WISCONSIN REGIONAL HAZE STATE IMPLEMENTATION PLAN REVISION FOR THE SECOND IMPLEMENTATION PERIOD

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WISCONSIN
DEPT. OF NATURAL RESOURCES

Table of Contents

List of Tables

List of Figures

List of Acronyms

AEI	Air Emissions Inventory
A-M	Ahlstrom-Munksjo
Amec	Amec Foster Wheeler
BART	Best Available Retrofit Technology
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CAMD	Clean Air Markets Division
CAMx	Comprehensive Air quality Model with extensions
CEMS	Continuous Emissions Monitoring System
CENSARA	Central States Air Resource Agencies
CSAPR	Cross-State Air Pollution Rule
CSN	Chemical Speciation Network
CTG	Control Techniques Guidelines
DSI	Dry Sorbent Injection
EGU	Electricity Generating Unit
EPA	U.S. Environmental Protection Agency
ERC	Emission Reduction Credit
ERTAC	Eastern Regional Technical Advisory Committee
ESP	Electrostatic Precipitator
FGD	Flue Gas Desulfurization
FGR	Flue Gas Recirculation
FLM	Federal Land Manager
G-P	Georgia Pacific
HC	Hydrocarbon
I/M	Inspection and Maintenance
IMPROVE	Interagency Monitoring of Protected Visual Environments
LADCO	Lake Michigan Air Directors Consortium
LNB	Low NOx Burner
LTS	Long-term Strategy
MACT	Maximum Achievable Control Technology
MANE-VU	Mid-Atlantic/Northeast Visibility Union
mmBtu	Million British Thermal Unit
MOVES	MOtor Vehicle Emissions Simulator
MW	Megawatt
NAAQS	National Ambient Air Quality Standard
NADP	National Atmospheric Deposition Program
NATTS	National Air Toxics Trends Network Sites
NCore	National Core Monitoring Network
NEI	National Emissions Inventory
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	Ammonia
NMHC	Non-methane Hydrocarbon
NOx	Nitrogen Oxides
NSR	New Source Review

List of Acronyms (continued)

OAQPS	Office of Air Quality Planning and Standards
OFA	Over-fire Air
PAMS	Photochemical Assessment Monitoring Stations
$PM_{2.5}$	Particulate Matter with Diameter less than 2.5 µm
PSAT	Particulate Matter Source Apportionment Tool
PSD	Prevention of Significant Deterioration
Q/d	Distance (d) weighted emissions (Q)
RACM	Reasonably Available Control Measures
RACT	Reasonably Available Control Technology
RAVI	Reasonably Attributable Visibility Impairment
RFG	Reformulated Gasoline
RPG	Reasonable Progress Goal
RPO	Regional Planning Organization
RSCR	Regenerative Selective Catalytic Reduction
SCR	Selective Catalytic Reduction
SIP	State Implementation Plan
SLAMS	State and Local Air Monitoring Stations
SNCR	Selective Non-catalytic Reduction
SO_2	Sulfur Dioxide
SPM	Special Purpose Monitoring
TIP	Tribal Implementation Plan
TSD	Technical Support Document
ULNB	Ultra Low NOx Burner
URP	Uniform Rate of Progress
VOC	Volatile Organic Compound
WDNR	Wisconsin Department of Natural Resources
WRAP	Western Regional Air Partnership

1. Introduction

This document is being submitted to fulfill Wisconsin's State Implementation Plan (SIP) requirements established by the federal Regional Haze Rule to remedy and protect visibility in designated mandatory Class I Federal areas, hereafter referred to as "Class I areas." The Regional Haze Rule was originally adopted on July 1, 1999 (64 FR 35714) and incorporated under 40 CFR § 51.308 as part of Subpart P – Protection of Visibility. The revised Regional Haze Rule, also referred to as the "Haze Rule", effective January 10, 2017, requires states to submit SIP revisions for the second implementation period (also known as "Round 2") no later than July 31, 2021 (82 FR 3078). This submittal, hereafter referred to as the Round 2 haze SIP, revises Wisconsin's regional haze SIP for the second implementation period (2018-2028).

1.1. Regulatory Background

The federal Clean Air Act (CAA) sets a national goal to restore visibility to natural conditions in Class I areas. Class I areas are designated by the U.S. Environmental Protection Agency (EPA) and include 156 protected national and state parks and wilderness areas. Section 169A(b)(2) of the CAA requires each state in which a Class I area resides – and any state from which emissions are reasonably anticipated to cause or contribute to impairment of visibility of such a Class I area – to make reasonable progress towards remedying the impairment due to man-made air pollution.

In conjunction with these state requirements, Section 169B of the CAA directs EPA to study the chemistry of visibility impairment and identify sources or regions contributing to the impairment of visibility at the Class I areas. Based on this information, EPA is then required to establish Visibility Transport Regions and Commissions consisting of states which together are found to contribute to visibility degradation at a Class I area. In 1999, EPA concluded that certain groups of states act together in impacting visibility, and therefore formed regional planning organizations (RPOs) in order to fulfill visibility requirements on a coordinated basis. Originally, EPA mandated Wisconsin as part of the Midwest RPO. The Lake Michigan Air Directors Consortium (LADCO) now represents the Midwest RPO, and includes the states of Minnesota, Michigan, Wisconsin, Illinois, Indiana, and Ohio. LADCO performs regional haze planning duties and technical assessments to help the region meet visibility requirements for the affected Class I areas.

40 CFR Part 51, Subpart P – Protection of Visibility implements the CAA visibility program. EPA structured this regulation to address two principal forms of identified visibility impairment: "reasonably attributable" impairment (i.e., impairment attributable to a single source/small group of sources) and "regional haze" (i.e., widespread haze from a multitude of sources which impairs visibility in every direction over a large area). The Regional Haze program provides mechanisms for extending requirements to contributing states and implementing controls as necessary across broad source categories, including area and mobile source sectors. The Regional Haze program adopts a schedule of remedying anthropogenic visibility impacts in Class I areas by 2064.

1.2. Regional Haze Rule and Applicable Wisconsin Requirements

The Haze Rule, codified at 40 CFR § 51.308, requires all states with Class I areas – and states contributing to those areas – to submit regional haze SIPs. Wisconsin submitted its regional haze SIP for the first planning period from 2008 – 2018 (also known as "Round 1") on January 18, 2012. EPA approved Wisconsin's Round 1 haze SIP on August 7, 2012 (77 FR 46952).[1] The Haze Rule also requires states to submit intermediate five-year progress reports that provide assessments of whether the approved regional haze SIP is being implemented appropriately and whether reasonable visibility progress is being achieved consistent with the projected visibility improvement in the SIP (40 CFR § 51.308(g) and (h)). Wisconsin's first five-year progress report, hereafter referred to as the Round 1 progress report, was submitted to EPA on March 17, 2017, and received EPA approval effective December 19, 2017 (82 FR 48766).[2]

The Haze Rule requires states to re-assess and revise an incremental progress plan every 10 years to meet continued reasonable progress goals for natural conditions by 2064. The original deadline for regional haze SIP revisions covering the second implementation period was July 31, 2018; however, EPA extended the deadline to July 31, 2021, in the 2017 amendments to the Regional Haze Rule.

The Haze Rule provides several general provisions that states must address in their periodic regional haze SIP revisions. Pursuant to 40 CFR § 51.308(f), these requirements include: (1) calculations of baseline, current and natural visibility conditions; progress to date; and the uniform rate of progress (URP); (2) a description of a long-term strategy (LTS) that addresses regional haze visibility impairment; (3) a description of the reasonable progress goals (RPG); (4) if applicable, monitoring plans to assess reasonably attributable visibility impairment; (5) progress report requirements; and (6) if applicable, a monitoring strategy and other implementation plan requirements. For contributing states like Wisconsin, meeting certain plan elements, such as RPG, is based on meeting the state's share of emission reductions as determined through the consultation process with LADCO, federal land managers (FLMs), and EPA.

The Wisconsin Department of Natural Resources (WDNR) relied on the following EPA documents to prepare Wisconsin's Round 2 haze SIP:

- "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period" memorandum[3] (hereafter referred to as "EPA Guidance")

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[1] "Regional Haze State Implementation Plan for Wisconsin", WDNR, January 2012. https://dnr.wisconsin.gov/sites/default/files/topic/AirQuality/HazeSIPAttachment2.pdf

[2] "Wisconsin Five-Year Regional Haze Progress Report", WDNR, March 2017. https://dnr.wisconsin.gov/sites/default/files/topic/AirQuality/WIHazeProgressReport.pdf

[3] "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period", US EPA, August 2019. https://www.epa.gov/sites/production/files/2019-08/documents/8-20-2019_-_regional_haze_guidance_final_guidance.pdf

- "Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program" memorandum[4] (hereafter referred to as "EPA Visibility Tracking Guidance")
- "Technical addendum including updated visibility data through 2018 for the memo titled 'Recommendation for the Use of Patched and Substituted Data and Clarification of Data Completeness for Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program'" [5] (hereafter referred to as "EPA Technical Addendum")
- "Availability of Modeling Data and Associated Technical Support Document for the EPA's Updated 2028 Visibility Air Quality Modeling" memorandum[6] (hereafter referred to as "EPA Modeling TSD"

On July 9, 2021, EPA provided a memorandum to states called, "Clarifications Regarding Regional Haze State Implementation Plans for the Second Implementation Period". Wisconsin's SIP submittal utilizes the guidance to clarify certain elements of the document.

The EPA Guidance notes that states have discretion to balance the factors and considerations required under the Haze Rule in determining control measures necessary to make reasonable progress.[7] The EPA Guidance also lists eight key process steps that EPA anticipates the states will typically follow when developing a regional haze SIP revision for the second implementation period. These eight steps are shown in Table 1, with details on each step provided in the EPA Guidance.

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[4] "Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program", US EPA, December 2018. https://www.epa.gov/sites/production/files/2018-12/documents/technical_guidance_tracking_visibility_progress.pdf

[5] "Technical addendum including updated visibility data through 2018 for the memo titled 'Recommendation for the Use of Patched and Substituted Data and Clarification of Data Completeness for Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program'," US EPA, June 2020. https://www.epa.gov/sites/production/files/2020-06/documents/memo_data_for_regional_haze_technical_addendum.pdf

[6] "Availability of Modeling Data and Associated Technical Support Document for the EPA's Updated 2028 Visibility Air Quality Modeling," US EPA, September 2019. https://www.epa.gov/sites/production/files/2019-10/documents/updated_2028_regional_haze_modeling-tsd-2019_0.pdf

[7] See EPA Guidance, p. 4: "*The CAA and the [Haze] Rule provide a process for states to follow…this process involves a state evaluating what emission control measures for its own sources, groups of sources, and/or source sectors are necessary in light of the four statutory factors, five additional considerations specified in the [Haze] Rule, and possibly other considerations… States have discretion to balance these factors and considerations in determining what control measures are necessary to make reasonable progress.*"

Table 1 - EPA Guidance Key Steps in Developing Round 2 Haze SIP

1[a]	Ambient data analysis
2	Determination of affected Class I areas in other states
3	Selection of sources for analysis
4	Characterization of factors for emission control measures
5	Decisions on what control measures are necessary to make reasonable progress
6[a]	Regional scale modeling of the LTS to set the RPGs for 2028
7A[a]	Progress, degradation, and URP glidepath checks
7B[b]	URP glidepath check
8	Additional requirements for SIPs

[a] Applies only to a state with a Class I area.

[b] Applies to a state only with respect to an out-of-state Class I area to which sources in the state may reasonably be anticipated to contribute to visibility impairment.

