smoke management plans, including agricultural and prescribed forest burning, constitute less than one percent of total wood smoke emissions in MANE-VU.

Wild fire emissions within Vermont and other MANE-VU states are also relatively small and infrequent contributors to regional PM emissions. However, Lye Brook and other MANE-VU class 1 areas are occasionally impacted by wild fire smoke emissions from other regions, such as from the lightning-induced forest fires in Quebec Province in July 2002. These natural wild fire smoke emissions occasionally impair visibility at Lye Brook, but are not considered manmade or controllable – and in fact are part of "natural background" conditions.

Vermont will continue to review the impacts from agricultural use of fire and prescribed fire for forest or ecosystem management. If those impacts become important for maintaining reasonable progress in the future, revisions to the regional haze SIP will include a smoke management plan. Vermont will continue to consult with the US Forest Service regarding potential impacts of prescribed fire on visibility in the Lye Brook Wilderness.

11.8 Estimated Effects of Long-Term Strategy on Visibility

40 CFR 51.308(d)(3)(v)(G) requires Vermont to consider, in developing its long-term strategy, the anticipated net effect on visibility due to projected changes in point, area, and mobile source emissions over the period addressed by the long-term strategy. NESCAUM conducted modeling to evaluate the expected improvements to visibility at affected Class I areas by 2018 as a consequence of implementing MANE-VU's long-term strategy. Those visibility improvements will result, in part, from the efforts identified in this SIP to reduce emissions that originate in Vermont and other MANE-VU states.

All Class I states affected by emissions originating in Vermont have (or will have) established reasonable progress goals for 2018 for each of their Class I areas. The control measures included in this SIP represent the reasonable efforts of Vermont, in conjunction with efforts of other MANE-VU states, toward achieving the reasonable progress goals established by the affected states.

Based on the most recent MANE-VU modeling, the proposed control measures will reduce sulfate levels at affected Class I areas by about one-third on the worst visibility days and by 6 to 31 percent on the best visibility days by 2018. Nitrate and elemental carbon levels will also show substantial reductions across all areas for both best and worst days, while smaller reductions in organic carbon levels will occur. Small increases are predicted for the fine soil component of regional haze. There is a possibility that the predicted increases in this component are not real but, rather, related to structural differences in the data sets used in the modeling for the baseline and future years. (Specifically, the fire emissions inventory used in VISTAS for the base year relied on an earlier version of fire emissions data than the one used for the 2018 inventory.) No changes are predicted for sea salt because the model does not

track this component.

The 2000-2004 visibility readings at affected Class I areas provide the baseline against which future visibility readings will be measured to assess progress deriving from implementation of Vermont's regional haze SIP and those of the other MANE-VU states. To determine baseline visibility for affected Class I areas, Vermont used the 2000-2004 IMPROVE monitoring data to calculate the average deciview values for the 20 percent best visibility days and the 20 percent worst visibility days over that period. Thus, the 20 percent best day and 20 percent worst day values represent average visibility conditions for the top and bottom quintiles.

To create the series of visibility graphs which follow, 2018 visibility estimates were made in accordance with EPA modeling guidance. First, 2002 daily average baseline concentrations were multiplied by their corresponding relative reduction factors to obtain 2018 projected concentrations for each day. The 2018 projected concentrations were then used to derive daily visibility in deciviews. As a final step, the deciview values for the 20 percent of days having best visibility were averaged, and the process repeated for the 20 percent of days having worst visibility. The resulting averages represent the projected upper and lower quintiles of visibility in 2018.

The following is provided to assist with interpretation of the line graphs in Figures 11.1 and Figures 11.3 through 11.6. Note that lower deciview values indicate better visibility.

