3. 2018 BOTW PROJECTIONS

In order to assess the projected visibility improvement at MANE-VU Class I areas prior to consideration of potential reasonable measures for adoption in a long-term emissions management strategy, a simulation of the MANE-VU "Beyond on the Way" (BOTW-1) inventory was conducted. As indicated in Chapter 2, this inventory/scenario combination represents additional measures beyond existing regulations that have been accepted by the OTC Modeling Committee for attainment of the 8-hour ozone and $PM_{2.5}$ NAAQSs. These measures include regulations on portable fuel containers, architectural and maintenance (AIM) coatings, and some consumer products. In addition, at the point that this inventory was "closed" for further changes, most states had indicated a willingness to adopt regulations limiting fuel sulfur content of distillate fuel oil to 500 ppm or lower.[4] While all states have subsequently agreed that they will pursue regulation of distillate AND residual fuel oil and that these regulations would cap distillate at 15 ppm fuel sulfur content by 2018, this additional level of reduction is not reflected in the BOTW-1 simulation discussed below.

The BOTW-1 scenario was processed through SMOKE for 2009 by NYDEC and for 2018 by NESCAUM and distributed to the other modeling centers in a manner similar to the 2002 base year scenario that was SMOKE processed by NYDEC. After each center had completed its portion of the processing, NESCAUM obtained the results for all projection years for analysis of haze metrics.

The results of this run are shown in Table 3-1 and Figures 3-1 and 3-2, which show relative reduction factors at each Class I area by species and the overall projected improvement in visibility in deciviews based on the 2009 (NYDEC) and 2018 (NESCAUM) BOTW-1 projections, respectively.

Table 3-1. 2018 twenty percent worst days relative reduction factors.

	Shenandoah	Dolly Sods	Brigantine	Great Gulf	Lye Brook	Moosehorn	Acadia
Sulfate	0.49	0.51	0.53	0.59	0.58	0.63	0.60
Nitrate	0.46	0.63	0.95	0.87	0.91	0.73	0.80
EC	0.58	0.71	0.62	0.73	0.67	0.77	0.75
OC	0.88	0.92	0.98	0.86	0.93	0.95	0.95
Sea Salt	1	1	1	1	1	1	1
Soil	1.27	1.26	1.28	1.16	1.13	1.09	1.10

[4] Delaware and Vermont had not given an indication by the time the inventory was closed.

Figure 3-1. Projected improvement in visibility at four Northeast sites based on 2009 and 2018 BOTW-1 projections.

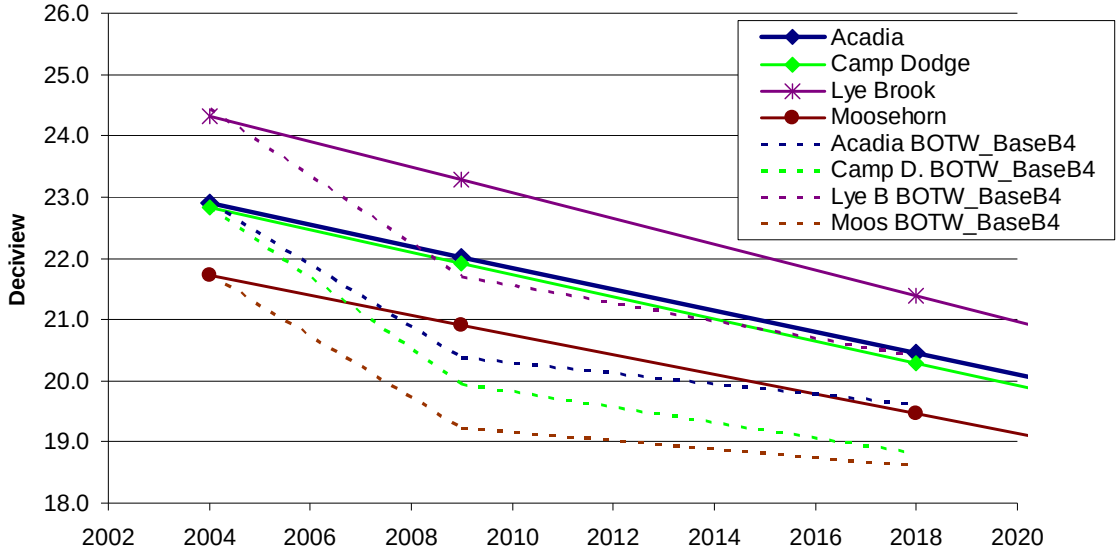
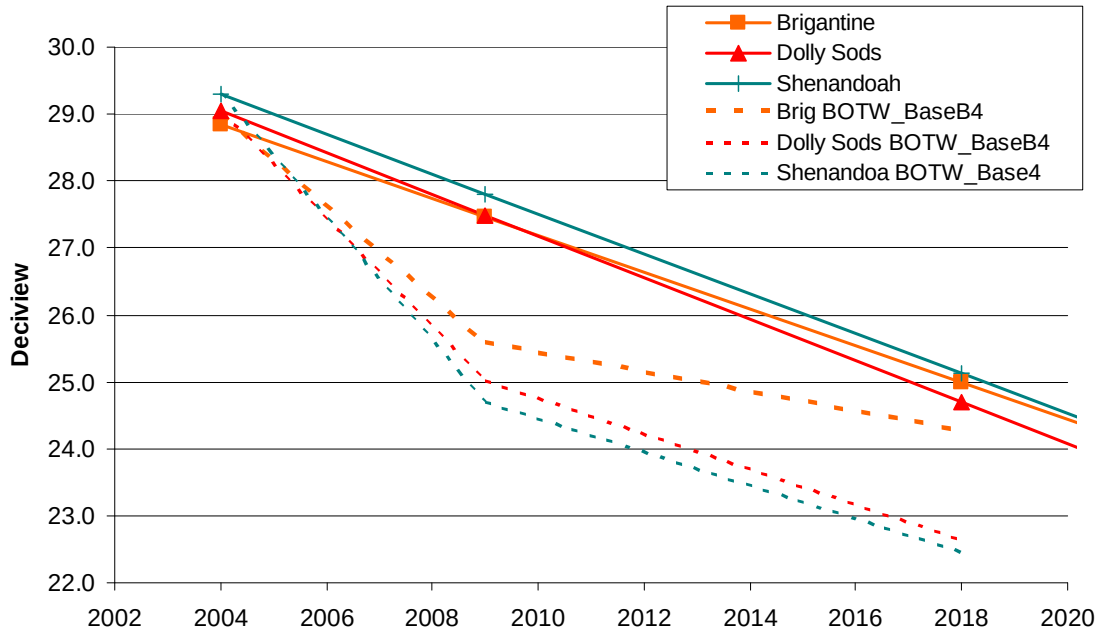


Figure 3-2. Projected improvement in visibility at three Mid-Atlantic sites based on 2009 and 2018 BOTW-1 projections.



The projections for the BOTW-1 scenario indicate that the adoption of 500 ppm distillate regulations by all MANE-VU states is sufficient to achieve visibility improvements beyond the uniform rate of progress defined by the 2064 natural conditions

visibility goal. However, it should be noted that USEPA guidance for setting reasonable progress goals asks states to consider reviewing all measures identified through the four-factor analysis process and to adopt each measure that is determined to be reasonable.

While the interpretation of USEPA guidance on this subject continues to be debated by various stakeholders and some states outside the MANE-VU region, MANE-VU believes that the four-factor analysis provisions in the Clean Air Act requires states to analyze additional measures and adopt those that are reasonable. We have identified and analyzed several additional measures for consideration in determining regional haze reasonable progress goals and these options are explored in Chapter 5.

4. 2018 POLLUTION APPORTIONMENT

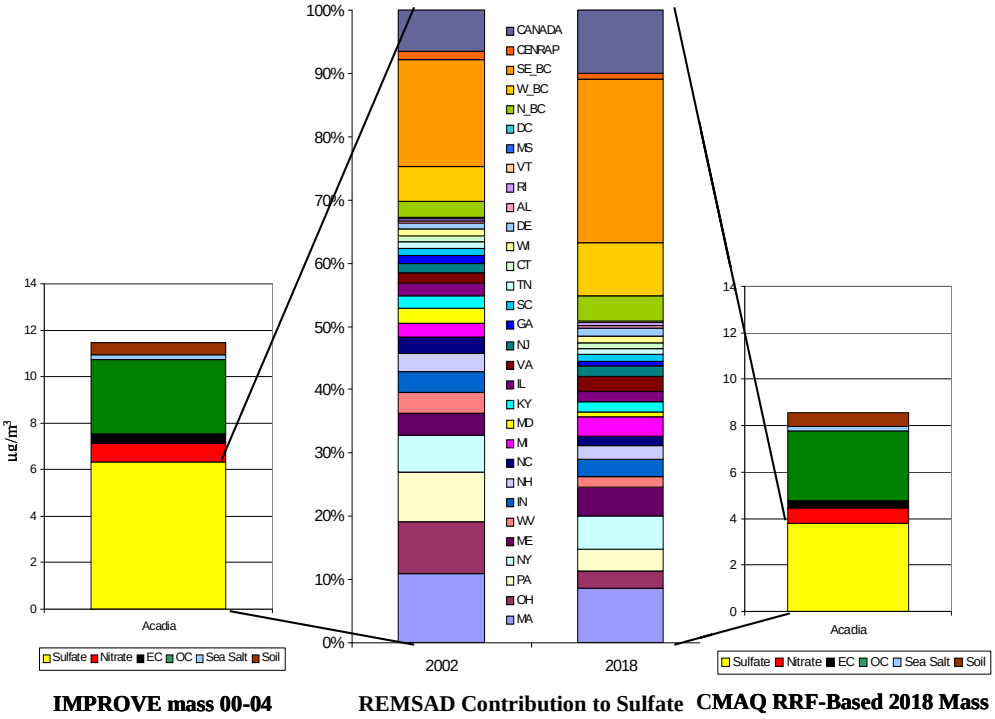
One requirement of the regional haze rule is a "pollution apportionment" that provides an assessment of the major contributors to MANE-VU visibility impairment by geographical region or by sector. MANE-VU had conducted an extensive apportionment of 2002 visibility impairment from sulfate in the prior *Contribution Assessment* report (NESCAUM, 2006a) and conceptual description (NESCAUM, 2006b). In order to update this work to reflect changes in the contributions by various states to visibility impairment projected for 2018, we have utilized the 2018 BOTW emission inventory and tagged all SO_2 emissions from each of 29 states in the eastern U.S. This required three separate runs with 11 tags per run. In addition, three tags for baseline (2002) boundary conditions (**N**orth, **S**outh_**E**ast, and **W**est) provide an estimate for sulfate contributions external to the model domain. Note their contribution includes emissions that originated within the domain, but were advected out of the modeling domain only to recirculate back into the domain (i.e. the state-specific tagged contributions represent, in this sense, a lower-bound).