The WDNR relied on the Haze Rule requirements in 40 CFR § 51.308(f), and the flexibility for states' discretion inherent therein, to prepare Wisconsin's Round 2 haze SIP. The WDNR also referred to the EPA Guidance in its SIP development process. This Round 2 haze SIP follows the EPA Guidance steps from Table 1 and references those steps as appropriate.[8] Appendix 1 contains EPA's checklist of regional haze SIP steps and references sections of this SIP that address each step.

2. Wisconsin Contribution to Visibility Impairment

The WDNR only considered out-of-state mandatory Class I Federal areas covered under the Haze Rule during development of this SIP revision.[9] Step 2 of the EPA Guidance states that "a state has the flexibility to use any reasonable method for quantifying the impacts of its own emissions on out-of-state Class I areas, and it may use any reasonable assessment for this determination." In identifying contribution for Round 1, Wisconsin considered a visibility impact of 2% or more of total light extinction on the 20% most impaired days as significant and impacting visibility.[10] The 2% total light extinction threshold was selected because LADCO's back trajectory and source apportionment modeling analyses showed that states contributing 2% or more account for 90-95% of total light extinction at Class I areas. In Round 1, WDNR

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[8] Although steps 6 and 7a only apply to states with Class I areas located within the state (Table 1), WDNR addresses the steps in this SIP, in part or in full, to support its approach in meeting the state's 40 CFR § 51.308(f) requirements.

[9] The Haze Rule does not apply to the two Class I areas located in Wisconsin. Rainbow Lake Wilderness Area in Bayfield County, Wisconsin, is a mandatory Class I Federal area maintained by the U.S. Forest Service. The EPA did not include the Rainbow Lake Wilderness Area in the list of 156 mandatory Class I areas where it deemed visibility to be an important value (44 FR 69122). The Forest County Potawatomi Community Class I area is a nonfederal Class I area, and as such, is not covered by the Haze Rule. The WDNR notified the Forest County Potawatomi Community when the draft Round 2 haze SIP was posted for public review (Section 4.2).

[10] Results of Round 1 source apportionment analyses for the Northern LADCO Class I Areas is available in Table II-2 of LADCO's Round 1 Regional Haze Summary Report "Regional Haze in the Midwest: Summary of Technical Information". https://www.ladco.org/wp-content/uploads/Documents/Reports/Regional_Haze/Round1/Consultation/regional_haze_in_the_upper_midwest_summary_of_technical_information_v2.2_feb_22_2008.pdf

determined that Wisconsin emissions impact visibility at the Isle Royale National Park and Seney Wilderness Area in Michigan and Boundary Waters Canoe Area and Voyageurs National Park in Minnesota (Figure 1). Hereafter, this Round 2 haze SIP may refer collectively to these four Class I areas as the "Northern LADCO Class I Areas."

To determine LADCO member state contributions to impaired visibility in all Class I areas for Round 2, LADCO used the Comprehensive Air quality Model with extensions (CAMx) Particulate Matter Source Apportionment tool (PSAT). LADCO assessed relative visibility impacts in 2028 by projecting representative emissions inventories and known emission controls for 2016, which is the most recent available base year. LADCO conducted the source apportionment modeling for the six LADCO member states and seven other states/regions in the US. The PSAT tool was also used to partition contributions from Canada/Mexico, biogenic emissions, prescribed fires, and all other fires. Details of the analysis and source-apportioned visibility contributions at Class I areas within the LADCO region for Round 2 are documented in LADCO's modeling technical support document (TSD), "Modeling and Analysis for Demonstrating Reasonable Progress for the Regional Haze Rule 2018 – 2028 Planning Period," or simply "LADCO TSD" (Appendix 2).

The WDNR retained the 2% light extinction threshold for determining Wisconsin's contribution to visibility impairment at Class I areas for Round 2. LADCO's Round 2 PSAT modeling results show that a 2% light extinction threshold applied to the six LADCO member states and seven other states/regions account for 92% or more of total light extinction at Northern LADCO Class I Areas on the most impaired days. This approach is consistent with the guidelines given in the EPA Guidance for determining affected Class I areas in other states. Using the 2% total light extinction threshold, WDNR determined that Wisconsin emissions continue to impact visibility at the Isle Royale National Park, Seney Wilderness Area, and Boundary Waters Canoe Area. Although Wisconsin's contribution to total light extinction at Voyageurs National Park in Minnesota is only 1% based on LADCO's 2016-based PSAT projections for 2028 (Table 2), WDNR is including it in the list of Class I areas Wisconsin impacts because Wisconsin contributions to light extinction at Voyageurs National Park met the 2% threshold during Round 1.

Figure 1 – Northern LADCO Class I Areas Affected by Wisconsin Emissions

In Round 1, analyses conducted by LADCO and Minnesota estimated that Wisconsin's average annual impact to visibility in the Northern LADCO Class I Areas ranged from 6 to 16%, depending on the methodology and year(s) considered. Based on LADCO's Round 2 source apportionment modeling for 2028 using the most recent available base year (2016), Wisconsin's estimated average annual impact to visibility at the Northern LADCO Class I Areas ranges from 1.0% to 6.2% (Table 2). Wisconsin must fulfill implementation plan requirements relative to Northern LADCO Class I Areas, as required by the Regional Haze Rule under 40 CFR § 51.308(f)(2).

Table 2 – LADCO State Contributions to Visibility Impairment in Northern LADCO Class I Areas on 20% Most Visibly Impaired Days

State	LADCO State 2028 PSAT Contributions – 2016 Base Year	
	Boundary Waters	***Seney***
Illinois	1.6%	6.3%
Indiana	0.6%	4.0%
Michigan	0.3%	6.0%
Minnesota	9.6%	3.0%
Ohio	0.4%	2.0%
Wisconsin	**2.3%**	**6.2%**
	Voyageurs	***Isle Royale***
Illinois	1.0%	4.0%
Indiana	0.5%	1.9%
Michigan	0.5%	3.5%
Minnesota	10.6%	5.0%
Ohio	0.5%	0.4%
Wisconsin	**1.0%**	**4.8%**

LADCO’s Round 2 2016-base year 2028 source apportionment modeling indicates that Wisconsin’s contributions to total light extinction at 42 other Class I areas outside of LADCO are nonzero, but are less than the 2% threshold. Wisconsin did not receive any “asks” from any states during the Round 2 planning process. As such, WDNR developed its LTS for Round 2 to ensure reasonable progress at the Northern LADCO Class I Areas.

3. Wisconsin Implementation Plan Elements

3.1. Regional Planning – LADCO and Regional Consultation

Under the Haze Rule, a state contributing to visibility impairment of a Class I area in another state is required to consult with the affected state to develop coordinated emission management strategies containing the emission reductions necessary to make reasonable progress (40 CFR § 51.308(f)(2)(ii)). States must also engage FLMs and consider their input when developing their proposed LTS and regional haze SIP revisions (40 CFR § 51.308(i)(2) and (4)). In addition to reiterating the Haze Rule's state-to-state and FLM consultation requirements, Step 8 of the EPA Guidance also encourages states to engage with their regional EPA offices in developing their regional haze SIPs. Wisconsin fulfilled these requirements and recommendations by engaging with LADCO and fellow LADCO states, FLMs including the U.S. Forest Service, U.S. Fish and Wildlife Service, and U.S. National Park Service, and EPA as described below.

At the beginning of the second implementation period in 2018, LADCO states reaffirmed their intent to work together to address Regional Haze Rule requirements. Wisconsin was part of the LADCO Regional Haze Workgroup which consisted of representatives of the member states, participating tribes, FLMs, EPA Region 5, and representatives from the EPA Office of Air Quality Planning and Standards (OAQPS). The Regional Haze Workgroup held monthly conference calls beginning in January 2018 to plan for the second regional haze implementation period and to guide the technical aspects of the regional haze planning effort.

This workgroup, supported by technical activities conducted by LADCO, completed the following major tasks:

- Developed emissions inventories for historic years (2011, 2016) and for the final year of the second implementation period (2028);
- Developed lists of national point sources, ranked by process-level emissions (Q) divided by distance (d) to the nearest Class I area, where Q/d is used as a quantitative metric of visibility impact;
- Discussed screening criteria for selecting sources for the four-factor analysis;
- Determined baseline and natural visibility conditions, and conducted URP and back trajectory analyses for all Class I areas;
- Performed state contribution and source appointment modeling; and
- Performed regional modeling of the LTS to set 2028 RPG.

Monthly LADCO Regional Haze Workgroup calls also included informal discussions with the FLMs, who described regional haze-related work underway at other regional planning organizations, such as the Central States Air Resource Agencies (CENSARA), the Western Regional Air Partnership (WRAP), and the Mid-Atlantic/Northeast Visibility Union (MANE-VU). The WDNR and FLMs had informal communication regarding four factor analysis recommendations and plans throughout the regional planning and consultation process.

Full documentation of this process, including meeting notes, technical reports, and modeling results from LADCO are available upon request. Major work products include:

- National point source inventories to facilitate states' four factor analyses and accompanying memorandum;
- Glidepaths for all Class I areas with projected 2028 visibility impairment based on a 2011 and a 2016 base year;
- Recent (2016) and future year (2028) emissions inventories for the LADCO member states; and
- LADCO's technical support document, "Modeling and Analysis for Demonstrating Reasonable Progress for the Regional Haze Rule 2018 – 2028 Planning Period" (LADCO TSD, Appendix 2).

3.2. Baseline, Current, and Natural Visibility Conditions

40 CFR § 51.308(f)(1) requires periodic regional haze implementation plans to contain the following:

- Baseline, natural, and current visibility conditions for the most impaired and clearest days.[11]
- Actual progress made on the most impaired and clearest days toward natural visibility conditions (1) since the baseline period and (2) in the previous implementation period up to and including the period for calculating current visibility conditions.
- The difference in deciviews by which the current visibility condition exceeds the natural visibility condition, for the most impaired and for the clearest days.
- The URP (reported in deciviews per year) for the most impaired days between baseline visibility conditions and natural visibility conditions.

3.2.1 Comparison of Baseline, Natural, and Current Visibility Conditions

To meet the requirements of 40 CFR § 51.308(f)(1)(i) – (iii), baseline, natural, and current visibility conditions at the Northern LADCO Class I Areas on the most visibly impaired and clearest days are reported in Table 3. Baseline, natural, and most recent (2014 – 2018) natural visibility condition values were taken from the EPA Technical Addendum.

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[11] For the first implementation period, states selected most impaired days as the monitored days with the 20% highest actual deciview values, regardless of the source of the particulate matter causing the visibility impairment. The Haze Rule, finalized in 2017, revised the definition for most visibly impaired days to correspond to days with the greatest anthropogenic visibility impairment. The EPA Visibility Tracking Guidance provides the methodology for calculating the 20% most (anthropogenically) impaired days.