- The irregular blue line (~) represents the 20 percent best visibility average value as determined from monitoring data for each year of the period 2001-2005.
- The irregular red line (~) represents the 20 percent worst visibility average value as determined from monitoring data for each year of the period 2001-2005.
- The straight orange line (—) represents the 20 percent best visibility average value as determined from monitoring data for the 5-year period of 2000-2004. (This line represents the *20 percent best visibility baseline condition*.)
- The straight blue line (—) represents the 20 percent worst visibility average value as determined from monitoring data for the 5-year period of 2000-2004. (This line represents the *20 percent worst visibility baseline condition*.)
- The straight broken line (▪▪▪) is a continuation of the 20 percent best visibility baseline, representing the 20 percent best visibility condition as it would be with no further degradation or improvement.
- The straight green line (—) represents the 20 percent worst visibility values that establish the uniform rate of progress for the period 2004-2064. (This line is sometimes referred to as the *uniform progress line*, or *"glide slope."* It was created by linear interpolation between the 20 percent worst visibility baseline value in 2004 and the 20 percent worst visibility value under natural conditions in 2064. If visibility improvements match this rate of progress, actual visibility will return to natural conditions in 2064.)
- The light-green dash (–) shown at 2064 represents the theoretical 20 percent best visibility value under natural conditions (i.e., no anthropogenic emissions).
- The purple star (*) represents the 20 percent best visibility value in 2018 after implementation of MANE-VU's long-term strategy, as predicted by the CMAQ model.

(This value is a *reasonable progress goal*.)

- The blue star (✳) represents the 20 percent worst visibility value in 2018 after implementation of MANE-VU's long-term strategy, as predicted by the CMAQ model. (This value is a *reasonable progress goal*.)

Figure 11.1 illustrates predicted visibility improvements at Lye Brook Wilderness. Observe that the blue star lies below the green line, indicating that, by 2018, the long-term strategy of this SIP will result in visibility improvements surpassing the uniform rate of progress on days of worst visibility. Similarly, the position of the purple star below the dashed line indicates that visibility requirements will be met, i.e., there will be no further degradation from baseline conditions on days of best visibility. Figure 11.2 presents bar graphs depicting expected improvements in haze-causing pollutant levels at the Lye Brook Wilderness. The graph on the left shows concentrations of visibility-impairing pollutants on days of best visibility for the 2000-2004 baseline period, 2018 modeled year, and natural background condition. The graph on the right is a similar plot for days of worst visibility. The graphs show that almost all of the expected improvements will result from reductions in sulfate concentrations. If the states adhere to MANE-VU's reasonable progress goals, sulfate levels (as a fraction of the total pollutant burden) will fall from about 60 percent in 2000-2004 to no more than 50 percent in 2018 and to less than 10 percent (natural conditions) in 2064.

Figures 11.3 through 11.6 are line graphs showing anticipated visibility improvements for the other MANE-VU Class I Areas. All locations are projected to meet or exceed their uniform-rate-of-progress goals for 2018. In addition, all areas are expected to see improvements in best-day visibility relative to baseline values.

Figure 11.1 Expected Visibility Improvement at Lye Brook Wilderness Based on Most Recent Projections