This tagging scheme provides a comprehensive reporting of the influence of most of these states to visibility impairment within the model domain. It also provides a partial accounting of the influence of several states along the western and southern edge of the model domain where only a portion of the states' emissions were tracked.

Results indicate that the relative contribution of states within the domain will decrease significantly due, in large part, to the anticipated SO_2 emissions reductions from the CAIR program. As a result, we see large *increases* in the *relative* contribution from Canada and the boundaries. This apparent increase is simply due to the fact that we are showing relative contributions and as a share of the total, these fixed contributions contribute a larger share after CAIR has reduced the contribution within the domain.

Figures 4-1 through 4-5 show the absolute magnitude of measured and projected sulfate at each MANE-VU class I monitor as well as the relative contributions of each state to that sulfate as contrasted against their 2002 contributions.

Figure 4-1. a. Measured and projected mass contributions in 2002 and 2018 at Acadia National Park on twenty percent worst visibility days.



b. 2002 and 2018 sulfate mass from at Acadia National Park, twenty percent worst days apportioned by REMSAD

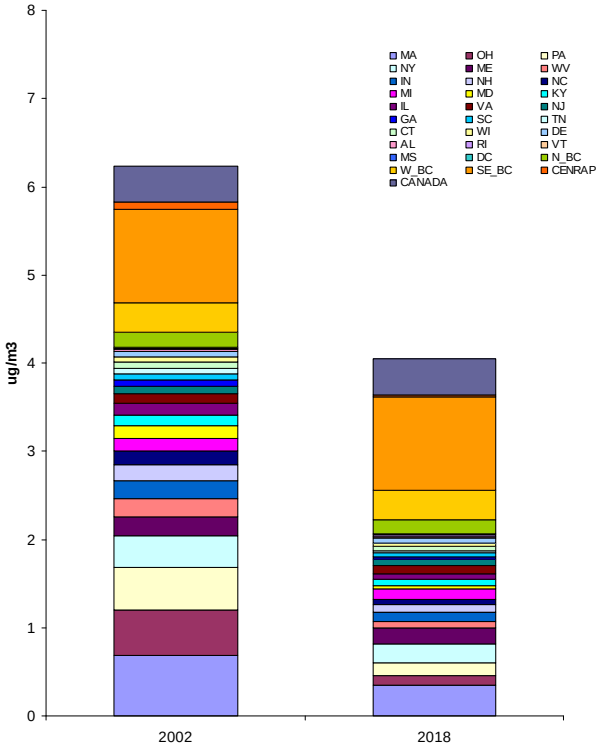
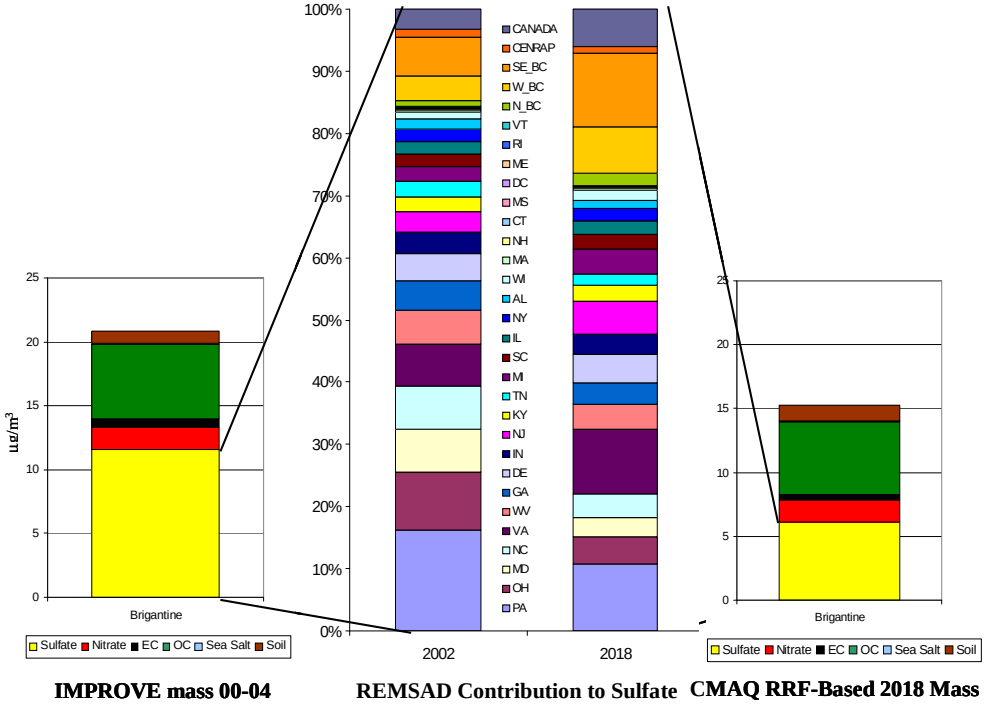


Figure 4-2. a. Measured and projected mass contributions in 2002 and 2018 at Brigantine Wildlife Refuge on twenty percent worst visibility days.



b. 2002 and 2018 sulfate mass from Brigantine Wildlife Refuge, twenty percent worst days from REMSAD

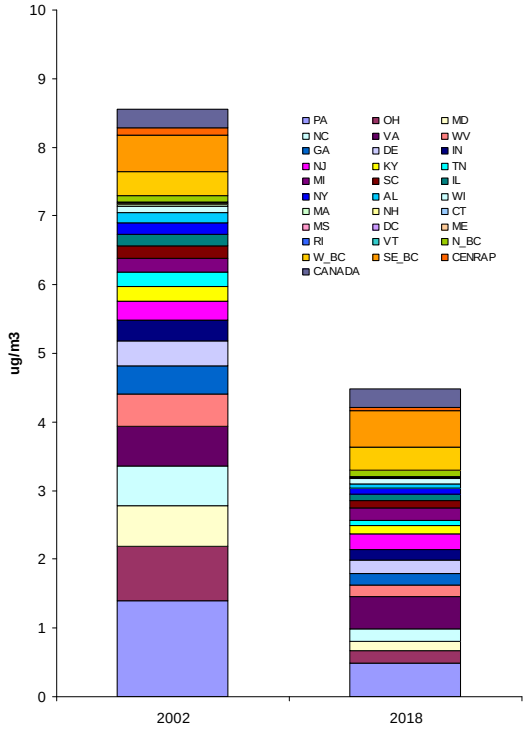
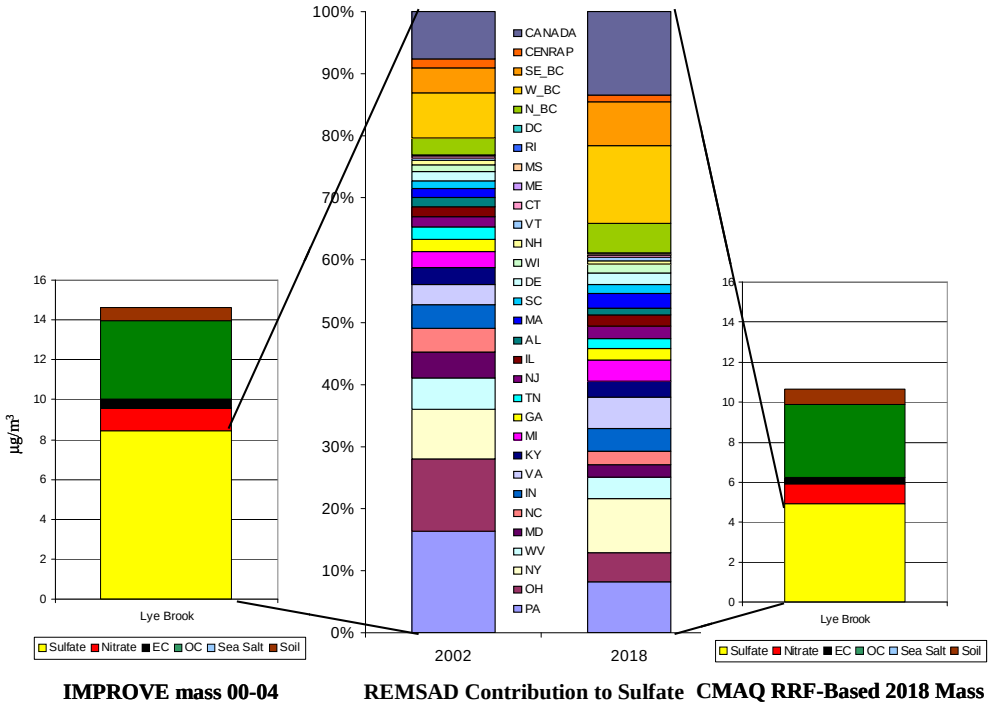