Table 3 – Comparison of Baseline, Current and Natural Visibility Conditions in deciviews for the 20% Clearest and 20% Most Visibly Impaired Days in Northern LADCO Class I Areas

Northern LADCO Class I Areas	Baseline Visibility (2000-2004)		Current Visibility (2014-2018)		Natural Visibility (2064)		Difference in Current – Natural Visibility	
	Clearest	Most Impaired	Clearest	Most Impaired	Clearest	Most Impaired	Clearest	Most Impaired
Isle Royale	6.77	19.63	5.30	15.54	3.72	10.17	1.58	5.37
Seney	7.14	23.58	5.27	17.57	3.74	11.11	1.53	6.46
Boundary Waters	6.50	18.43	4.48	13.96	3.48	9.09	1.00	4.87
Voyageurs	7.15	17.88	5.31	14.18	4.27	9.37	1.04	4.81

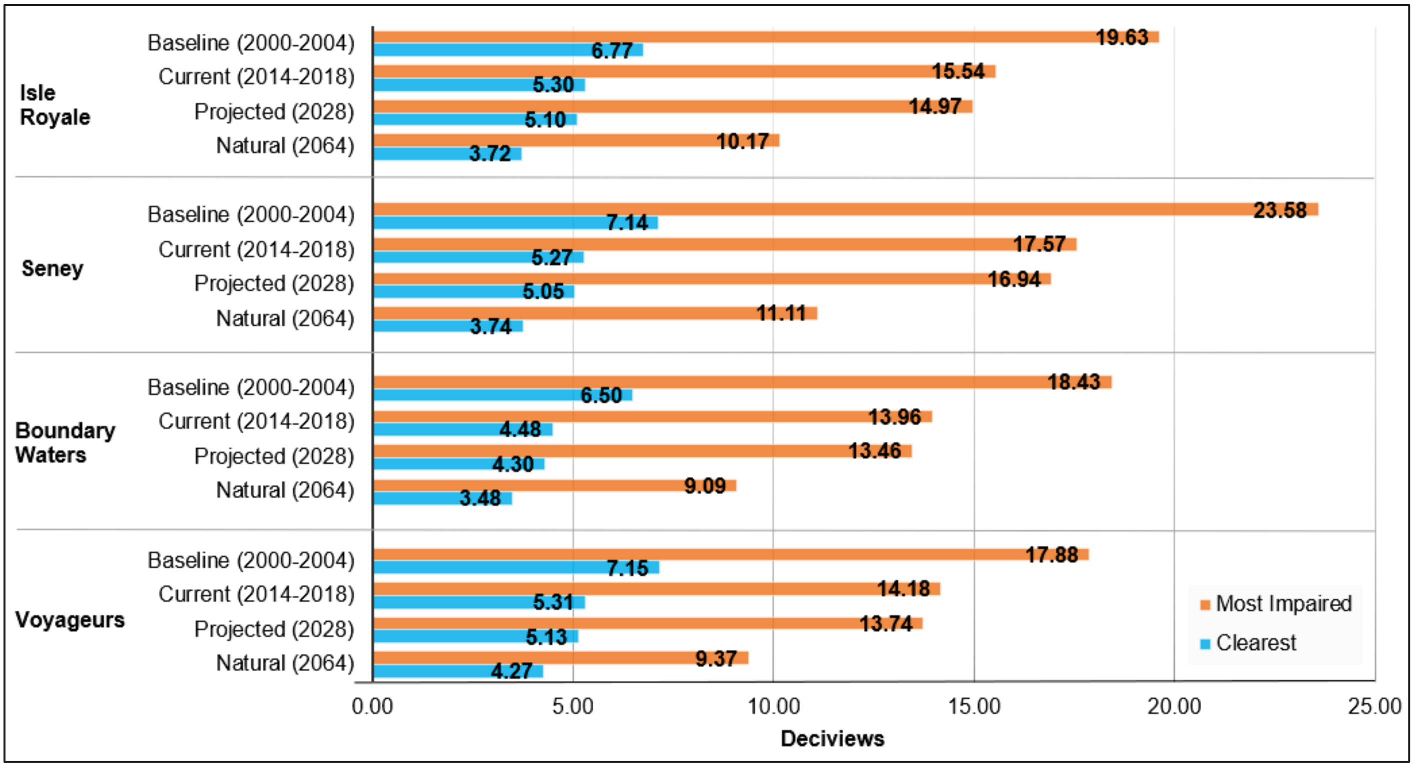
Table 3 uses the following terms from 40 CFR Part 51, Subpart P – Protection of Visibility (40 CFR § 51.301):

> Baseline visibility condition means the average of the five annual averages of the individual values of daily visibility for the period 2000-2004 unique to each Class I area for either the most impaired days or the clearest days.
>
> Natural visibility condition means the average of individual values of daily natural visibility unique to each Class I area for either the most impaired days or the clearest days.
>
> Current visibility condition means the average of the five annual averages of individual values of daily visibility for the most recent period for which data are available unique to each Class I area for either the most impaired days or the clearest days.

3.2.2 Progress to Date

To meet requirements of 40 CFR § 51.308(f)(1)(iv), Figure 2 shows the progress made towards achieving natural visibility conditions for the Northern LADCO Class I Areas for the most impaired and clearest days. The “Current (2014-2018)” visibility bars in Figure 2, which represent visibility during the 2014-2018 period and also correspond to the final years of the first implementation period, show improved visibility relative to baseline conditions on the most impaired and clearest days. “Projected 2028” visibility values show that conditions on the most impaired days are expected to improve throughout the second planning period. Additionally, projected visibility values indicate conditions on the clearest days will not degrade over the second implementation period.

Figure 2 – Progress Towards Achieving Natural Visibility Conditions Since the Baseline Period in Northern LADCO Class I Areas



Projected 2028 visibility values were forecast by LADCO using CAMx to simulate regional haze from the 2016 base year. LADCO selected CAMx for this study because it is a component of recent U.S. EPA modeling platforms for investigating the drivers of regional haze in the U.S. Section 3 of the LADCO TSD (Appendix 2) provides more details about the CAMx 2016 modeling platform, including base (2016) and future year (2028) emissions inventories, photochemical modeling data and configurations, and model performance evaluation methods.

3.2.3 Difference between Current and Natural Visibility Conditions

Table 3 reports the number of deciviews by which the current visibility conditions between 2014-2018 in Northern LADCO Class I Areas exceed the natural visibility conditions on the most impaired and clearest days. Therefore, the requirements of 40 CFR § 51.308(f)(1)(v) are met.

3.2.4 Uniform Rate of Progress

Under section 51.308(f)(1)(vi)(A) of the Haze Rule, states are required to report the URP for each Class I area *in the state*. The URP represents the rate of improvement in visibility (measured in deciviews of improvement per year) that would need to be maintained during each implementation period in order to reach natural conditions by 2064 for the most impaired days, given the starting point of the 2000-2004 baseline visibility condition. Since there are no mandatory Class I Federal areas within Wisconsin that are covered by the Haze Rule, Wisconsin does not need to report the URP for any Class I area. However, WDNR is voluntarily reporting the URP for the Northern LADCO Class I Areas (Table 4). Table 4 shows that current visibility conditions (2014 – 2018) for the most impaired days are below the URP for 2018 for each of the four Northern LADCO Class I Areas. Additionally, LADCO 2028 visibility modeling indicates that visibility on the most impaired days will also be below the URP at the end of Round 2 (Table 4).

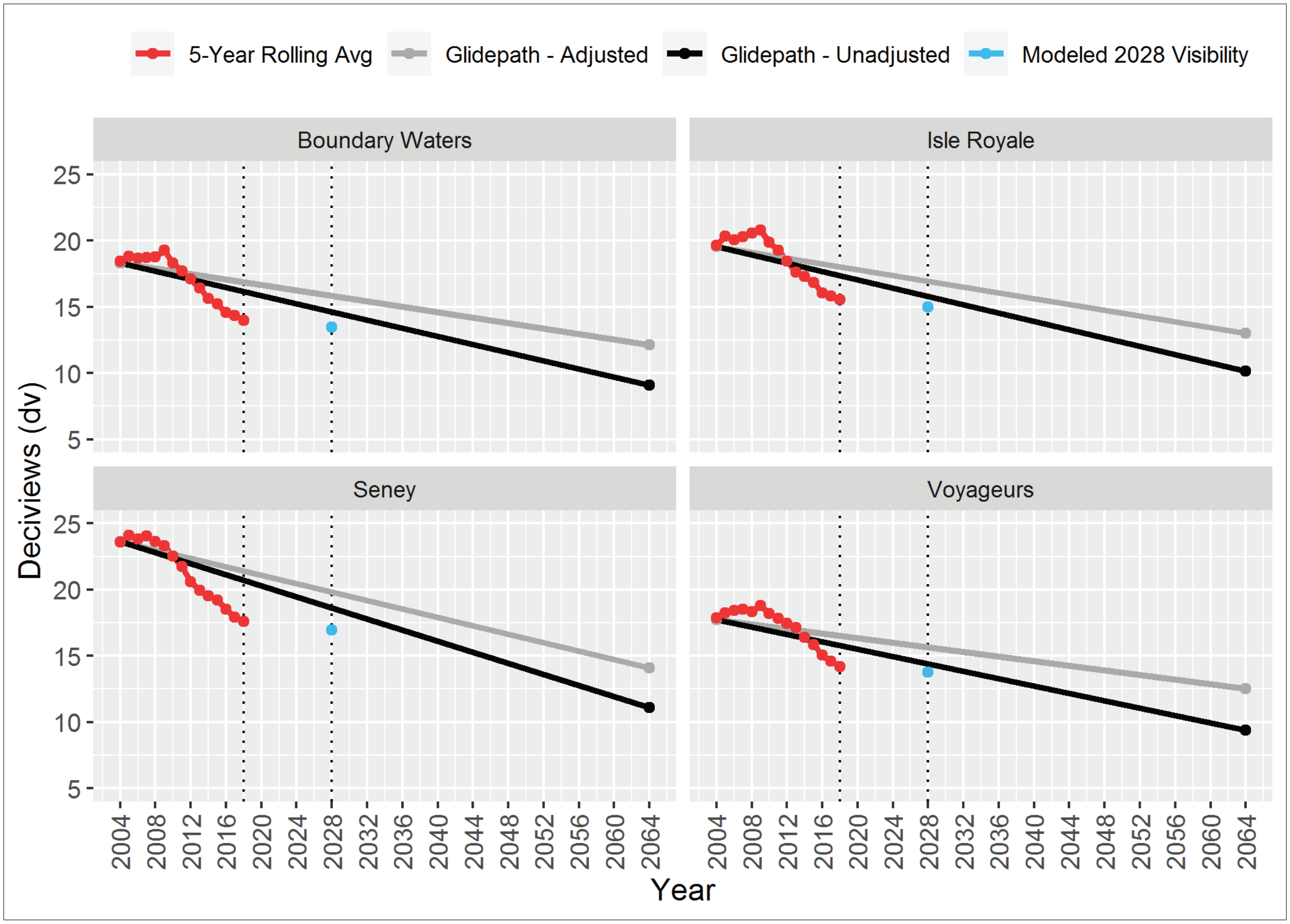
Table 4 – Uniform Rate of Progress Values on Most Visibly Impaired Days in Northern LADCO Class I Areas for the Second Implementation Period.

Northern LADCO Class I Areas	Uniform Annual Rate of Improvement (dv/yr)	URP at 2018	URP at 2028	Current (2014-2018) Visibility	Modeled 2028 Visibility	Current– URP for 2018	Modeled – URP for 2028
Isle Royale	0.16	17.34	15.85	15.54	14.97	-1.80	-0.88
Seney	0.21	20.56	18.59	17.57	16.94	-2.99	-1.65
Boundary Waters	0.16	16.17	14.69	13.96	13.46	-2.21	-1.23
Voyageurs	0.14	15.82	14.48	14.18	13.74	-1.64	-0.74

The URP glidepaths for the Northern LADCO Class I Areas are plotted in Figure 3. Visibility data in Figure 3 corresponding to the 20% most impaired days, averaged over a 5-yr rolling period from 2000 – 2018, were taken from the LADCO TSD (Appendix 2) and are in agreement with EPA's 2020 Technical Addendum. Visibility conditions at the Northern LADCO Class I Areas are well below the glidepaths at the beginning of Round 2 (2018) and are expected to continue to be below the unadjusted glidepaths at the end of the second implementation period (2028). The position of current and projected visibility conditions relative to the glidepath is one measure for evaluating whether a state is meeting its RPG (Section 3.7 of this Round 2 haze SIP).