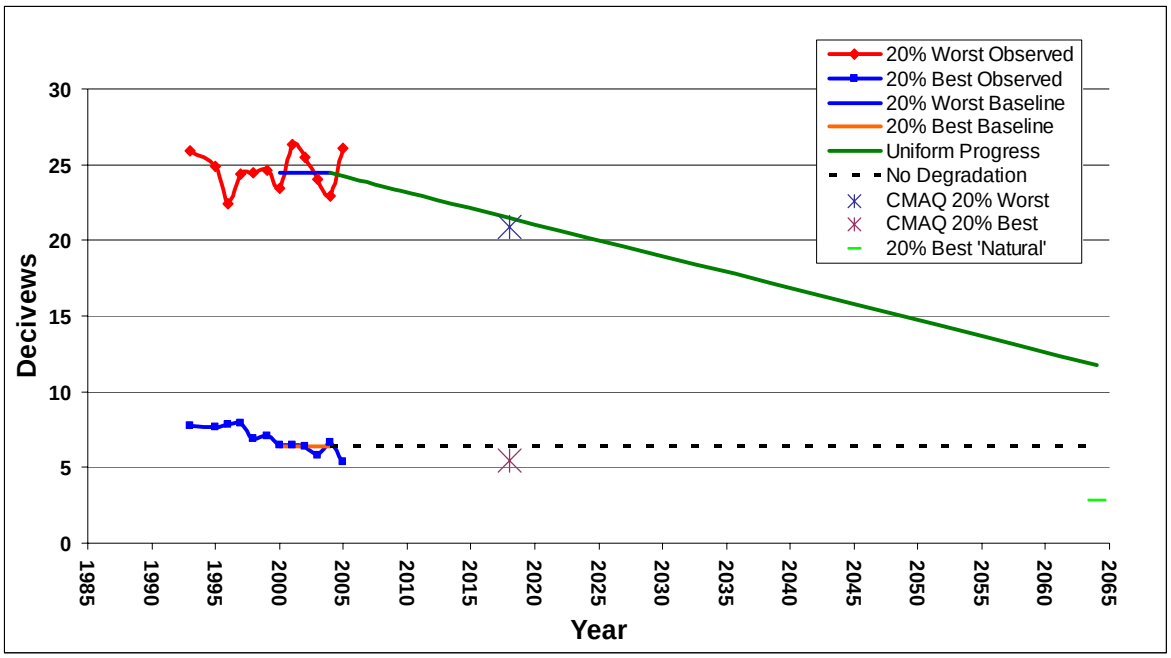


Figure 11.2 Expected Improvements in Pollutant Concentrations at Lye Brook Wilderness on Best and Worst Days

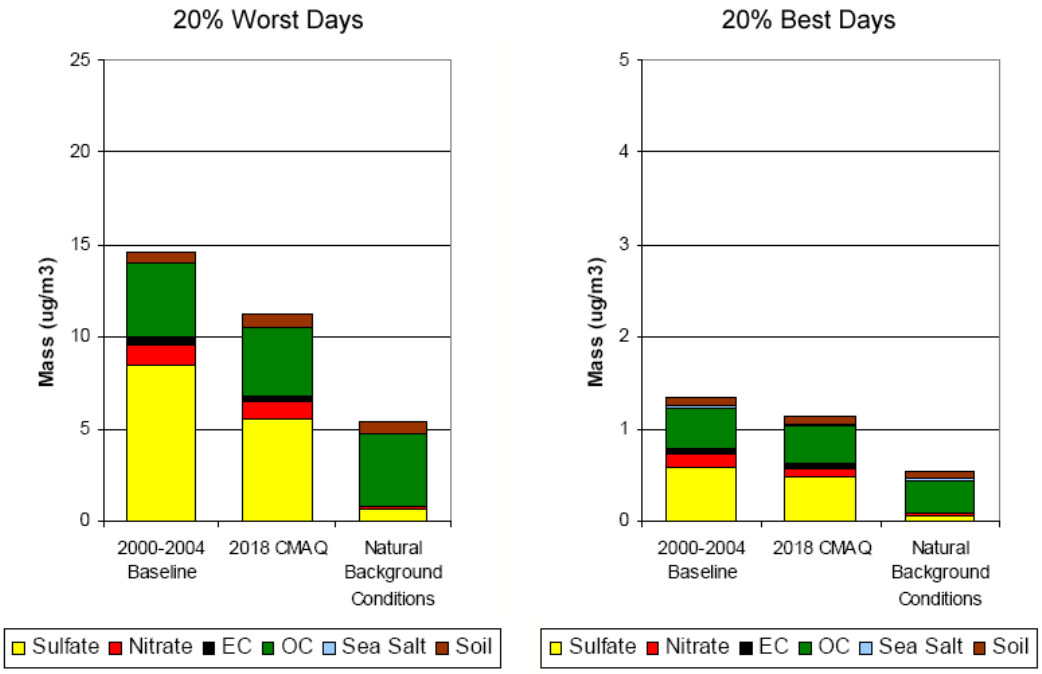


Figure 11.3 Expected Visibility Improvement at Acadia National Park Based on Most Recent Projections