Figure 4-3. a. Measured and projected mass contributions in 2002 and 2018 at Lye Brook Wilderness Area on twenty percent worst visibility days.



b. 2002 and 2018 sulfate mass from Lye Brook Wilderness Area, twenty percent worst days from REMSAD

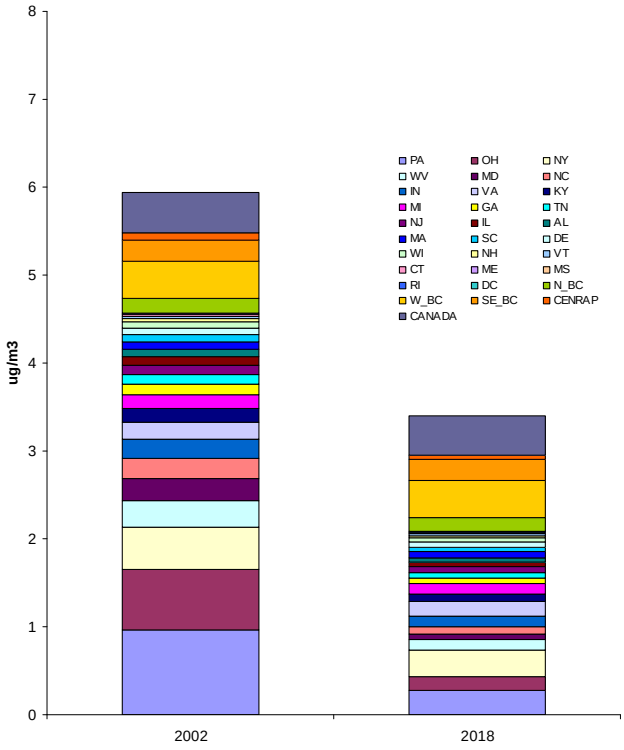
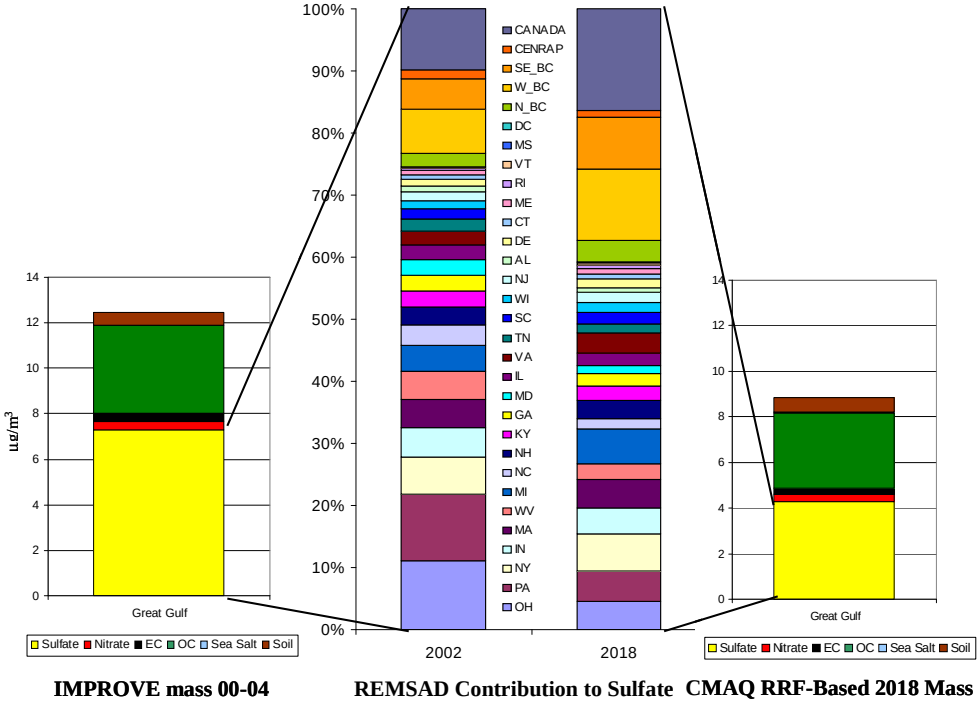


Figure 4-4. a. Measured and projected mass contributions in 2002 and 2018 at Great Gulf Wilderness Area on twenty percent worst visibility days.



b. 2002 and 2018 sulfate mass from Great Gulf Wilderness Area, twenty percent worst days from REMSAD

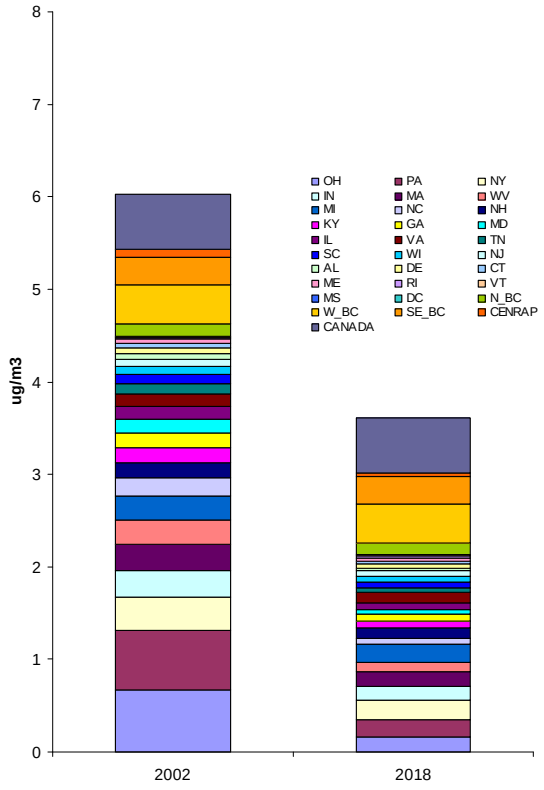
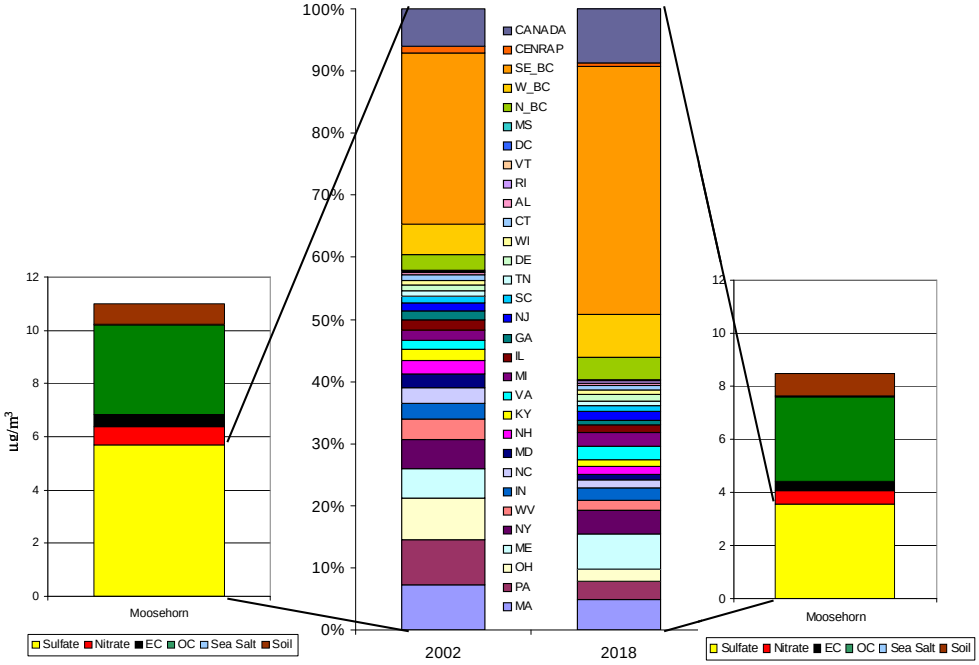
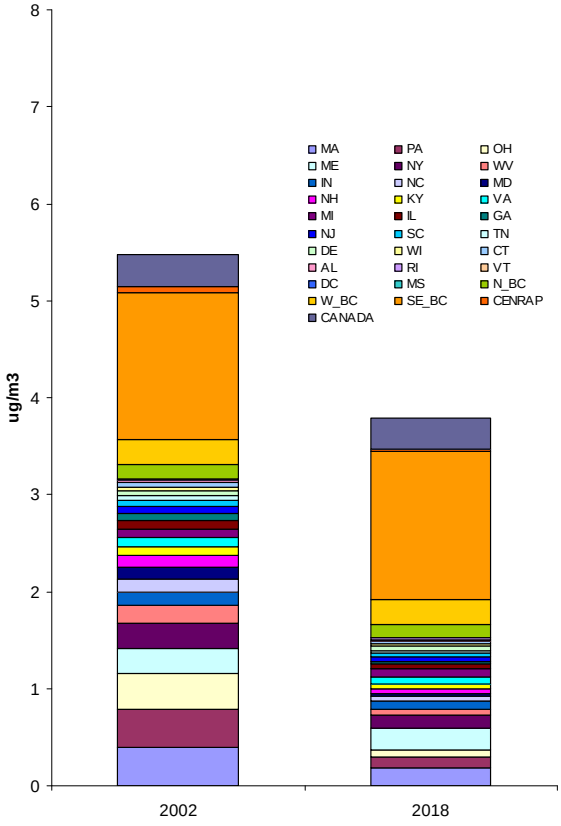


Figure 4-5. a. Measured and projected mass contributions in 2002 and 2018 at Moosehorn National Wildlife Refuge on twenty percent worst visibility days.