Section 51.308(f)(1)(vi)(B) of the Haze Rule allows states the flexibility to propose to adjust the URP to account for anthropogenic emissions from outside of the United States and/or for impacts from prescribed fires. LADCO used EPA's 2028 Regional Haze emissions modeling platform (2028fg Regional Haze projection year file) from the EPA Modeling TSD to calculate adjusted glidepaths for the Northern LADCO Class I Areas (Figure 3). Since current and projected visibility conditions demonstrate that the Northern LADCO Class I Areas are expected to meet URP conditions for the second implementation period regardless of whether the unadjusted or adjusted glidepaths are considered (Figure 3), WDNR did not propose glidepath adjustments for Round 2. The WDNR does note, however, that the Round 2 RPGs for the Northern LADCO Class I Areas also meet the 2038 points of the adjusted URP glidepaths (Figure 3), which correspond to the end of the third planning period.

Figure 3 – Uniform Rate of Progress on Most Visibly Impaired Days in Northern LADCO Class I Areas. Dotted lines indicate the start (2018) and end (2028) of the second implementation period.



3.3. Emissions Inventory

The Haze Rule requires states without Class I areas to document emissions information in their regional haze SIP revisions to meet the following requirements:

- *The state must document the technical basis, including emissions information, on which the state is relying to determine the emission reduction measures that are necessary to make reasonable progress in each Class I area it affects (see 40 CFR § 51.308(f)(2)(iii)). A state may meet this requirement by relying on technical analyses developed by a regional planning organization and approved by all state participants. States must include emissions information for a year at least as recent as the most recent year for* *which the state has submitted emission inventory information to comply with the CAA's triennial reporting requirements.*

- *States reasonably anticipated to contribute to visibility impairment at a Class I area must provide emissions inventories for the most recent year for which data are available, and estimates of future projected emissions, and commit to updating the inventory periodically (see 40 CFR § 51.308(f)(6)(v)).*
- *So that the plan revision will serve also as a progress report, the state must address in the plan revision, progress report elements related to emissions inventories for the period since the most recent progress report (see 40 CFR § 51.308(f)(5)). Specifically, section 51.308(g)(4) of the Haze Rule requires an analysis tracking the change in emissions, identified by type of source or activity, at least through the most recent year for which the state submitted emission inventory information in compliance with the triennial reporting requirements. The analysis must extend through the most recent year of emissions data available for [point] sources that report directly to a centralized emissions data system.*

Wisconsin participated in the development of technical analyses, including emission inventory information, by LADCO and its member states, and is relying in part on those analyses to satisfy the emission inventory requirements. Wisconsin's emissions for the 2016 base year and the 2028 projected year used in LADCO modeling are provided below and satisfy elements of section 51.308(f)(6)(v) of the Haze Rule, which requires that states provide recent and future year emissions inventories of pollutants anticipated to contribute to visibility impairment in any Class I areas. The 2017 version of the National Emissions Inventory (NEI) is also provided below, as it corresponds to the year of the most recent triennial national emissions inventory, required under section 51.308(f)(2)(iii) of the Haze Rule. In addition to future emissions reductions expected by the end of Round 2, WDNR is reporting actual emissions reductions achieved over the period since the Round 1 progress report, to meet the progress report elements in 40 CFR § 51.308(f)(5). Collectively, the emissions inventories provided in the subsections below show a continued decreasing trend in Wisconsin emissions across the first and second planning periods. These statewide emissions reductions are one of the components of Wisconsin's LTS for Round 2.

3.3.1 Modeled Emissions for 2016 and 2028

LADCO developed emissions inventories for the 2011 and 2016 base years because EPA modeling platforms that included projections to 2028 were readily available for these years during the second planning period. This SIP revision reports Wisconsin's 2016 base year emissions and projected 2028 emissions because 2016 represents the most recent, complete inventory year. Additionally, LADCO's 2016 base year projections represent the best available information on electricity generating unit (EGU) and non-EGU forecasts for the Midwest and Eastern U.S. available as of September 2020. Future year projections of Wisconsin emissions based on 2011 can be found in the LADCO TSD (Appendix 2).

LADCO developed emissions inventories for pollutants which are reasonably anticipated to cause or contribute to visibility impairment in Class I areas (Appendix 2): nitrogen oxides (NOx), sulfur dioxide (SO_2), particulate matter with diameter less than 2.5 µm ($PM_{2.5}$), ammonia

(NH_3), and volatile organic compounds (VOC). These pollutants are listed in approximate order of decreasing impact on visibility in Northern LADCO Class I Areas (LADCO TSD). Historically, particulate sulfate had contributed more than particulate nitrate to visibility impairment at the Northern LADCO Class I Areas. This changed in approximately 2016.[5] LADCO's 2016-base year speciated particulate tracer modeling projections for 2028 support this trend of particulate nitrate surpassing particulate sulfate in visibility impairment contribution on the most impaired days. Additionally, LADCO's speciated particulate tracer modeling indicates that in 2028, particulate nitrate from Wisconsin contributes approximately twice as much to visibility impairment at Northern LADCO Class I Areas as the state's particulate sulfate on the most visibly impaired days (Figure 8-22 and Table 8-6 of the LADCO TSD, Appendix 2).

A summary of statewide 2016 emissions by source category is provided in Table 5. The on-road mobile source sector accounted for the majority of NOx emissions in 2016. Non-EGU point sources, followed by EGU point sources, were responsible for the majority of SO_2 emissions.

Table 5 – Wisconsin Statewide Emissions for 2016 Base Year

Category	Emissions (tons)				
	NH_3	NOx	$PM_{2.5}$	SO_2	VOC
Point - EGU	578	16,087	1,258	12,958	710
Point - Non-EGU[a]	891	24,303	4,169	20,590	22,073
Area[b]	59,119	33,655	53,366	2,075	81,793
On-road	1,861	80,086	2,845	413	34,837
Off-road[c]	44	23,906	2,431	54	41,548
Total	**62,494**	**178,037**	**64,069**	**36,089**	**180,961**

[a] Emissions from aircraft and airports are included in the Non-EGU point source sector.
[b] Agricultural emissions from livestock and crops are included in the Area source sector.
[c] Marine and rail emissions are included in the Off-road source sector.

LADCO's process for developing the 2016 base year emissions inventory and projecting emissions to year 2028 is briefly described here, with detailed information provided in Section 3.4 of the LADCO TSD (Appendix 2). LADCO primarily used 2016 and 2028 emissions data from the US EPA 2016v1("2016fh_16") emissions modeling platform, but made the following modifications to the inventories:

- LADCO replaced the 2028 EGU in EPA's "2016fh" emissions modeling platform with 2028 forecasts estimated with the Eastern Regional Technical Advisory Committee (ERTAC) EGU Tool version 16.1. LADCO considers that the ERTAC EGU Tool provides more accurate estimates of the growth and control forecasts for EGUs in the Midwest and Northeast states than the approach used in U.S. EPA's "2016fh" modeling platform.
- LADCO modified the ERTAC EGU 16.1 inventory forecasts for 2028 to exclude the emissions from 62 EGU units that will shut down before 2028. These shutdowns were announced after the ERTAC EGU 16.1 emissions were developed.
- So that emissions projected to 2028 reflect realistic operations, LADCO developed "typical emissions" for non-EGU point sources in the LADCO region that were temporarily shut down in 2016, but restarted operations in 2017.

- LADCO adjusted 2016 non-EGU point source emissions to account for 5,700 extra tons of NOx emissions that were incorrectly reported from a Wisconsin wastewater treatment plant in 2016.

Wisconsin's future year emissions for the end of the second planning period are summarized by sector in Table 6. Overall, significant decreases in SO_2, NOx, and VOC emissions are expected between the 2016 and 2028 inventory years (Table 6).

Table 6 – Wisconsin Statewide Emissions for 2028 Projected Year

Category	**Emissions (tons)**				
	NH_3	**NOx**	**$PM_{2.5}$**	**SO_2**	**VOC**
Point - EGU	1,875	12,916	1,018	4,700	864
Point - Non-EGU[a]	896	24,206	4,225	19,559	22,108
Area[b]	60,146	30,053	53,158	2,046	82,126
On-road	1,687	25,272	1,025	229	16,538
Off-road[c]	49	13,894	1,250	36	25,025
ERCs[d]		2,634			135
Total	**64,653**	**108,975**	**60,676**	**26,570**	**146,796**
% Change from 2016	**3.5%**	**-38.8%**	**-5.3%**	**-26.4%**	**-18.9%**

[a] Emissions from aircraft and airports are included in the Non-EGU point source sector.

[b] Agricultural emissions from livestock and crops are included in the Area source sector.

[c] Marine and rail emissions are included in the Off-road source sector.

[d] Emission reduction credits (ERCs) are based on creditable VOC and NOx emission reductions resulting from the permanent shutdown on/around April 10, 2018 of boilers B20, B21, B22 and B23 at the Pleasant Prairie power plant (Construction Permit #18-RAB-050-ERC) in Kenosha County. Note that WDNR is including the ERCs in Wisconsin's 2028 emissions inventory; LADCO's 2028 inventory does not include the ERCs.

Large reductions in EGU SO_2 emissions, 64% between 2016 and 2028, resulting from shutdowns and the implementation of emission controls, contribute to the overall 26% decrease in total SO_2 emissions between the two inventory years (Tables 5 and 6). On-road and off-road mobile source controls are projected to result in significant NOx emissions reductions of 68% and 42%, respectively, between 2016 and 2028. Total $PM_{2.5}$ emissions are expected to decrease slightly. The WDNR deems the small projected increase in NH_3 emissions between 2016 and 2028 to be insignificant relative to the visibility improvements resulting from NOx, SO_2, and VOC emissions reductions (Table 6).

The 2016 base year and future year 2028 emissions inventories, which were developed by LADCO and its member states, meet elements of the Haze Rule's requirements under sections 51.308(f)(2)(iii) and 51.308(f)(6)(v). To meet the Haze Rule's section 51.308(f)(6)(v) requirement regarding updated emissions inventories, WDNR commits to periodically updating Wisconsin's emissions inventory for pollutants reasonably anticipated to cause or contribute to visibility impairment in Class I areas to support future regional haze progress reports and SIP revisions.

3.3.2 Wisconsin 2017 Triennial Emissions Inventory

To meet the remaining elements of the Haze Rule's section 51.308(f)(2)(iii), Table 7 provides a summary of Wisconsin source emissions in 2017, which corresponds to the year of the most recent triennial NEI. Wisconsin is also in compliance with the Air Emissions Reporting Requirements in 40 CFR Part 51, Subpart A, which satisfies the requirement to provide for an emissions inventory for the most recent year for which data are available (Haze Rule section 51.308(f)(6)(v); EPA Guidance Section II.B.8.c).

Table 7 – Wisconsin 2017 Emissions

Category	Emissions (tons)				
	NH_3	NOx	$PM_{2.5}$	SO_2	VOC
Point - EGU	1,339	19,542	698	13,246	905
Point - Non-EGU[a]	351	21,304	4,125	14,490	19,863
Area[b]	63,060	26,349	54,770	1,883	92,811
On-road	1,881	64,770	2,279	358	34,751
Off-road[c]	53	36,590	2,641	93	38,571
Total	**66,684**	**168,554**	**64,513**	**30,070**	**186,902**

[a] Emissions from aircraft and airports are included in the Non-EGU point source sector.
[b] Agricultural emissions from livestock and crops are included in the Area source sector.
[c] Marine and rail emissions are included in the Off-road source sector.