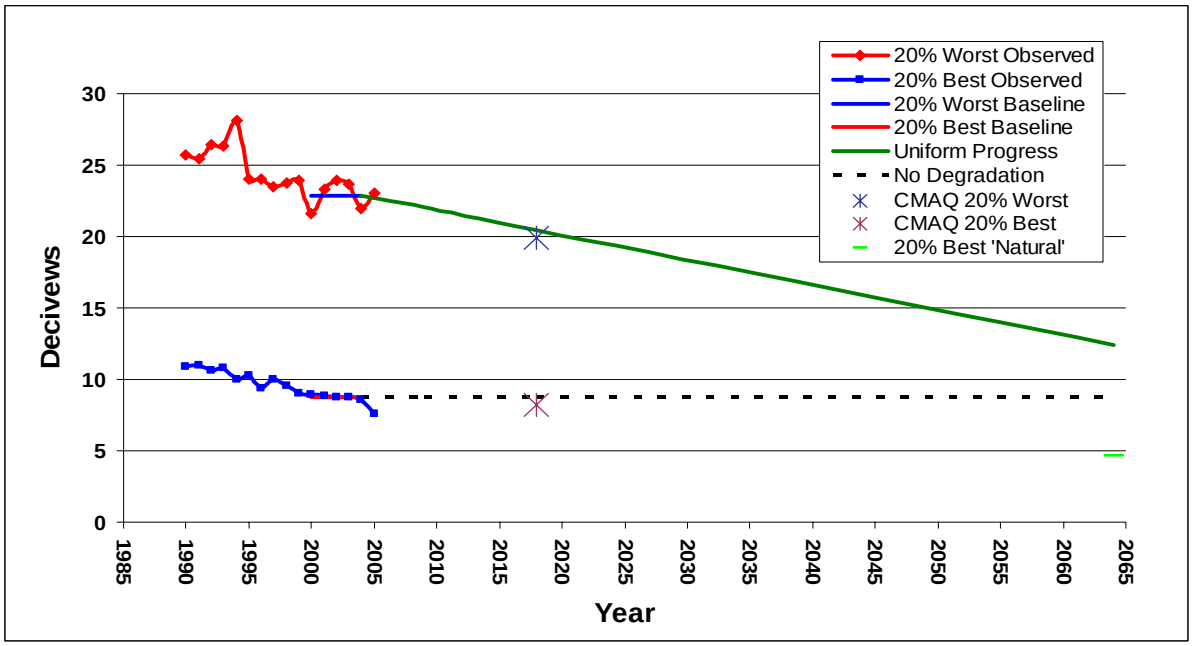


Figure 11.4 Expected Visibility Improvement at Brigantine National Wildlife Refuge Based on Most Recent Projections