IMPROVE mass 00-04 **REMSAD Contribution to Sulfate** **CMAQ RRF-Based 2018 Mass**

b. 2002 and 2018 sulfate mass from Moosehorn National Wildlife Refuge, twenty percent worst days from REMSAD



5. CONTROL STRATEGY EVALUATION

We evaluated the visibility benefits of four potential control strategies aimed at reducing regional haze at Class I areas in the MANE-VU region beyond what has been included in the "OTB/OTW" scenario described earlier. These programs include two separate but linked low-sulfur content fuel initiatives (the S1 and S2 strategies), the BART provisions of the Regional Haze Rule, and controls on EGUs at the 167 stacks most likely to affect MANE-VU Class I areas ("167 EGU strategy"). This chapter reviews the control strategies in more detail, describes the potential emissions reductions, and evaluates the potential visibility benefits of each strategy in combination with the others.

5.1. Reduced sulfur fuel content (S1 and S2)

The MANE-VU states have agreed through consultations to pursue a low sulfur fuel strategy within the region. This phased strategy would be implemented in two steps; however, both components of the strategy are to be fully implemented by 2018. We have analyzed both steps of the program as separate strategies, but it is the combined benefit of implementing the program that is relevant to the question of program benefits in 2018.

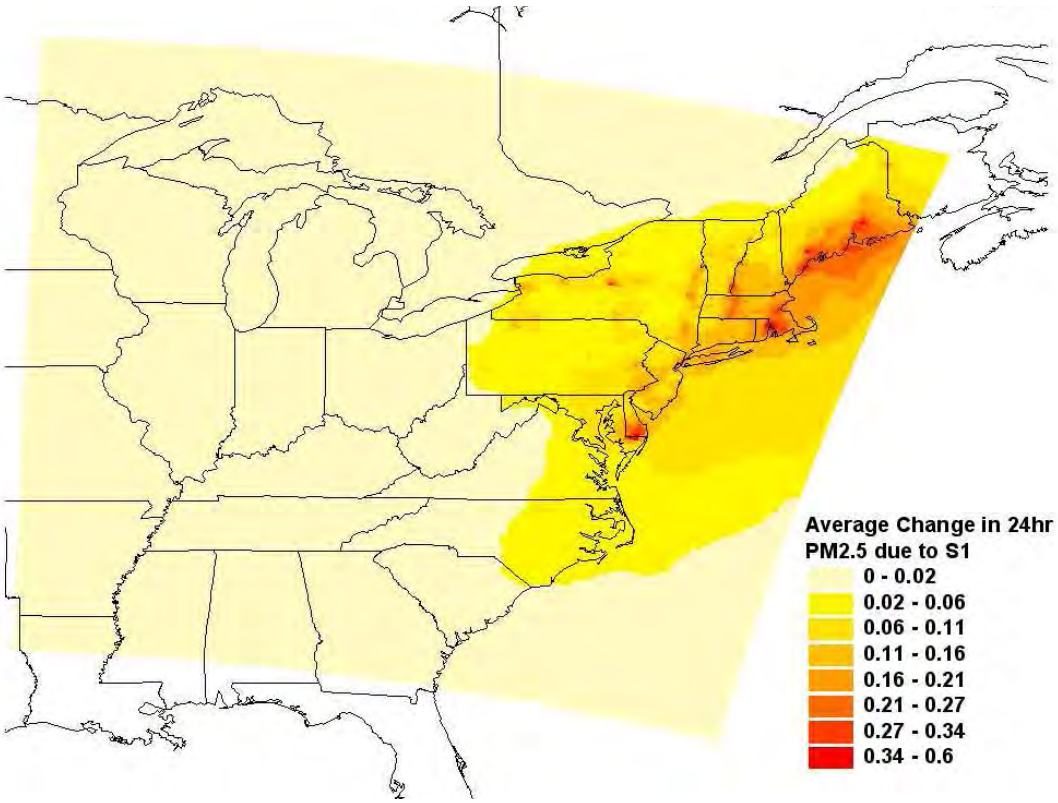
The S1 strategy involves the lowering of fuel-sulfur content in distillate (No. 2 oil) from current levels that range between 2,000 and 2,300 ppm down to 500 ppm by weight. It also restricts the sale of heavier blends of residual oil (No. 4 fuel oil and No. 6 bunker fuels) that have sulfur content greater than 0.25 percent sulfur and 0.5 percent sulfur by weight, respectively. The S2 strategy further reduces the fuel-sulfur content of the distillate fraction to 15 ppm sulfur by weight. The residual oil is maintained at the same S1 level for this strategy.

The S1 strategy and S2 strategy are to be implemented in sequence with slightly different timing for an "inner zone"[5] and the remainder of MANE-VU. All states, however, have agreed to pursue the adoption and implementation of an "emission management" strategy, as appropriate and necessary, to reduce the sulfur content of distillate oil and residual fuel oil as specified in the MANE-VU statements adopted June 20, 2007 by the MANE-VU Board. Thus for the purposes of this analysis, we have examined the benefits of the S1 and S2 strategies separately below.

Based on the fuel sulfur limits within the S1 strategy, we estimated a decrease of 140,000 tons of SO_2 emitted from distillate combustion and 40,000 tons of SO_2 from residual combustion in MANE-VU. Figure 5-1 displays the resulting average change in 24-hr average $PM_{2.5}$ between the baseline case (OTB/OTW) and the control case where the S1 fuel strategy has been implemented.

[5] The inner zone includes New Jersey, Delaware, New York City, and potentially portions of eastern Pennsylvania.

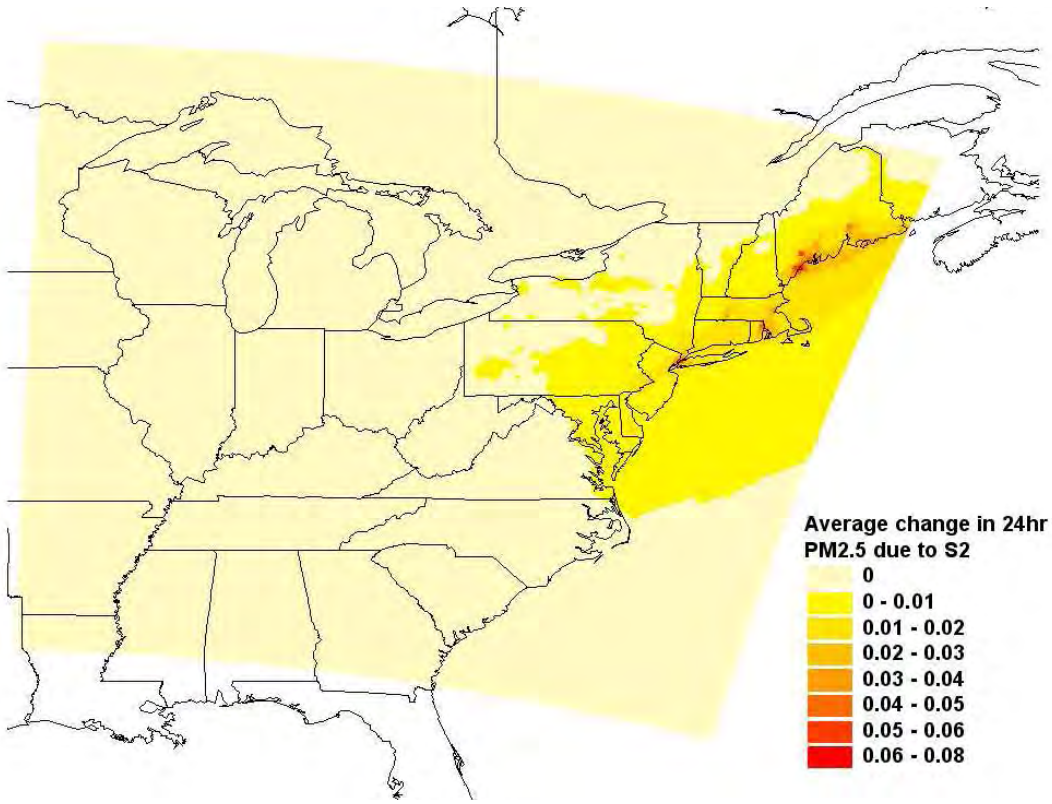
Figure 5-1. Average change in 24-hr $PM_{2.5}$ due to S1 emission reductions ($\mu g/m^3$)



We used the concentration changes in Figure 5-1 above to derive visibility benefits. Because the S1 fuel sulfur program only affects sources within MANE-VU, that region sees the largest $PM_{2.5}$ reduction and the greatest visibility benefits.