The methodology for developing the 2017 inventory is briefly described here, with more detailed information provided in EPA's 2017 NEI TSD.[12] Emissions from EGU and non-EGU point sources are reported by the sources to the 2017 Wisconsin Air Emissions Inventory (AEI) database. EGU emissions are corroborated by the EPA Clean Air Markets Division (CAMD) EGU database. On-road and off-road mobile source emissions are from the 2017 NEI, prepared using version 2014b of the MOtor Vehicle Emission Simulator (MOVES) model. Marine, aircraft, and rail source emissions are also from the 2017 NEI. Likewise, area source emissions are based on the 2017 NEI.

3.3.3 Changes in Emissions Since First Implementation Period and Progress Report

To meet the emissions inventory progress report requirement of the Round 2 haze SIP under section 51.308(g)(4) of the Haze Rule (as required under 40 CFR §51.308(f)(5)), Appendix B of the EPA Guidance recommends that "the 2021 SIP cover a period approximately from the first full year that was not actually incorporated in the previous progress report through a year that is as close as possible to the submission date of the 2021 SIP." Wisconsin's Round 1 progress report, submitted in March 2017, covered emissions through 2015. The WDNR is therefore reporting the change in emissions from 2016, the first year not incorporated in the Round 1 progress report, to 2017 for sector level emissions, which is the most recent inventory year available at the sector level. Emissions changes for point sources, which report emissions to a centralized emissions data system (See 40 CFR § 51.308(g)(4)), are tracked through 2019.

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[12] "2017 National Emissions Inventory Complete Release Technical Support Document," US EPA, April 2020.

Wisconsin Sector-Level Emissions Changes

Table 8 reports the change in sector-level emissions between the 2016 and 2017 inventory years. Overall emissions reductions in SO_2 and NOx are due to emissions decreases in the point source, area, and on-road sectors (Table 8). NH_3, VOC, and $PM_{2.5}$ contribute less to visibility impairment than SO_2 and NOx, so their small increases are significantly outweighed by the emissions reductions in the other pollutants.[13]

Table 8 – Change in Wisconsin Emissions since Progress Report

Category	% Change, from 2016 to 2017[a]				
	NH_3	NOx	$PM_{2.5}$	SO_2	VOC
Point - EGU	132%	21%	-45%	2%	27%
Point - Non-EGU	-61%	-12%	-1%	-30%	-10%
Area	7%	-22%	3%	-9%	13%
On-road	1%	-19%	-20%	-13%	0%
Off-road	20%	53%	9%	73%	-7%
Total	**7%**	**-5%**	**1%**	**-17%**	**3%**

[a] 2016 and 2017 emissions inventory values are reported in Table 5 and Table 7, respectively.

Table 9 compares the emission targets set for the final year of the first implementation period (2018) and the emissions modeled for the final year of second implementation period (2028). The WDNR notes the Round 1 2018 Target and the Round 2 2028 modeling were based on different emission estimation procedures for some sectors between different versions of the NEI. Under section 51.308(g)(4) of the Haze Rule, Wisconsin is "not required to back-cast previously reported emissions to be consistent with more recent emissions estimation procedures…"

Table 9 – Comparison of Wisconsin Round 1 and Round 2 Emissions

Category	NH_3	NOx	$PM_{2.5}$	SO_2	VOC
	Round 1 - 2018 Emissions Targets (tons) [a]				
EGU	683	36,047	7,445	75,007	1,179
Non-EGU	419	33,363	47	48,147	34,204
Area	106,244	22,804	49,744	7,998	109,427
On-road	7,326	45,705	1,287	660	22,572
Off-road	66	34,957	2,830	1,227	61,424
Total	**114,738**	**172,876**	**61,353**	**133,039**	**228,806**
	Round 2 – 2028 Emissions Modeling (tons) [b]				
Round 2 2028 Modeling	**64,653**	**108,975**	**60,676**	**26,570**	**146,796**
	% Change to Round 2 2028 Modeling				
Relative to Round 1 2018 Target	**-44%**	**-37%**	**-1%**	**-80%**	**-36%**

[a] Round 1 2018 Target emissions are from Table 11 of Wisconsin's Round 1 progress report.
[b] Emissions are reported in this Round 2 haze SIP (Table 6).

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[13] The following pollutants contribute to current visibility impairment in Northern LADCO Class I Areas in approximate order of decreasing impact on visibility: NOx, SO_2, $PM_{2.5}$, NH_3, and VOC.

Comparison of the total emissions reported for the 2017 NEI (Table 7) to the Round 1 2018 Target indicates that more significant reductions in SO_2 and NH_3 emissions were achieved over Round 1 than initially expected, such that the 2017 NEI SO_2 and NH_3 emissions were 77% (or 102,969 tons) and 42% (or 48,054 tons) lower, respectively, than the Round 1 2018 Targets. Reductions in NOx and VOC emissions over Round 1 were consistent with the modeled projections reported in the Round 1 progress report, as evidenced by the similarity in the 2017 NEI and Round 1 2018 Targets for NOx and VOC (Table 7; Table 9). The WDNR expects significant NOx and VOC reductions by the end of the second planning period (Table 9).

Wisconsin Point Source Emission Trends

The Haze Rule and EPA Guidance provide flexibility to determine how emission reductions can be used for demonstrating reasonable progress. This SIP revision compares the 2016 base year emissions and 2028 projected emissions with the 2018 Target emissions that were used for Wisconsin's approved Round 1 haze SIP, to properly account for the control measures and associated emission reductions that should be credited towards reasonable progress for Round 2. As described in Section 5.1 of the LADCO TSD (Appendix 2), the LADCO Workgroup agreed that the priority emission sources affecting visibility of the Northern Class I areas to evaluate further for reasonable progress are NOx and SO_2 from point sources (EGUs and non-EGUs). For Wisconsin in particular (as described in Section 3.3.1), speciated particulate tracer analysis demonstrates that particulate nitrate, and to a lesser extent, particulate sulfate account for the majority of Wisconsin's contribution to visibility impairment at Northern LADCO Class I Areas (see Figure 8-22 and Table 8-6 of LADCO TSD, Appendix 2).

Table 10 and Figures 4A and 4B show the NOx and SO_2 emission reduction trends from Wisconsin's point source EGU and non-EGU sectors from Round 1 to Round 2. Appendix 3 includes specific information on Wisconsin's larger point sources, including control measures added from Round 1 to Round 2 and the associated NOx and SO_2 emissions reflecting those controls. The information in this section also satisfies the requirements in sections 51.308(f)(5) and 51.308(g)(4) of the Haze Rule, by providing an analysis tracking the change in point source emissions from the Round 1 progress report that extends through the most recent year of emissions data available (2019).

For the 2028 projected point source emissions shown in Table 6 (also referred to as "2028 Modeled"), the EGU projections include shutdowns or other on-the-books controls as of September 2020, while the non-EGU projections primarily carry forward the 2016 base year emissions unless noted otherwise (see Section 3.4.2 of LADCO TSD, Appendix 2). There are significant emission reductions from the following unit shutdowns and committed controls in Wisconsin that are not included in LADCO's 2028 Modeled emissions (see Appendix 3):

- Alliant Energy Columbia power plant shutdown (2025)
- We Energies South Oak Creek power plant shutdown (2023-2024)
- Georgia-Pacific Green Bay Broadway mill – retirement of coal boiler B29 (2018); replacement of coal boilers B26 and B28 with three natural gas boilers (2019-2020)
- Catalyst Paper – Biron mill – coal boiler B23 fuel switch to natural gas (2017)
- Cardinal FG – Menominee – installation of selective catalytic reductions (SCR) (2020)

- Cardinal FG – Portage – installation of SCR (2019)
- Green Bay Packaging Inc. mill – replacement of coal boiler B26 with two natural gas boilers (2019)
- Ahlstrom-Munksjo – De Pere mill – 10% annual heat input limitation for coal boilers B23 and B24 (2017)

The WDNR developed the point source projected emissions scenario “2028 Adjusted” shown in Table 10 and Figures 4A and 4B to reflect these additional emission reductions. Much of these emission reductions are also reflected in the non-EGU 2019 actual emissions. Accounting for the lower EGU and non-EGU projected emissions in the 2028 Adjusted scenario is expected to produce more beneficial visibility results than the 2028 Modeled scenario used for the visibility modeling in Section 3.2. Further, even more significant emission reductions (about 2,200 tons NOx and 3,800 tons SO_2) beyond the 2028 Adjusted levels have been demonstrated recently from the A-M Kaukauna, A-M Rhinelander, and Wisconsin Rapids paper mills, but these reductions cannot yet be attributed to on-the-books controls and therefore have not yet been included in the 2028 Adjusted scenario.

Table 10 – Round 1 and Round 2 Annual NOx and SO_2 Emissions for Wisconsin EGUs and Non-EGUs[a]

WI Point Sector	Round 1 SIP (2005-2018)		Round 2 SIP (2019-2028)			
	2005 Base	2018 Target[b]	2016 Base[c]	2019[c]	2028 Modeled[d]	2028 Adjusted[e]
			NOx			
Point – EGU	71,416	36,047	16,573	12,359	12,916	8,724
Point – Non-EGU	36,030	33,363	24,665	21,549	24,206	20,611
TOTAL	**107,446**	**69,410**	**41,238**	**33,908**	**37,122**	**29,335**
Progress from Round 1 2018 Target (% Change)	**---**	**---**	**-41%**	**-51%**	**-47%**	**-58%**
			SO_2			
Point – EGU	181,430	75,007	14,139	5,092	4,700	2,882
Point – Non-EGU	59,778	48,147	20,307	15,266	19,559	15,417
TOTAL	**241,208**	**123,154**	**34,446**	**20,358**	**24,259**	**18,299**
Progress from Round 1 2018 Target (% Change)	**---**	**---**	**-72%**	**-83%**	**-80%**	**-85%**

[a] Emissions/control information for larger individual Wisconsin facilities are shown in Appendix 3.

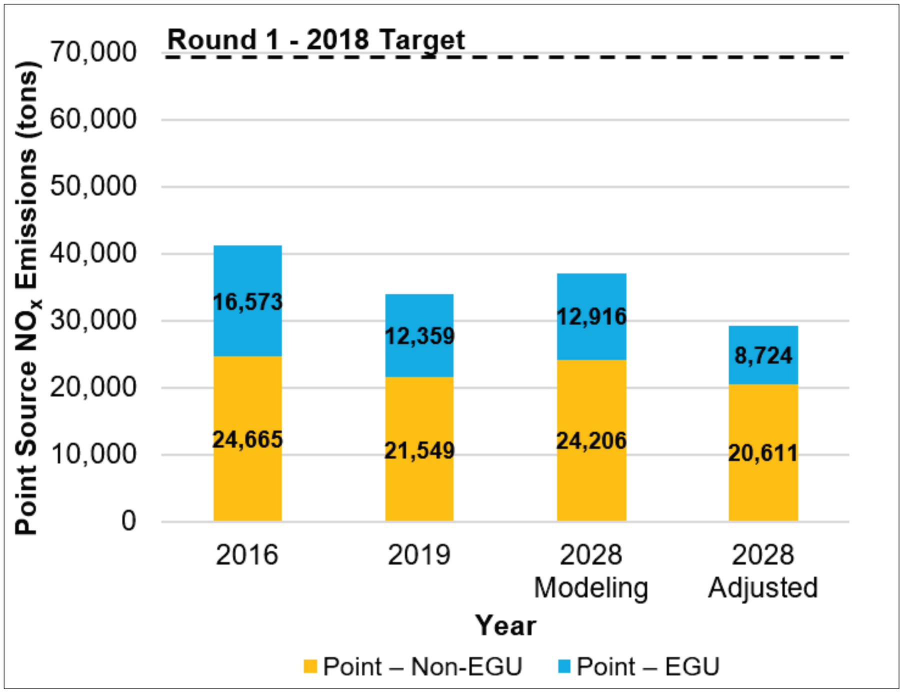
[b] 2018 Target = 2005 emissions projected to 2018 by WDNR for Round 1 SIP, using on-the-books controls known as of May 2011 for EGUs and non-EGUs.