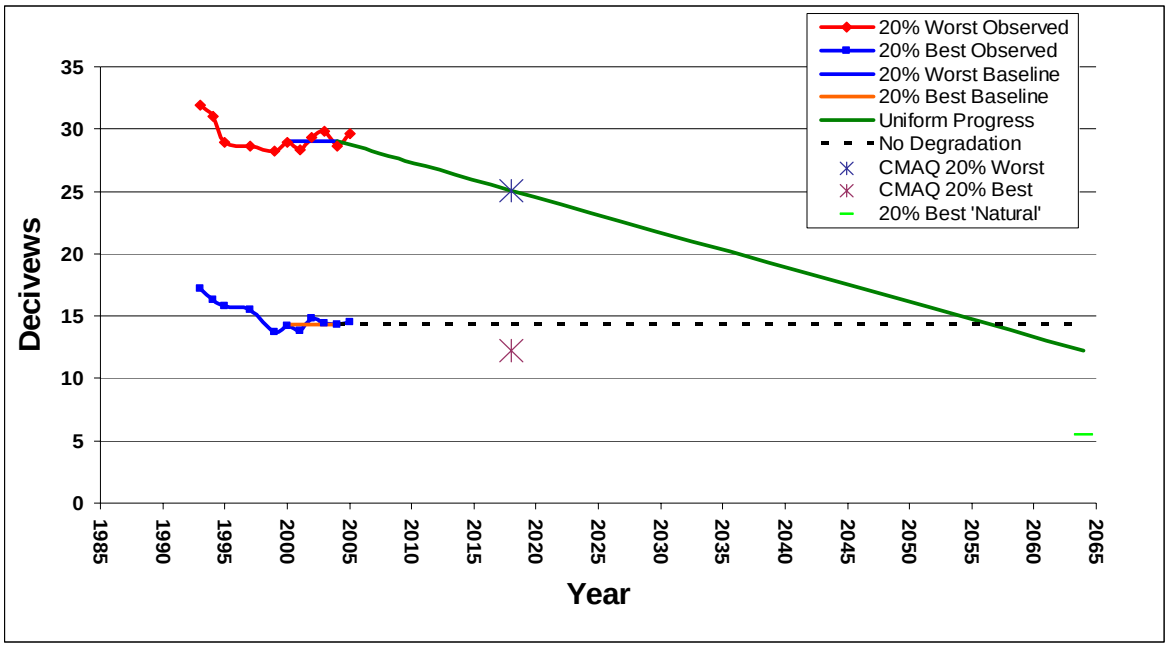
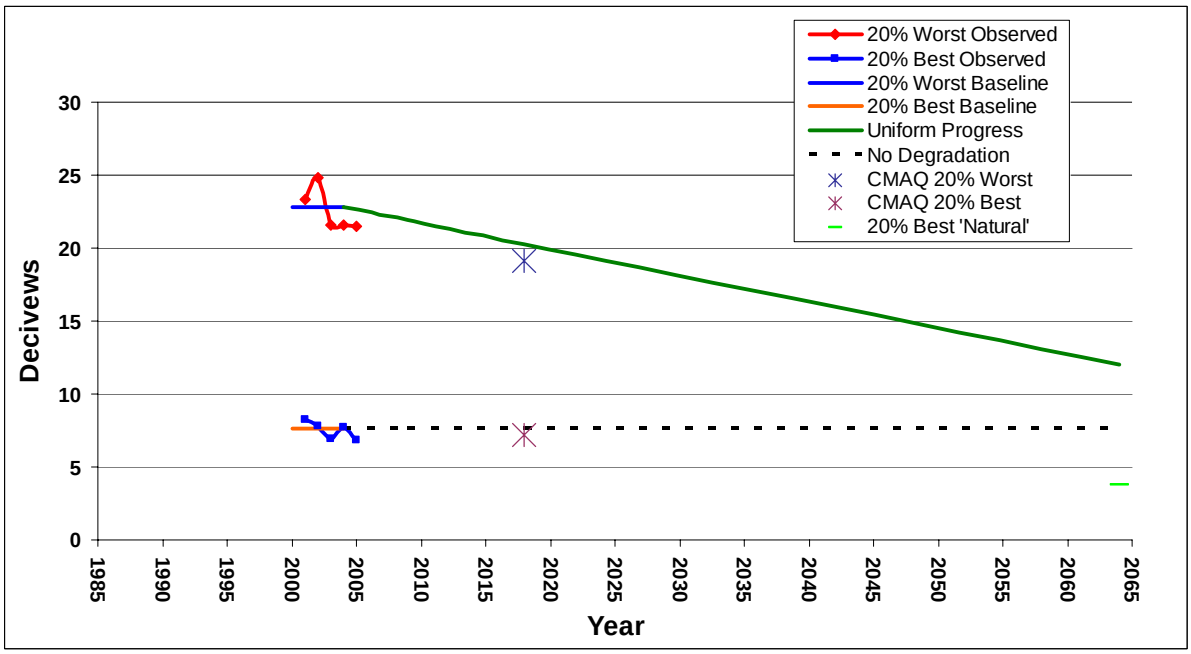
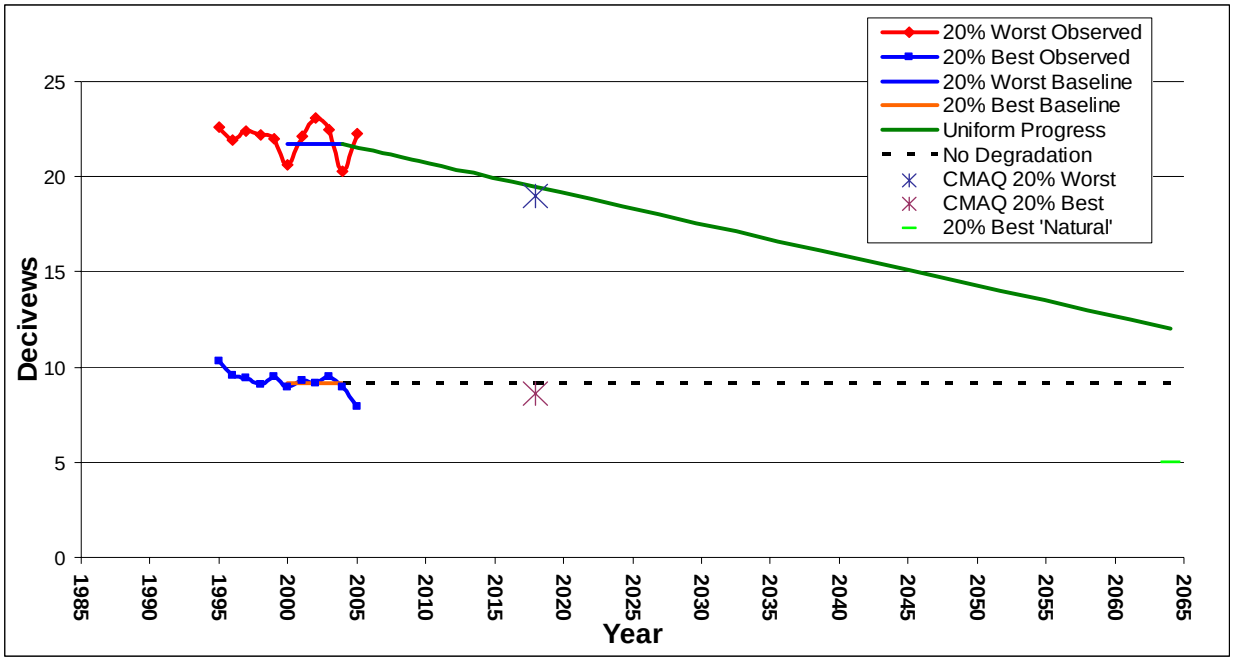