The S2 fuel strategy further reduces the sulfur content of distillate from 500 ppm to 15 ppm while keeping the sulfur limits on residual oils to 0.25 percent and 0.5 percent for No. 4 and No. 6 oils, respectively. By lowering the distillate fuel sulfur limit from 500 ppm to 15 ppm, we estimate an additional reduction of 27,000 tons of SO_2 emissions in MANE-VU from distillate combustion in 2018. Figure 5-2 displays the average change in 24-hr $PM_{2.5}$ calculated from CMAQ modeled concentrations between the S1 scenario and the S2 scenario. It reflects the predicted change in $PM_{2.5}$ due solely to the change from 500 ppm to 15 ppm distillate. Due to a high baseline fuel sulfur level, the incremental change in $PM_{2.5}$ concentration is much smaller between 500 ppm and 15 ppm than the baseline to 500 ppm levels observed in the S1 scenario.

Figure 5-2. Average change in 24-hr $PM_{2.5}$ due to S2 emission reductions, relative to S1 ($\mu g/m^3$)



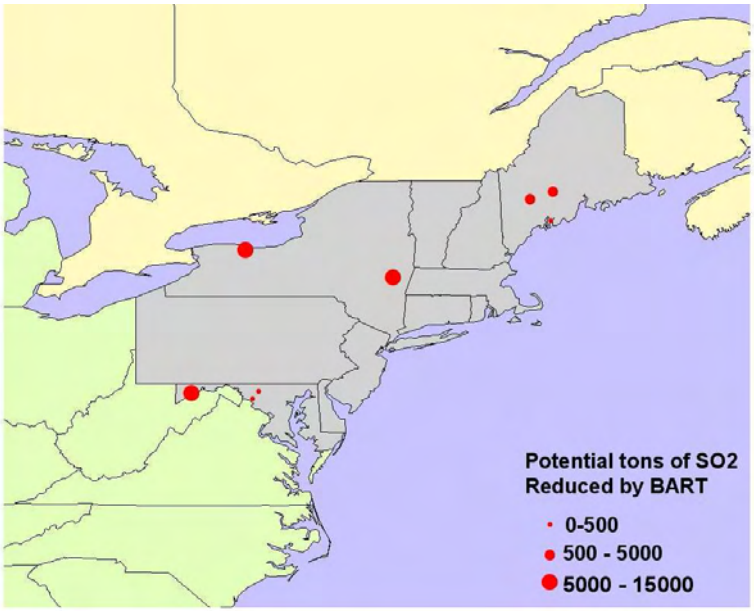
To determine the full benefit of the fuel strategies being considered relative to the OTB/OTW baseline, we can look at the combined benefits from the S1 (500 ppm distillate and 0.25/0.5 percent residual oil) strategy *and* the S2 (15 ppm distillate) strategy. The combined benefits can be gauged in Figures 5-6 through 5-14 and are shown in the results presented in Table 5-2 at the end of this section.

5.2. Best Available Retrofit Program (BART)

To assess the impacts of the implementation of the BART provisions of the Regional Haze Rule, we included estimated reductions anticipated for BART-eligible facilities in the MANE-VU region in the 2018 CMAQ modeling analysis. An inital survey of state staff indicated that these 14 units would likely be controlled under BART alone and were modeled in this analysis. These states provided potential control technologies and levels of control, which were in turn incorporated into the 2018 emission inventory projections. NESCAUM (2007) provides the survey approach. Updates to this preliminary assessment (including the removal of six Pennsylvania sources with combined emissions reductions of 6600 tons of SO_2) will be incorporated into the Best and Final modeling run scheduled to be completed in March, 2008. Figure 5-3 displays the locations of the BART sources and estimated SO_2 reductions expected in

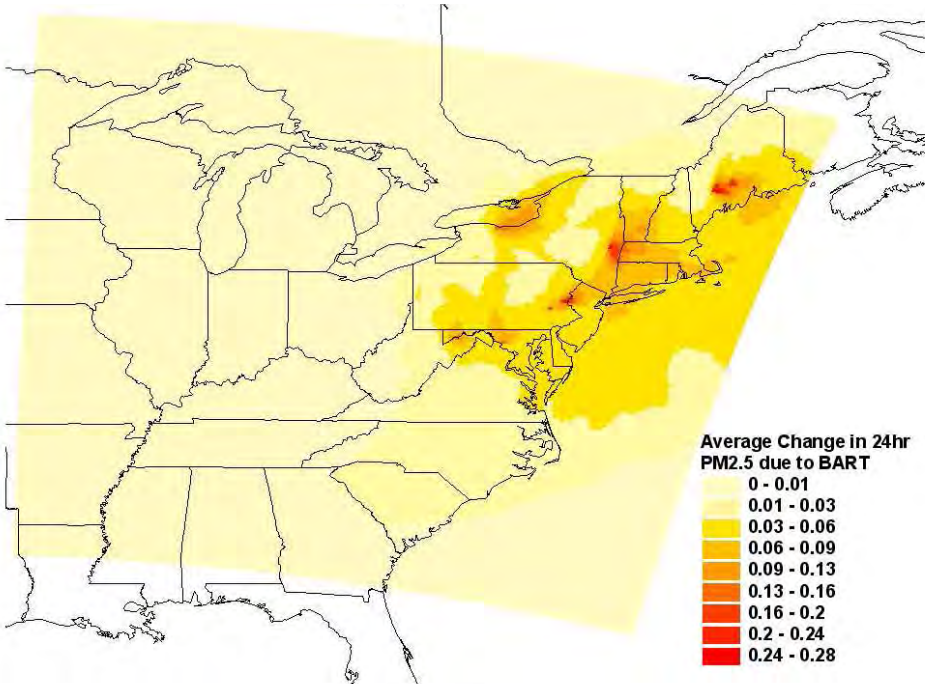
2018. Additional visibility benefits are likely to result from installation of controls at BART-eligible facilities that are located in adjacent RPOs. These benefits are not accounted for in the present analysis.

Figure 5-3. Potential reductions from BART-eligible sources in the MANE-VU region (tons)



We applied the SO_2 reductions at the initial 14 facilities relative to the 2018 OTB/OTW emissions inventory. Figure 5-4 shows the average change in 24-hr $PM_{2.5}$ concentrations within the modeling domain used to calculate the visibility benefits.

Figure 5-4. Average change in 24-hr $PM_{2.5}$ due to BART emission reductions ($\mu g/m^3$)



5.3. 167 EGU Strategy

The MANE-VU states have recognized that SO_2 emissions from power plants are the single largest contributing sector to the visibility impairment experienced in the Northeast's Class I areas. The SO_2 emissions from power plants continue to dominate the inventory. Sulfate formed through atmospheric processes from SO_2 emissions are responsible for over half the mass and approximately 70-80 percent of the extinction on the worst visibility days (NESCAUM, 2006a,b). In order to ensure that EGU controls are targeted at those EGUs with the greatest impact on visibility in MANE-VU, a modeling analysis was conducted to determine which sources those were. A list of 167 EGU stacks was developed (MANE-VU, 2007) that includes the 100 largest impacts at each MANE-VU Class I site during 2002. MANE-VU is currently asking for 90 percent control on all units emitting from those stacks by 2018 as part of consultations within MANE-VU and with other RPOs. MANE-VU recognizes that this level of control may not be feasible in all cases. The Best and Final modeling run currently underway will incorporate State comments gathered during the inter-RPO consultation process.

The "167 EGU strategy," if implemented as defined here, could lead to large reductions in SO_2 emissions due to installation of stack control technologies such as SO_2 scrubbers. To determine the possible health benefits of this EGU control program, we modeled 2018 emissions for the 167 EGUs in the Northeast, Southeast, and Midwest at levels equal to 10 percent of their 2002 emissions. We used CMAQ to model sulfate concentrations in 2018 after implementation of this control program and converted

sulfate concentrations to $PM_{2.5}$ concentrations. Figure 5-5 displays the average change in 24-hr $PM_{2.5}$ seen between the OTB/OTW baseline and the EGU stack control program.

Figure 5-5. Average change in 24-hr $PM_{2.5}$ due to 167 EGU emission reductions ($\mu g/m^3$)