[c] Emissions are from WDNR AEI. (**Note:** NOx emissions at Theda Clark Medical Center were over-reported by 905 TPY in 2016 (see Appendix 2, Table A2-1), and are thus also over-reported for 2028 Modeled emissions and 2028 Adjusted emissions.)

[d] Projected emissions modeled by LADCO for visibility impact.

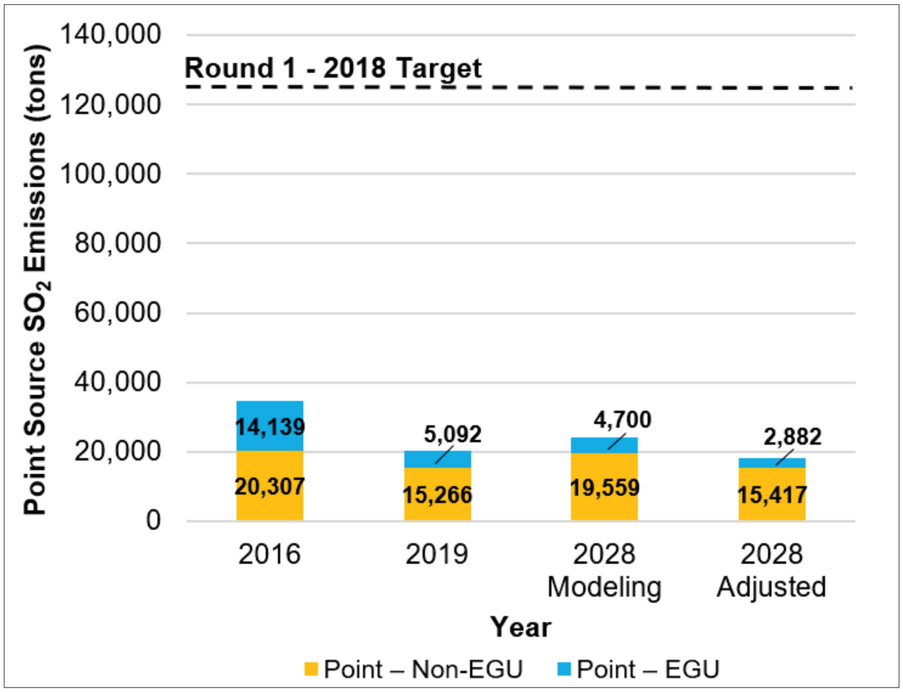
[e] Adjustments to 2028 Modeled emissions by accounting for shutdowns and committed controls not included in LADCO visibility modeling (see Appendix 3). The 2028 Adjusted emissions for the A-M Rhinelander and A-M Kaukauna mills are the same as 2016 Base (and 2028 Modeled) emissions, and do not yet reflect recently demonstrated emission reductions associated with SO_2 National Ambient Air Quality Standard requirements (see Sections 3.5.1 and 3.6.1).

Figure 4A – Round 1 and Round 2 Annual NOx Emissions for Wisconsin EGUs and Non-EGUs[a]



[a] This figure displays emissions information provided in Table 10.

Figure 4B – Round 1 and Round 2 Annual SO_2 Emissions for Wisconsin EGUs and Non-EGUs[a]



[a] This figure displays emissions information provided in Table 10.

3.4. Selection of Sources and Consideration of the Four Statutory Factors

The Haze Rule requires states to evaluate and determine the emission reduction measures that are necessary to make reasonable progress by considering four factors: 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 anthropogenic source of visibility impairment (see 40 CFR § 51.308(f)(2)(i)). The state should consider evaluating major and minor stationary sources or groups of sources, mobile sources, and area sources. The state must also include in its SIP a description of the criteria it used to determine which sources or groups of sources it evaluated and how the four factors were taken into consideration in selecting the measures for inclusion in its long-term strategy.

3.4.1 Selection of Sources for Analysis

The EPA Guidance indicates that states should select the emission sources for which an analysis of emission control measures will be completed in the second implementation period and explain the basis for these selections. The EPA Guidance also states that for the purpose of this source selection step, a state may consider estimated visibility impacts (or surrogate metrics for visibility impacts), the four statutory factors, the five required factors listed in section 51.308(f)(2)(iv), and other factors that are reasonable to consider.

The Haze Rule allows states significant flexibility when selecting sources for further analysis, primarily requiring that a state provide "a description of the criteria it used to determine which sources or groups of sources it evaluated…" (see 40 CFR § 51.308(f)(2)(i)). The EPA Guidance expands on this, saying that the Haze Rule "does not explicitly list factors that a state must or may not consider when selecting the sources, and that a state opting to select a set of its sources to analyze must reasonably choose factors and apply them in a reasonable way given the statutory requirement to make reasonable progress towards natural visibility."[14]

As noted in Section 3.1, Wisconsin participated in a LADCO-facilitated consultation process with the other LADCO states, as well as EPA and FLMs. To assist states with their source selection, this workgroup generated source lists based on various Q/d thresholds. The EPA Guidance says that this technique could be useful to states as they select sources for potential four-factor analysis.[15]

The LADCO Workgroup considered unit-level Q/d thresholds of 1, 4, and 10, and LADCO provided key information for the different thresholds, such as the number of state and regional emission units over the thresholds and the corresponding percent of the total point source emissions impact at the Class I areas included in the analysis (Northern LADCO Class I Areas and nearby Class I areas). The individual states could then use this information to inform which sources in the state to select for further analysis. Additional details about this process and the

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[14] See EPA Guidance, part 3 "Step 3: Selection of Sources" on p. 10.

[15] See EPA Guidance, part 3(b) "Estimating baseline visibility impacts for source selection", on p. 13.

work products associated with it, including a summary comparison for the different Q/d thresholds examined, can be found in Section 5 of the LADCO TSD (Appendix 2).

Wisconsin used the Q/d information developed by the LADCO Workgroup to select emission units over a Q/d of 10 at three facilities, described in Table 11, for further analysis.

Table 11 – Wisconsin Facilities with Units Over Q/d=10 Selected for Further Analysis

NAICS	NAICS Name	EPA Facility ID	Facility Name	# of Affected Units at Facility	Sum of Unit Q/d (Tons/km)[a]	Sum of Unit Emissions (Tons)[a]
221112	Fossil Fuel Electric Power Generation	7692911	WPL – Edgewater Generating Station	2	23	7,368
322121	Paper (except Newsprint) Mills	6467811	Ahlstrom-Munksjo – Kaukauna	1[b]	22[b]	6,319[b]
322121	Paper (except Newsprint) Mills	7048011	Ahlstrom-Munksjo – Rhinelander	1	12[c]	2,753[c]

[a] 2016 base year emissions, consisting of: NH_3, NOx, $PM_{2.5}$, and SO_2. Q/d values from LADCO Regional Haze workgroup spreadsheet "Process level report of Q/d sources" (V. 6.9) at LADCO Regional Haze TSD – Second Implementation Period (see Appendix 2, Table A2-1 for the Wisconsin processes).

[b] Note that a second unit, coal boiler B09, is being added to the analysis in a later step (see Section 3.4.2).

[c] The primary emission unit, coal boiler B26, did not operate for two months during 2016 due to a facility project. Therefore, these emissions and the resulting Q/d for B26 are underestimated by about 20%.

Considering the Haze Rule requirements and the flexibilities afforded states under both the Haze Rule and EPA Guidance, WDNR used the following criteria to select these units:

- These are the Wisconsin units with the highest Q/d values based on the LADCO Workgroup's assessments (see Figure 5A). Lacking other sources of information like source-specific apportionment modeling, these sources are therefore presumed to contribute the most to Northern LADCO Class I Areas when considering all Wisconsin sources. Also, collectively the LADCO region emission units with Q/d values similar to these four Wisconsin units (i.e., above 10) account for about half of the LADCO region's total point source emissions impact at Class I areas (see Section 5.2 of LADCO TSD, Appendix 2).

- The Northern LADCO Class I Areas' haze indices are already below their URP glidepaths through 2028 (see Section 3.2). These visibility improvements reflect controls and other operational limitations that are in place or on the way, before consideration of any additional measures for the second implementation period. The EPA Guidance – expanding on the flexibility allowed in the Haze Rule – clearly acknowledges the usefulness of looking at projected visibility progress when selecting sources.[16]

- Wisconsin point sources collectively have already significantly reduced emissions since Round 1 (see Section 3.3), and these reductions have contributed to the impacted Class I areas being below their URP glidepaths. As with projected visibility progress, an analysis of emission reductions is also acknowledged in the EPA Guidance as potentially useful when selecting sources.[17]

- Within the LADCO region alone, there are 45 emission processes with greater Q/d impacts than Wisconsin's highest Q/d process, and 81 non-Wisconsin LADCO processes with greater Q/d impacts than Wisconsin's second-highest process.[18] Selection of additional Wisconsin sources for analysis would only be appropriate after an assessment of emissions reductions necessary at those non-Wisconsin processes.

- Wisconsin sources contribute significantly less than other LADCO states to total Q/d impact (see Figure 5B). Therefore, selecting the highest contributing Wisconsin sources is appropriate.

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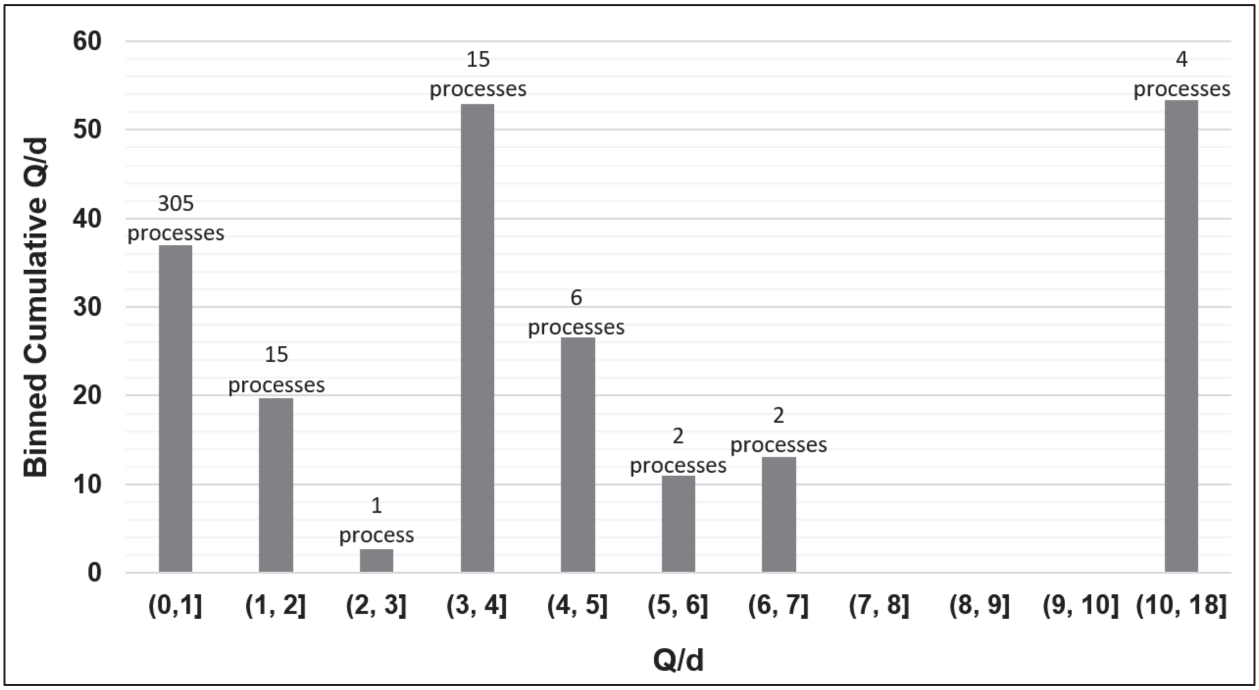
[16] See EPA Guidance, part 3(e) "Option to consider the five additional factors when selecting sources," on p. 22: *"A projection of the anticipated net effect on visibility progress that will occur during the second implementation period due to projected changes in emissions from sources within the state can be a useful consideration in determining which in-state sources to select… The fact that visibility conditions in 2028 will be on or below the URP glidepath is not a sufficient basis by itself for a state to select no sources for analysis of control measures; however, the state may consider this information when selecting sources."*

[17] See EPA Guidance, part 3(e) on p. 22: "*This factor [emission reductions due to ongoing air pollution control programs] is inherently considered in the process of source selection if visibility impacts are used to select sources, since those visibility impacts depend on emission reductions from ongoing air pollution control programs."*

[18] See LADCO Regional Haze workgroup November 2019 spreadsheet "Process level report of Q/d sources" (V. 6.9) at LADCO Regional Haze TSD – Second Implementation Period (see also Appendix 2, Table A2-1). This analysis uses 2016 emissions. Generally, each of these emission processes represents an individual emission unit.