Figure 11.5 Expected Visibility Improvement at Great Gulf Wilderness Based on Most Recent Projections*



* The visibility improvement estimate for Great Gulf Wilderness also serves as an estimate for Presidential Range - Dry River Wilderness.

Figure 11.6 Expected Visibility Improvement at Moosehorn National Wildlife Refuge Based on Most Recent Projections*



11.9 Vermont's Share of Emission Reductions

40 CFR 51.308(d)(3)(ii) of the Regional Haze Rule requires Vermont to demonstrate that its implementation plan includes all measures necessary to obtain its share of emission reductions needed to meet the reasonable progress goals. The modeling analyses referenced in Subsection 11.8, above, demonstrate that the Vermont/MANE-VU long-term strategy is sufficient to meet these visibility goals.

As demonstrated in Section 2 of this plan, Vermont sulfur emissions, **in total**, currently contribute less than 1 percent of sulfate in the Lye Brook Wilderness Area and less than half of 1 percent of sulfate in any other Class 1 area. These contributions will be even smaller as Vermont complies with the MANE-VU low-sulfur fuel oil strategy, as **nearly 85% of Vermont's SO_2 emissions originate from ICI boilers and residential heating units** which would be reduced significantly by 2018 by the MANE-VU (outer zone states) low sulfur fuel strategy.

The basis for the long-term strategy is a statement adopted by MANE-VU on June 20, 2007 (see Part 3.3.3, The MANE-VU "Ask"). This document provides that each state will have up to 10 years to pursue adoption and implementation of reasonable control measures for NO_X and SO_2 emission reductions. Vermont's regional haze SIP is wholly consistent with this long-term strategy. To meet its obligation, Vermont agrees to pursue the following general and specific emission reduction measures:

* The visibility improvement estimate for Moosehorn Wilderness also serves as an estimate for Roosevelt/Campobello International Park.

- Participation in a regional low-sulfur fuel oil strategy that will result in SO_2 emission reductions from ICI boilers and residential heating units across the state;
- Continued evaluation of other possible control measures for haze-causing emissions.

11.10 Vermont Commitments to Specific Regulatory Changes That Will Further Protect Visibility

The MANE-VU regional long-term strategy for reaching reasonable progress goals for visibility established at Class I areas in the MANE-VU region implies no large scale sulfur emissions reductions from existing sources in Vermont except for the sulfur-in-fuel limitations to be implemented on a regional market basis (see Section 11.9 above). Nevertheless, Vermont intends to establish a secondary welfare standard for particulate matter measures as sulfate ion and a significance level for single source impact relative to regional haze at Lye Brook Wilderness Area. These regulatory changes will further limit the potential for impacts from both new and existing Vermont sources of sulfur oxides or particulate matter emissions that contribute (however slightly) to haze in the Lye Brook Wilderness Area.