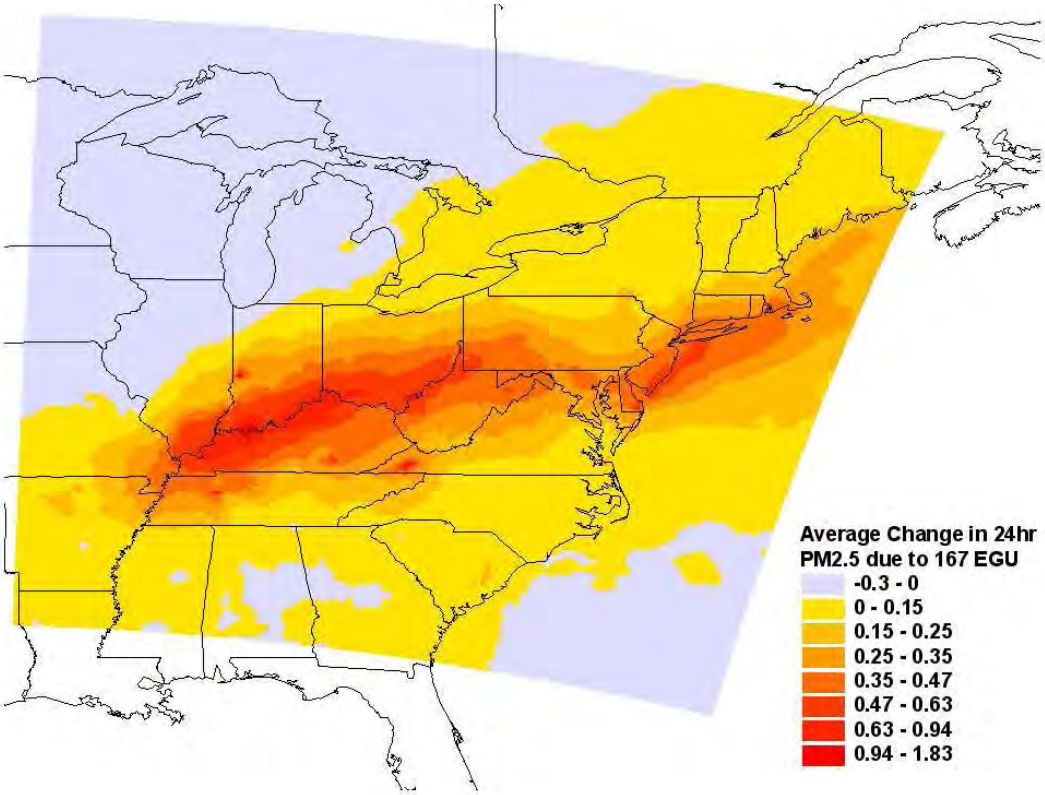


Figure 5-5 shows that significant reductions of $PM_{2.5}$ are predicted for the MANE-VU region as well as for portions of the VISTAS and Midwest RPO regions as a result of the targeted EGU strategy.

Figures 5-6 through 5-14 show the visibility benefits – relative to the uniform rate of progress determined our national visibility goal of natural conditions in 2064 – of the OTB/OTW scenario as well as for the four potential measures analyzed here. In addition to these measures, MANE-VU has asked neighboring RPOs to consider non-EGU emissions reductions comparable to our low sulfur fuel strategies, which are expected to achieve a greater than 28 percent reduction in non-EGU SO_2 emissions in 2018. The figures indicate that additional progress could be achieved depending upon what strategies are identified by VISTAS and the Midwest RPO in response to this request.

Figure 5-6. Visibility improvement relative to uniform rate of progress at Acadia National Park

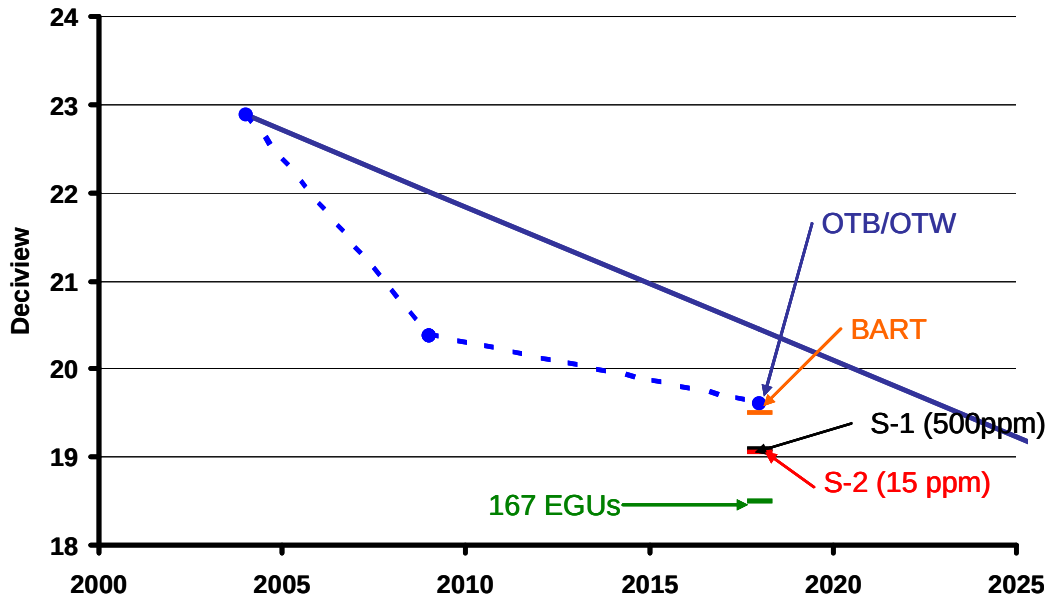


Figure 5-7. Visibility improvement relative to uniform rate of progress at Brigantine National Wildlife Refuge.

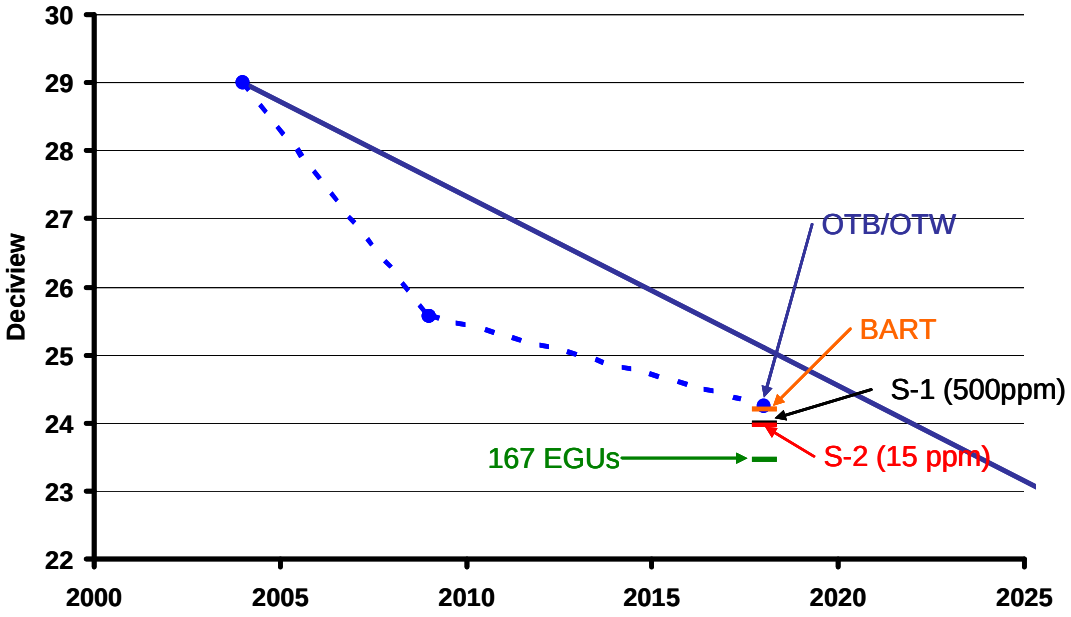


Figure 5-8. Visibility improvement relative to uniform rate of progress at Great Gulf Wilderness Area

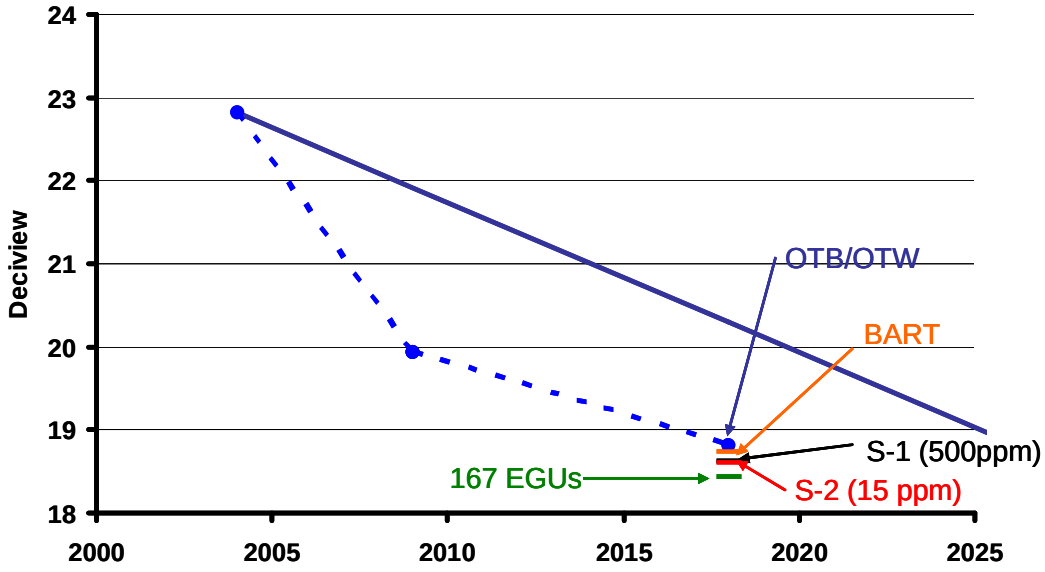


Figure 5-9. Visibility improvement relative to uniform rate of progress at Lye Brook Wilderness Area