Figure 5A – Wisconsin: Cumulative Q/d vs. Q/d Bin[a,b,c]

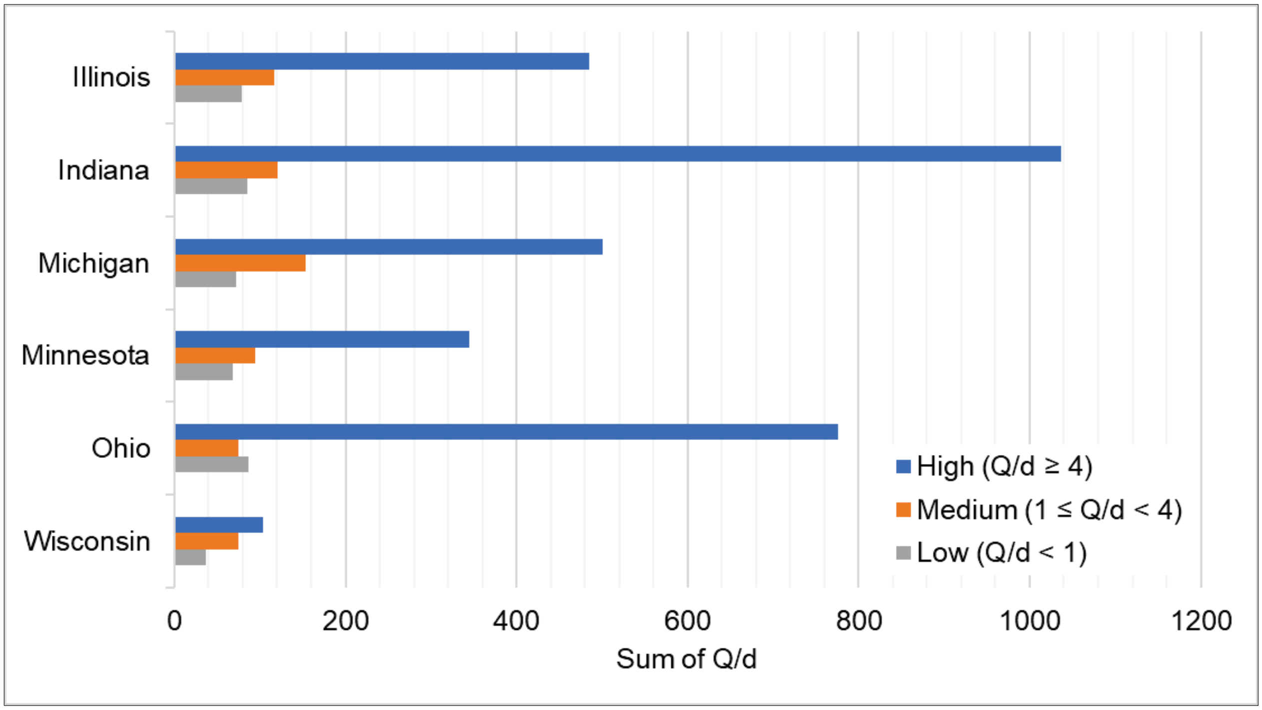


[a] Q/d values from LADCO Regional Haze workgroup spreadsheet "Process level report of Q/d sources" (V. 6.9) at LADCO Regional Haze TSD – Second Implementation Period (see Appendix 2, Table A2-1 for the Wisconsin processes). The Q/d analysis uses 2016 emissions. **Note:** Each emission process over Q/d=1 represents an individual emission unit, with the exceptions of the petroleum coke process (Q/d=3.9) and coal process (Q/d=17.9) for the A-M Kaukauna mill unit B11, and the biomass process (Q/d=1.1) and coal process (Q/d=3.2) for the Wisconsin Rapids mill unit B21.

[b] A-M Rhinelander coal boiler B26 (Q/d=12) did not operate for two months during 2016 due to a facility project, therefore emissions and the resulting Q/d for B26 are underestimated by about 20%.

[c] Theda Medical Center's B01--1 process (Q/d=3.2) was erroneously reported in the LADCO Regional Haze workgroup spreadsheet "Process level report of Q/d sources" (V. 6.9) at LADCO Regional Haze TSD – Second Implementation Period (see also Appendix 2, Table A2-1). Actual NOx emissions from this process totaled 4.65 pounds instead of 905 tons in 2016, giving an overall Q/d=0.25 for this process. The WDNR did not correct this error, in order to ensure consistency with the LADCO spreadsheet.

Figure 5B – Sum of Q/d by LADCO State at Different Source (Process) Priority Levels[a]



[a] Q/d values from LADCO Regional Haze workgroup spreadsheet "Process level report of Q/d sources" (V6.9) at LADCO Regional Haze TSD – Second Implementation Period. The Q/d analysis uses 2016 emissions.

As discussed in Section 3.3.1, Wisconsin's particulate sulfate is projected to contribute approximately half that of particulate nitrate to visibility impairment at the Northern LADCO Class I Areas, particularly at Seney and Isle Royale, to which Wisconsin contributes most significantly (Table 2). Significant NOx emissions reductions at Wisconsin point sources over Round 1 have led to several sectors (mobile, area and point) together being responsible for the remaining Wisconsin NOx emissions (i.e., particulate nitrate contributions). While Wisconsin point sources achieved significant SO_2 emission reductions over Round 1, Wisconsin's remaining SO_2 emissions (i.e., particulate sulfate contributions) still originate primarily from point sources (mainly non-EGUs). Wisconsin's selected units represent 32% of the total Q/d for Wisconsin processes over a Q/d of 1 (45 processes), and capture 28% of total Wisconsin point source emissions for Wisconsin processes over a Q/d of 1, including 41% of SO_2 emissions and 14% of NOx emissions (Appendix 2, Table A2-2).[19]

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[19] These percentages are higher when removing the 905 TPY overreported NOx emissions at Theda Clark Medical Center, and when adding 229 TPY NOx and 319 TPY SO_2 emissions for A-M Rhinelander to account for coal boiler B26 not operating for two months due to a facility project. These percentages are also higher when using 2028 Modeled or 2028 Adjusted point source emissions, because the selected units represent a larger portion of the NOx and SO_2 emission inventories. (**Note:** the additional selection for further analysis of A-M Kaukauna coal boiler B09 (Q/d=4.1) in Section 3.4.2 is also not reflected in these percentages.)

3.4.2 Characterization of Factors for Emission Control Measures

After sources are identified for further analysis, the EPA Guidance provides that states should identify potential emission control measures for the selected sources, develop data on the four statutory factors and on visibility benefits if they will be considered.

Not all sources identified in the initial filtering need to be brought forward to the four-factor analysis. In particular, in its information gathering process, a state may find that some or all of the sources have already implemented or plan to implement emission reduction measures which achieve sufficient reasonable progress and should not require a further evaluation of control measures.[20] LADCO provided a unit-level spreadsheet for states to use, as they deemed necessary, to collect additional emissions and control information (see Section 5.2 of LADCO TSD, Appendix 2). Wisconsin filled in the necessary emissions and control information in the LADCO spreadsheet for the units listed in Table 12. A summary of key operational information from this exercise, as well as additional information gathered by WDNR, is provided below for the units selected for further analysis and the facilities where they are located. A summary of the potential NOx and SO_2 control options for the units in Table 12 is provided below as well.

Characterization of Sources

As the EPA Guidance notes in Step 4(b), a state generally needs to use emissions information to estimate the emission reductions from the potential control measures it has identified for further evaluation. This information on emission reductions then feeds into the estimation of visibility benefits and into calculations of cost effectiveness.

The WDNR also considers source information from this step – which also is utilized in Section 3.6 for determining the emission reduction measures necessary to make reasonable progress – as part of documenting the technical basis on which the state is relying for that determination (see 40 CFR § 51.308(f)(2)(iii)). Table 12 provides a summary of this source characterization step along with WDNR comments for each unit regarding a potential four-factor analysis. A discussion and summary of key operational information then follows below for each unit.

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[20] See EPA Guidance, Section II.B.3.c) and f).

Table 12 – Summary of Unit Information for Wisconsin Units Selected for Further Analysis

EPA Facility ID	Facility Name	Unit ID	2016 Emissions (Tons)		2016 Q/d	2028 Modeled Emissions (Tons)		Future Control Description	Four-factor Analysis Comment
			NOx	SO_2		NOx	SO_2		
7692911	WPL – Edgewater	B24	821	2,983	12.2	0	0	Retired in 2018	No additional information or analyses needed
7692911	WPL – Edgewater	B25	486	2,998	11.0	0	0	Alliant Energy announced publicly that unit will retire in mid to late 2022	
6467811	A-M – Kaukauna	B11	1,070	5,213	22.0	1,070	5,213	2010 1-hour SO_2 NAAQS requirements	Proceed with information gathering and four-factor analyses
6467811	A-M – Kaukauna[a]	B09	239	920	4.06	239	920	2010 1-hour SO_2 NAAQS requirements	Proceed with information gathering and four-factor analyses
7048011	A-M – Rhinelander[b]	B26	1,145	1,596	12.2	1,145	1,596	2010 1-hour SO_2 NAAQS requirements	Proceed with information gathering and four-factor analyses

NAAQS = National Ambient Air Quality Standard

[a] Boiler B09 added to analysis because the electrostatic precipitator and exhaust stack (S09) for B11 is common with boiler B09, and B09 operates in tandem with B11 (i.e., if B11 uses less fuel, B09 uses more).

[b] Boiler B26 did not operate for two months during 2016 due to a facility project, therefore the 2016 emissions (and the associated Q/d value) and 2028 Modeled emissions for B26 are underestimated by about 20%.

WPL – Edgewater Generating Station

Alliant Energy - Edgewater Generating Station (Edgewater) is an existing coal-fired electric generating facility located in Sheboygan, Wisconsin. Until recently, Edgewater included three generating units with a total nameplate capacity of 770 megawatts (MW). Coal fired boiler B23 (Unit 3) retired on December 31, 2015. Coal fired boiler B24 (Unit 4) operated selective non-catalytic reduction for NOx control from 2011 until the boiler's retirement on September 30, 2018. Coal fired boiler B25 (Unit 5) with a nameplate capacity of 380 MW has operated a dry scrubber for SO_2 control since 2016, and selective catalytic reduction for NOx control since 2014. Moreover, Alliant Energy has announced publicly that B25 will be retired before 2023.[21] Since boiler B24 is retired, and boiler B25 is already well controlled and is expected to retire by 2023, no further analysis of additional emission control measures is necessary for these two units.