The setting of an ambient sulfate standard and the incorporation of a significance level for ambient sulfate impact will also establish in the Vermont SIP a level of significance of impact relative to regional haze at Lye Brook Wilderness Area that is consistent with the assumptions made by MANE-VU in identifying the most significant large stationary sources impacting on visibility at Class I areas in MANE-VU. Vermont intends to revise its current Air Pollution Control Regulation §5-312 "Sulfates – Secondary Ambient Air Quality Standard" which is a standard applicable to maximum 24-hour ambient concentration and summer seasonal mean ambient concentration in Lye Brook Wilderness Area and other areas of Vermont Sensitive to Acidic Deposition (lands above 2500 feet elevation). It is likely that the two standards will remain at their current levels (2 ug/m^3), however the sulfate ion concentration will be identified as the relevant measure of ambient impact considered to be in violation if exceeded. Based on data relevant to all the planning for this regional haze plan, it is already well established that both of these standards are violated by sulfate particulate matter transported into Vermont from outside the state. The new regulation is expected to be adopted within the next year (by 2010) and will be submitted as part of the long-term strategy portion of this Vermont Regional Haze SIP.

In conjunction with the minor changes to existing regulation §5-312, Vermont intends to revise the level of significant impact for sulfate ion which is currently contained in Vermont Air Pollution Control Regulation TABLE 3 "Levels of Significant Impact for Nonattainment Areas". Currently, the regulation establishes a significance level for seasonal (April thru September 6 month average) "sulfates" at 0.2 ug/m^3 as well as a 24-hr maximum significance level for "sulfates" at 2.0 ug/m^3. Both of these significance levels are used in New Source Review (or evaluation of an existing source's impact potential) to identify whether a single source is significantly impacting on the current violations of the Vermont Secondary Ambient Air Quality Standards for Sulfates. Both of the current significance levels will be reduced by at least an order of magnitude. As currently being drafted, a summer seasonal sulfate level of 0.004 ug/m^3 and a 24-hour maximum of 0.10 ug/m^3 will be specified as representing significant sulfate impacts from individual sources. The revision of these significance levels

will establish in Vermont regulation, new significance levels for sulfate ion that are consistent with the MANE-VU criteria for identifying single EGU stacks that were included in the list of "Top 167 EGU Stacks Affecting MANE-VU Class I Areas", which is a major component of the MANE-VU long-term strategy. It is Vermont's intention to use these revised "levels of significant impact" to determine whether newly proposed (or existing) sources, located within Vermont (or in upwind states), are significantly contributing to exceedances of Vermont's sulfate standard, and therefore significantly contributing to Lye Broook visibility impairment. When this SIP has been approved by EPA, Vermont assumes that sources exceeding this significance level will be considered by EPA to be interfering with Vermont's ability to assure reasonable progress toward the Clean Air Act §169 national visibility goal.

The significance levels being considered currently to replace the existing ones are on a par with the EPA 9/21/07 Federal Register Proposal for $PM_{2.5}$ Increments, Significant Impact Levels (SILs) and Significant Monitoring Concentrations (SMCs). Under the EPA proposal, the SILs for annual and 24-hr maximum $PM_{2.5}$ for Class I areas suggest levels close to the levels Vermont is considering. The proposal will not be finalized for several months but after public hearing and comment is expected to be adopted as revisions to the Vermont Air Pollution Control Regulations by 2010. These revised regulations will be submitted to EPA for inclusion in Vermont's Regional Haze SIP as part of its long-term strategy for restoration of natural visibility in Lye Brook Wilderness Area.

11.11 Emission Limitations and Compliance Schedules

40 CFR 51.308(d)(3)(v)(C) requires Vermont to establish emission limitations and compliance schedules to meet reasonable progress goals. Emission limitations and compliance schedules are already in place for the Vermont and other state programs outlined in Subsection 11.3 of this section. For the additional reasonable control measures described in Subsection 11.4, certain emission limitations like the MANE-VU low sulfur fuel strategy and any additional measures deemed to be necessary may need to be established by law through revisions to VT Statutes Title 10 Chapter 23 (Air Pollution Control) and/or amendments to Vermont's Air Pollution Control Regulations.

Vermont will continue to evaluate all measures included in the long-term strategy to ascertain whether they remain reasonable to implement by 2018 and will formalize that determination in the first regional haze SIP progress report, due in 2012. Vermont intends to adopt all reasonable control measures as expeditiously as practicable, in a manner consistent with state law, so that they may be in place by the end of the ten-year planning period.