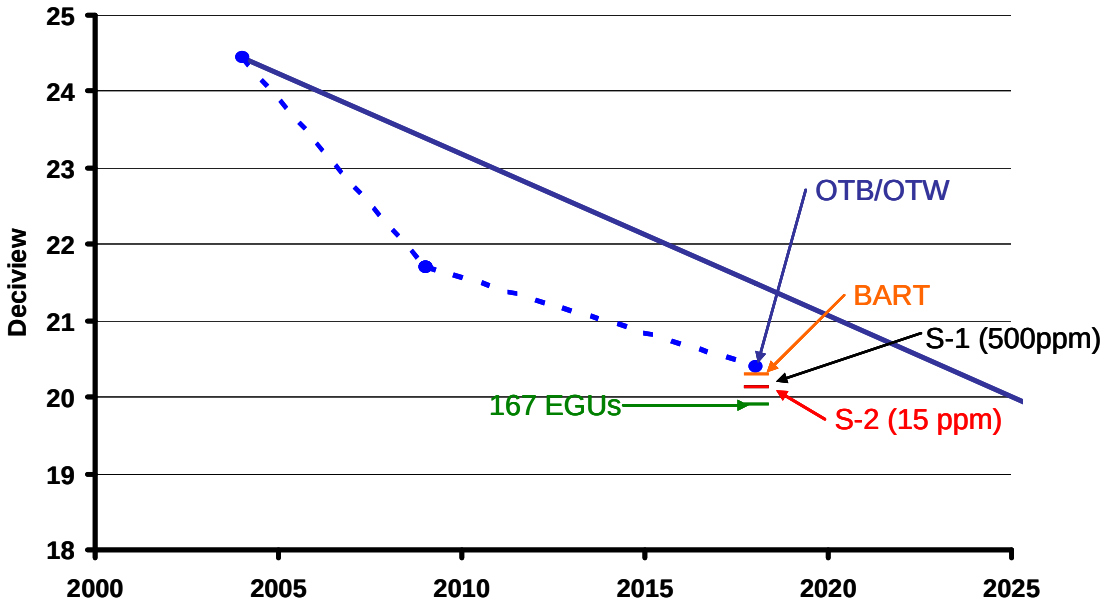


Figure 5-10. Visibility improvement relative to uniform rate of progress at Moosehorn National Wildlife Refuge

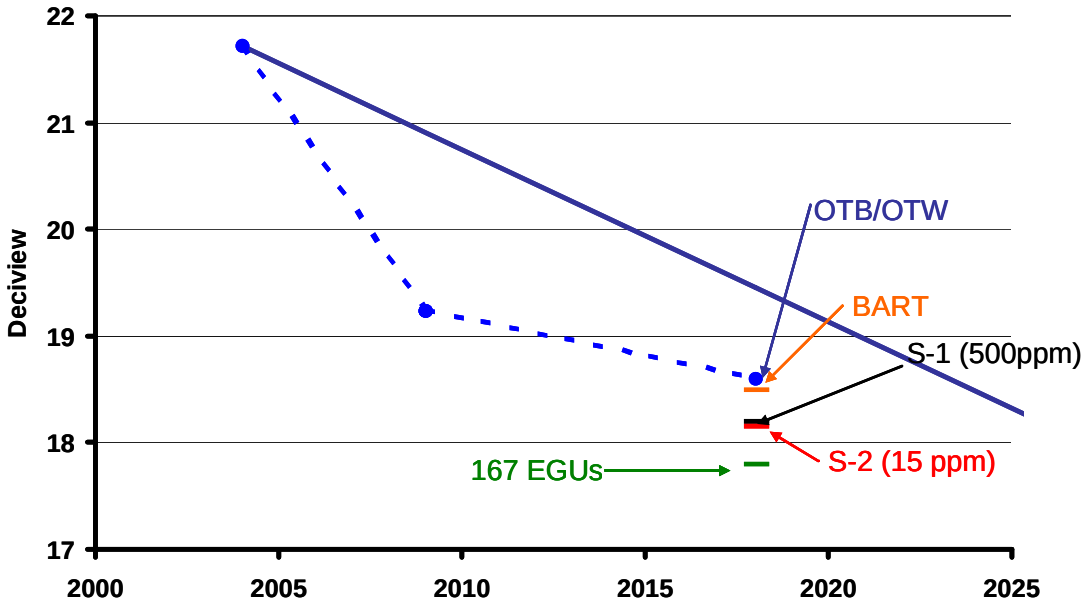


Figure 5-11. Visibility improvement relative to uniform rate of progress at Shenandoah National Park

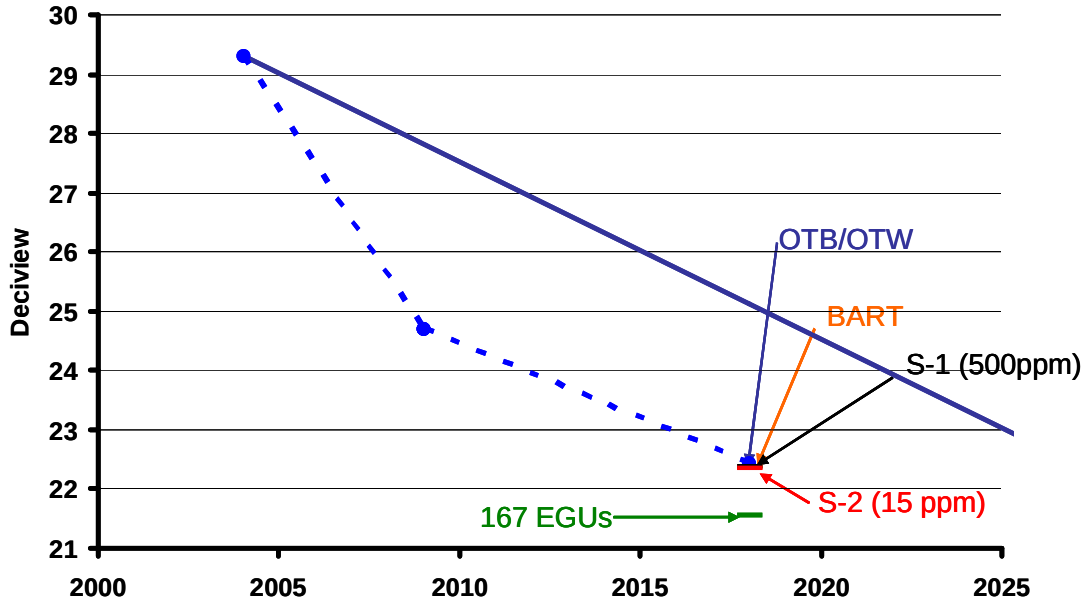


Figure 5-12. Visibility improvement relative to uniform rate of progress at Dolly Sods Wilderness Area

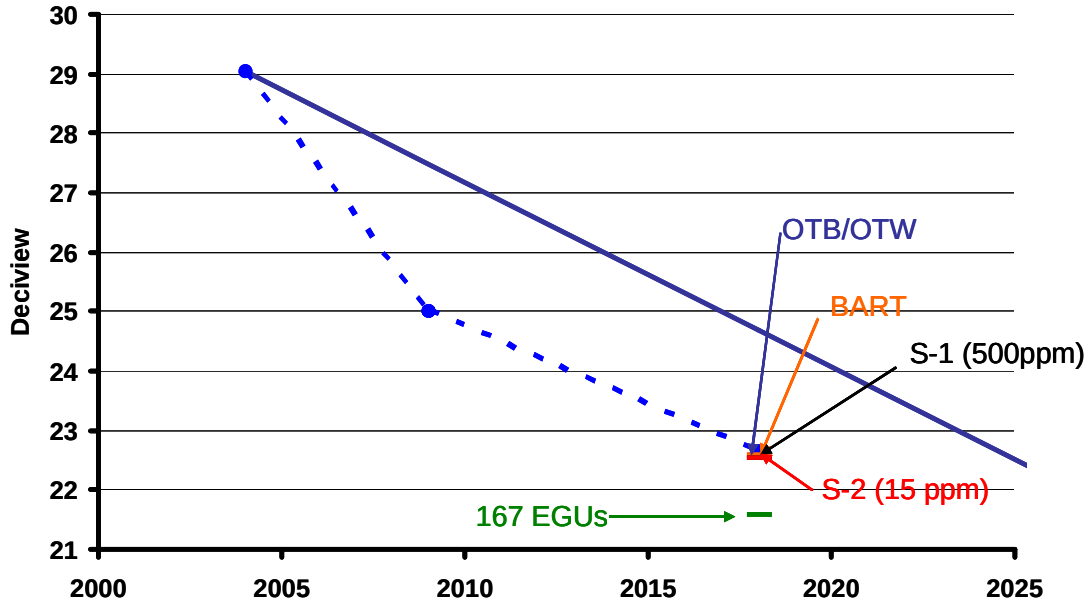


Figure 5-13. Visibility improvement relative to uniform rate of progress at Presidential Range-Dry River Wilderness Area

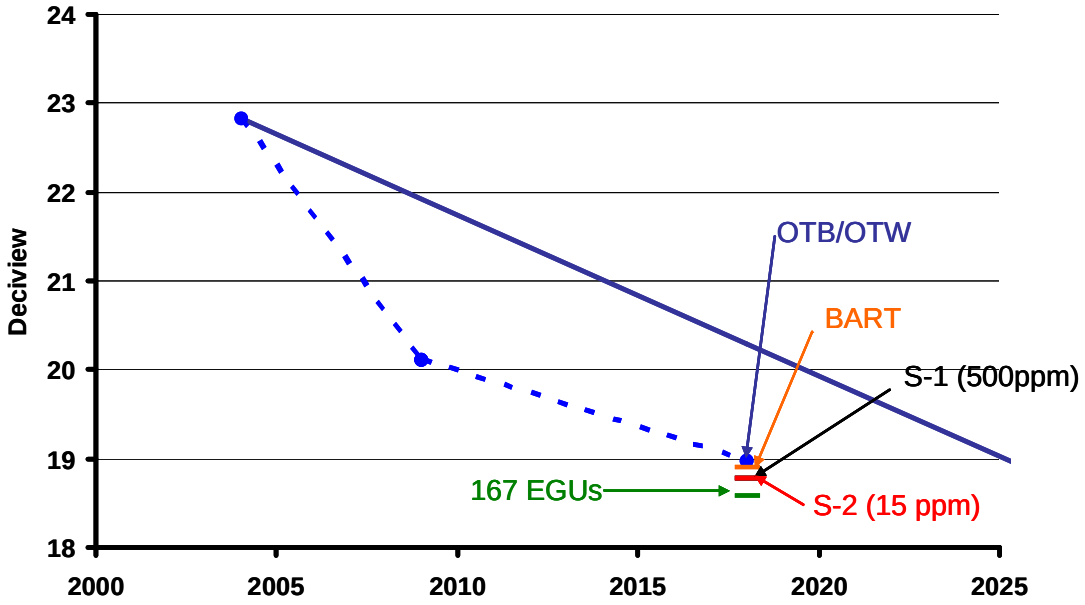
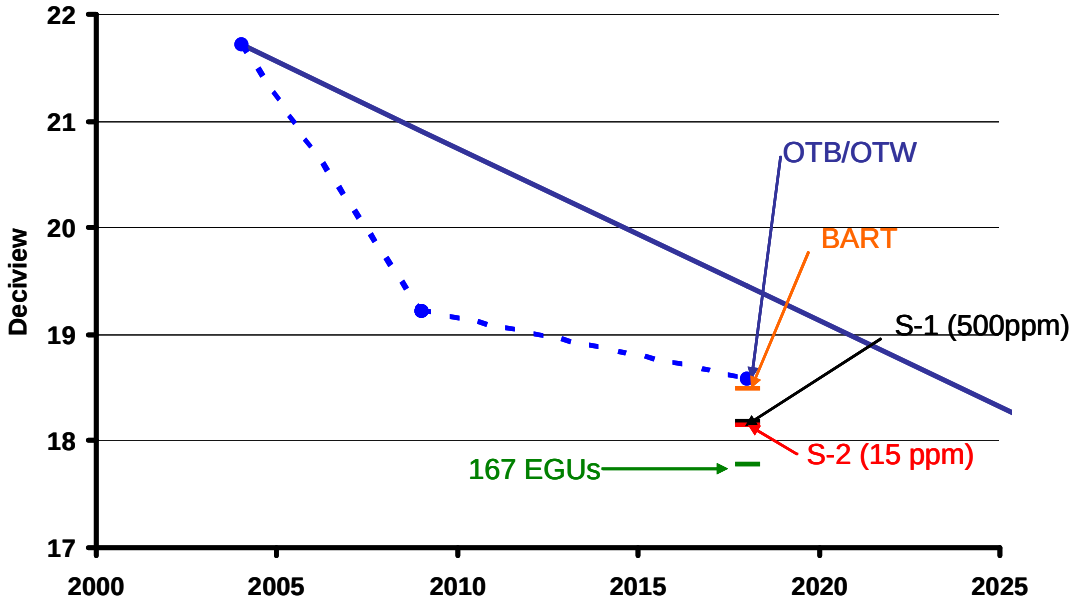


Figure 5-14. Visibility improvement relative to uniform rate of progress at Roosevelt-Campobello International Park



Tables 5-1 and 5-2 summarize the sulfate mass reductions and the deciview targets that represent the progress shown in the prior figures.

Table 5-1. Projected 2018 twenty percent worst day sulfate mass reduction at MANE-VU Class I areas under various control assumptions.

MANE-VU Class I Area	Baseline [2000-2004]	OTB/OTW [2018]	BART	S-1	S-2	167 EGUs
Acadia National Park, ME	6.32	2.40	0.08	0.29	0.03	0.37
Brigantine Wilderness, NJ	11.58	5.35	0.07	0.20	0.02	0.51
Great Gulf Wilderness, NH	7.28	2.96	0.06	0.09	0.01	0.13
Lye Brook Wilderness, VT	8.46	3.49	0.09	0.13	0.01	0.18
Moosehorn Wilderness, ME	5.67	2.03	0.07	0.21	0.03	0.24
Presidential Range – Dry River Wilderness, NH	7.28	2.96	0.06	0.09	0.01	0.13
Roosevelt-Campobello International Park, NB	5.67	2.03	0.07	0.21	0.03	0.24

Notes on Table 5-1:

1. Baseline values represent the average sulfate mass ($\mu g/m^3$) over the 5 year baseline period on the 20 percent worst days.
2. OTB/OTW represents the combined estimated mass reduction ($\mu g/m^3$) due to all "on the books" measures.
3. BART mass reduction reflects preliminary estimates of emission reductions resulting from BART determinations. These determinations are still in the process of being conducted, however, and thus are subject to change.
4. S-1 oil strategy assumes the adoption of 500 ppm distillate, 0.25 percent S for all No. 4 oil and 0.5 percent S for all No. 6 residual oil.
5. S-2 oil strategy assumes the adoption of 15 ppm distillate, 0.25 percent S for all No. 4 oil and 0.5 percent S for all No. 6 residual oil.
6. 167 EGU strategy benefits are based on net reductions after each of the 167 stacks is controlled to at least the 90 percent level and after the identified emissions reductions (beyond 2018 projections contained in the Base B emissions files) are redistributed among all other CAIR-eligible EGUs in the modeling domain.

Table 5-2. Projected 2018 twenty percent worst day deciview goals for MANE-VU Class I areas under various control assumptions

MANE-VU Class I Area	Baseline [2000-2004]	OTB/OTW [2018]	+BART	+S-1	+S-2	+167 EGUs
Acadia National Park, ME	22.89	19.62	19.51	19.10	19.05	18.50
Brigantine Wilderness, NJ	29.01	24.26	24.19	24.00	23.98	23.47
Great Gulf Wilderness, NH	22.82	18.81	18.74	18.62	18.61	18.43
Lye Brook Wilderness, VT	24.45	20.40	20.29	20.13	20.12	19.90
Moosehorn Wilderness, ME	21.72	18.59	18.50	18.20	18.16	17.80
Presidential Range – Dry River Wilderness, NH	22.82	18.98	18.90	18.78	18.77	18.59
Roosevelt-Campobello International Park, NB	21.72	18.58	18.49	18.19	18.15	17.79

Notes on Table 5-2:

1. Baseline values represent the 5-year average baseline conditions (dv) on the 20 percent worst days.
2. OTB/OTW represents the projected deciview goal due to all OTB/OTW measures.
3. Pluses indicate that the deciview goals assume implementation of all measures to the left of and including the column indicated.
4. BART reflects preliminary estimates of emissions reductions due to BART determinations. These determinations are still in the process of being conducted and thus are subject to change.
5. S-1 oil strategy assumes the adoption of 500 ppm distillate, 0.25 percent S for all No. 4 oil and 0.5 percent S for all No. 6 residual oil.
6. S-2 oil strategy assumes the adoption of 15 ppm distillate, 0.25 percent S for all No. 4 oil and 0.5 percent S for all No. 6 residual oil.
7. 167 EGU strategy benefits are based on net reductions after each of the 167 stacks is controlled to at least the 90 percent level and after the identified emissions reductions (beyond 2018 projections contained in the Base B emissions files) are redistributed among all other CAIR-eligible EGUs in the modeling domain.

6. CONCLUSIONS

This report provides details on modeling platforms and input data as well as a description of the processing steps that were undertaken to prepare inputs for use in simulating future air quality on an eastern U.S. domain that includes MANE-VU Class I areas. The findings are consistent with previous work documenting the role of SO_2 emissions in the formation of visibility impairing fine particulate in the eastern U.S. (NESCAUM, 2006a, b). This report goes further, however, in terms of providing detailed simulations of (1) projected visibility impairment in 2018 under a "beyond on the way" scenario that represents a starting point for the regional haze program; (2) state-by-state apportionment of 2018 emissions for that 2018 "beyond on the way" scenario; and (3) sensitivity analysis of the projected benefits of several additional measures that are being considered by the MANE-VU states for inclusion in reasonable progress goals.

The findings of these simulations suggest that:

- The "beyond on the way" scenario – defined by CAIR with other "on the books" measures and the limitation of fuel sulfur content to 500 ppm for all No. 2 "distillate" fuel oil sold in the MANE-VU region – is sufficient to achieve visibility improvement beyond the so-called "uniform rate of progress" defined by uniform visibility improvement between now and 2064, the planning horizon for the regional haze program.
- The 2018 pollution apportionment suggests that this improvement is due to significant reductions in the relative contributions of almost all eastern U.S. states, resulting in a *relative* increase (though not an absolute increase) in the projected contribution from areas outside the modeling domain (e.g., Canada and the model domain boundary conditions).
- Potential additional emissions reduction strategies (including the reduction of fuel sulfur content of No. 2 distillate to 15 ppm, limits on sulfur content of residual oil, control of BART-eligible sources, and additional EGU controls beyond CAIR) could yield significant further reductions of sulfate and corresponding significant visibility improvements at MANE-VU Class I areas and should be considered with respect to the four statutory factors in setting reasonable progress goals.

As MANE-VU states consider these results and conduct consultations with each other and neighboring RPOs, NESCAUM will prepare a "best and final" modeling scenario for 2018 that may assist the Class I states in setting reasonable progress goals based on their assessment of which measures are reasonable to implement. This final model run is anticipated to be complete in March 2008.

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