11.12 Enforceability of Emission Limitations and Control Measures

40 CFR 51.308(d)(3)(v)(F) requires Vermont to consider the enforceability of emissions limitations and control measures in developing its long term strategy. All control measures incorporated into law or codified in administrative rules will be enforceable. Any facility subject to state or federal permit requirements, including Title V facilities, will be required to comply with the specific permit conditions that reference the applicable provisions of those laws and rules.

The key statutory provisions that allow for the enforceability of emissions limitations and control measures related to regional haze are:

- 10 VSA chapter 23, Air Pollution Control (see e.g., 10 VSA § 554, which authorizes the adoption and amendment of rules; 10 VSA § 556, which authorizes a permitting program for the construction or modification of air contaminant sources; 10 VSA § 556a, which authorizes a permitting program for the operation of air contaminant sources; 10 VSA § 558,which authorizes the establishment of emission control requirements that may be necessary to prevent, abate, or control air pollution; 10 VSA § 567, which authorizes rules to control emissions from motor vehicles; and 10 VSA § 568, which provides for penalties for the violation of 10 VSA chapter 23 or any rules adopted thereunder);

- 10 VSA chapter 201, Administrative Environmental Law Enforcement, which authorizes enforcement of 10 VSA chapter 23;

- 3 VSA § 2822(j)(1), which establishes fees for air pollution control permits and registrations issued under 10 VSA chapter 23

Provisions of the Vermont Air Pollution Control Regulations of particular relevance to the regional haze SIP are:

- § 5-221(1) Prohibition of Potentially Polluting Materials in Fuel (Sulfur limitation in fuel);

- § 5-312 Sulfates - Secondary Ambient Air Quality Standards;

- Subchapter V: Review of New Air Contaminant Sources;

- Subchapter X: Operating Permits; and

The Vermont Air Pollution Control Regulations rules provide for enforceable emission control measures and compliance schedules to meet the applicable requirements of the Clean Air Act and rules promulgated by EPA. The Vermont rules also define the permit program and fee structure for stationary sources, to ensure that national ambient air quality standards are achieved.

In order to comply with and implement the MANE-VU low-sulfur oil strategy, Vermont commits to revising the § 5-221(1) of the Vermont Air Pollution Control Regulations, which currently specifies a sulfur limitation in fuel of 2% sulfur by weight to limit the sulfur content of distillate oil to 0.05% sulfur by weight (500 ppm) by no later than 2014, of #4 residual oil to 0.25-0.5% sulfur by weight by no later than 2018, and of #6 residual oil to no greater than 0.5 % sulfur by weight by no later than 2018, and to reduce the sulfur content of distillate oil further to 15 ppm by 2018, depending on supply availability.

Ultimately, Vermont's Regional Haze SIP is dependent on the implementation of enforceable emission limitations and control measures, both within the state and in other states identified as contributing to visibility impairment at Vermont's Lye Brook Wilderness Area. Because Vermont has no jurisdiction over other states, the attainment of regional progress goals will, to a large extent, be predicated on the good-faith efforts of contributing upwind states to meet their fair share of emission reductions through implementation of their own enforceable control measures. While Vermont can provide assurances regarding the implementation of in-state emission controls, the bulk of regional-haze-causing pollutants in the Lye Brook Wilderness will continue to come from out-of-state sources.

11.13 Prevention of Significant Deterioration

In Subchapter 5 of Vermont's Air Pollution Control Regulations, the permit review requirements for new major stationary sources or major modifications (emitting > 50 tons of any air contaminant) require in § 5-502 (4) an Air Quality Impact Evaluation that demonstrates the new allowable emissions will not result in an exceedance of the remaining increments for SO_2, NO_2 or PM_{10} in any Class 1 area (i.e. Lye Brook). The applicant must also demonstrate "that the increase in allowable emissions will not cause an adverse impact on visibility in any sensitive area or in any Class I Federal area and will not interfere with reasonable progress toward the remedying of existing man-made visibility impairment in a sensitive area. Said demonstration shall be submitted to the Agency and the appropriate Federal Land Manager at least 60 days prior to the close of the public comment period on the source or modification" (where Sensitive Area is defined as "any portion of the area comprising Lye Brook Wilderness Area and all other terrain in Vermont at or above the elevation of 2500 feet above mean sea level"). In this manner, new major sources and existing sources making major modifications will be constructed and operated in a manner that will not degrade air quality or visibility. The PSD permitting program is an integral part of Vermont's long-term strategy for meeting its regional haze goals.