Ahlstrom-Munksjo – Kaukauna Mill

Ahlstrom-Munksjo (A-M) Kaukauna is a kraft pulp and paper mill that manufacturers unbleached pulp. Processes include kraft chemical recovery processes, paper machines, a boiler house and a wastewater treatment plant. The boiler house operation includes five steam generating units which provide steam for the mill production processes and electricity generation. The baseline information pertinent to further analysis of these units is provided in Table 13A. Boiler B07 is a stoker fired steam generating unit capable of burning multiple fuels and is equipped with a multi-cyclone and wet scrubber (for particulate matter control) in series. Boilers B08 and B10 are kraft recovery steam generating units capable of burning multiple fuels and equipped with an electrostatic precipitator (ESP). Boiler B09 is a single cyclone steam generating unit capable of combusting multiple fuels and is equipped with a multi-cyclone and ESP in series. Boiler B11 is a twin cyclone steam generating unit capable of combusting multiple fuels and is equipped with a multi-cyclone and ESP in series. The ESP and exhaust stack (S09) for B11 is common with boiler B09, and B09 operates in tandem with B11 (i.e., if B11 uses less fuel, B09 uses more). The SO_2 emissions from each of the boilers B09 and B11 are limited to 5.5 Lbs/mmBtu, averaged over 30 days, in Title V permit #445031180-P22.

Note that the primary emissions for this mill (SO_2) are already being addressed under the 2010 1-hour SO_2 National Ambient Air Quality Standard (NAAQS), which is expected to require a commitment to lower SO_2 emissions beyond the 2016 base year emission levels. This factor is considered further in Sections 3.5 and 3.6.

Ahlstrom-Munksjo – Rhinelander Mill

A-M Rhinelander is a paper mill with four paper machines producing a variety of specialty papers including greaseproof, label backing, and wet strength papers. The sulfite pulp mill was shut down in June 1984. The mill continues with its paper making operations using purchased pulp. The paper converting portion of the facility performs silicon coating, laminating, and other coating operations. Two natural gas-fired boilers and a coal fired cyclone boiler produce steam for the manufacturing operations with the cyclone boiler being the primary boiler. The SO_2

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[21] https://www.alliantenergy.com/AlliantEnergyNews/NewsReleases/NewsRelease052220.

emissions from coal boiler B26 is limited to 3.0 Lbs/mmBtu, averaged over 24 hours, in Title V permit #744008100-P22. Two steam generation turbines produce most of the electricity the facility needs. The baseline information pertinent to further analysis of these units is provided in Table 13B.

Note that, as with A-M Kaukauna, the primary emissions for this mill (SO_2) are already being addressed under the 2010 1-Hour SO_2 NAAQS, which is expected to require a commitment to lower SO_2 emissions beyond the 2016 base year emission levels. This factor is considered further in Sections 3.5 and 3.6.

Table 13A – Characterization of Unit-level Factors for A-M Kaukauna Mill

Parameter	B07	B08	B09	B10	B11	Stack S09 (B09 + B11)
Boiler type	Stoker	Kraft recovery	Single cyclone furnace	Kraft recovery	Twin cyclone furnace	
Installation year	1948	1953	1957	1961	1967	
Fuel capacity (mmBtu/hr)	204	206	192	322	379	
Primary fuel	Bark	Black liquor	Coal - bituminous	Black liquor	Coal - bituminous	
Secondary fuel(s)[a]	Other	Other	Petroleum coke, other	Other	Petroleum coke, other	
Current status	Firing bark	Firing black liquor	Firing coal	Firing black liquor	Firing coal	ESP, DSI
Baseline Operations (2016):						
Fuel consumption, calc. (1,000 mmBtu/yr)	705	1,544	839	2,095	2,597	3,436
Fuel sulfur content (% by wt)	0	1.3	Coal – 2.8 Coke – 4.0	1.3	Coal – 2.8 Coke – 4.0	3.0
SO_2 emissions (annual tons)	0	166	920	231	5,213	6,133
SO_2 annual emission rate, calc. (lbs/mmBtu)	0	0.22	2.19	0.22	4.01	3.57
SO_2 CEMS emission rate (lbs/mmBtu)	**Stack S09:** 4.58 – average daily maximum 3.84-4.40 – 30-day average maximum range (calc.)					
NOx emissions (annual tons)	64	78	239	100	1,070	1,309
NOx annual emission rate, calc. (lbs/mmBtu)	0.27	0.10	0.57	0.10	0.82	0.76

CEMS = Continuous Emissions Monitoring System
DSI = Dry Sorbent Injection

ESP = Electrostatic Precipitator

[a] Amount of pet coke fired in B09 and B11 is limited to 25% by weight. "Other" fuels include natural gas, residual fibers, #6 fuel oil, treatment plant sludge, and/or tire derived fuel.

Table 13B – Characterization of Unit-level Factors for A-M Rhinelander Mill

Parameter	B26[a]	B28	B30
Boiler type	Single Cyclone Furnace	Gas boiler	Gas boiler
Installation year	1958 (modified 1996)	1996	2014
Fuel capacity (mmBtu/hr)	300	280	95
Primary fuel	Bituminous coal	Natural gas	Natural gas
Secondary fuel(s)	None	Light liquid fuel	None
Current status	Firing coal	Firing natural gas	Firing natural gas
Baseline Operation (2016):			
Fuel consumption, calc. (1,000 mmBtu/yr)	1,688	705	131
Fuel sulfur content (% by wt)	1.24	0	0
SO_2 emissions (annual tons)	1,596	0	0
SO_2 annual emission rate, calc. (lbs/mmBtu)	1.89	0	0
NOx emissions (annual tons)	1,145	11	7
NOx annual emission rate, calc. (lbs/mmBtu)	1.36	0.03	0.10

[a] Note that boiler B26 did not operate for two consecutive months during 2016 due to a facility project, therefore operation and emissions for B26 are underestimated by about 20%.

Identification of Potential Control Measures

As part of the four-factor analysis work, LADCO contracted Amec Foster Wheeler to perform an analysis (2015 LADCO Four-Factor Analysis) of the economic and non-air quality environmental impacts of potential control scenarios that could be implemented by LADCO states to reduce emissions from large source categories of NOx and SO_2 in order to make reasonable progress toward meeting visibility improvement goals.[22] The purpose of the analysis was to present information that could be used by states to develop policies and implementation plans to address reasonable progress goals. The control options identified for industrial boilers at paper mills are summarized in Tables 14A and 14B.

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[22] "Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas." Report prepared for LADCO by Amec Foster Wheeler, Oct. 27, 2015. Available in Appendix 2.

Table 14A – Potential NOx Control Options for Industrial Coal Boilers at Paper Mills

Technology[a]	NOx Reduction
Boiler Tuning/ Optimization	5-15%
LNB	40-50%
LNB + OFA	40-60%
LNB + FGR	50-70%
SNCR	10-70%
RSCR	60-75%
ULNB	45-85%
SCR	70-90%

FGR = Flue Gas Recirculation
LNB = Low NOx Burner
OFA = Over-fire Air
RSCR = Regenerative Selective Catalytic Reduction
SCR = Selective Catalytic Reduction
SNCR = Selective Non-catalytic Reduction
ULNB = Ultra Low NOx Burner

[a] Description and applicability details for each technology can be found in Table 3-1 of the 2015 LADCO Four-Factor Analysis (see Appendix 2).

Table 14B – Potential SO_2 Control Options for Industrial Coal Boilers at Paper Mills

Technology[a]	SO_2 Reduction
Conventional Dry FGD – DSI	35-50%
Conventional Dry FGD – Spray Dryer	90-95%
Advanced FGD	95-99%
Wet FGD	90-99%

DSI = Dry Sorbent Injection
FGD = Flue Gas Desulfurization

[a] Description and applicability details for each technology can be found in Table 3-3 of the 2015 LADCO Four-Factor Analysis (see Appendix 2). Pre-combustion (e.g., fuel substitution) and combustion modifications (i.e., conversion to fluidized bed) were discussed briefly but not assessed in detail in the 2015 LADCO Four-Factor Analysis, due to highly variable costs determined by individual boiler characteristics and functions.

Characterization of the Four Factors

The EPA Guidance provides that after a state has identified the potential control measures for evaluation and the emissions information to be used in that evaluation for the sources selected in Step 3, a state should begin collecting information to characterize the four statutory factors required for consideration under 40 CFR § 51.308(f)(2)(i).

The 2015 LADCO Four-Factor Analysis compiled information from various reference sources on cost-effectiveness of retrofitting controls onto industrial coal boilers, and summarized the cost-effectiveness and factors affecting the cost of each control option. The report summarized the other statutory factors (time necessary for compliance, energy and non-air impacts, and remaining useful life) as well for industrial coal boilers.

In Round 1, WDNR also developed information on the availability, cost and effectiveness of controls (as well as the other statutory factors) for industrial coal boilers as part of implementing Best Available Retrofit Technology (BART) for a paper mill source.[23] The EPA Guidance provides that it may be appropriate for a state to rely on a previous BART analysis for the characterization of a factor, if the previous analysis was sound and no significant new information is available.[24] The WDNR used this BART information to supplement the 2015 LADCO Four-Factor Analysis, where appropriate. Details of how the BART information was used to inform characterization of the four factors for A-M Kaukauna and A-M Rhinelander can be found in Appendix 4.

Tables 15A and 15B present summaries of the four-factor analysis for NOx and SO_2 from the industrial coal boilers. Both the 2015 Amec analysis and the supplemental 2020 WDNR analysis (based on relevant BART experience) are provided for completeness. Detailed four-factor analysis results for individual control options considered are provided in Appendix 4.[25]

This four-factor information is considered further in Section 3.6, along with the required additional five factors (Section 3.5) and other factors, to determine what control measures are reasonable to meet the requirements for an LTS.

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[23] See Wisconsin's Round 1 Regional Haze SIP (pp 24-25), BART TSD for Non-EGUs, and Final BART Determination, available under "Regional Haze - Round 1" tab at https://dnr.wisconsin.gov/topic/AirQuality/Particles.html.

[24] See EPA Guidance, Section II.B.4.h) "Reliance on previous analysis and previously approved approaches," on p. 36.

[25] A-M Rhinelander provided comment that 1) many of these technologies, including FGD, could exceed the profit margin(s) of the facilities and, therefore, have the potential to force facility closures, and 2) FGD provides technical challenges with installation, as well as additional costs, that are not addressed in the four-factor analyses (see Appendix 9).

Table 15A – Summary of Results from Four-Factor Analysis for NOx

Analysis	Control Category	Cost-effectiveness (2019$/ton)
Amec/LADCO 2015 Analysis[a]	Combustion modifications	\$490-\$4,690
	Post-combustion	\$1,640-\$9,380[b]
WDNR 2020 Analysis based on G-P Green Bay mill BART[c]	Combustion modifications	\$225-\$1,103
	Post-combustion	\$1,680-\$2,770

G-P = Georgia Pacific

[a] Costs (\$/ton) from 2015 LADCO Four-Factor Analysis were adjusted to 2019 by multiplying by a factor 1.09, based on the 2020 Chemical Engineering Plant Cost Index. Also see Tables 1-1 and 3-2 of the 2015 LADCO Four-Factor Analysis (Appendix 2), which include details on compliance timeframe, energy and non-air quality environmental impacts, and remaining useful life.

[b] A value of \$17,000/ton was used for the upper end cost for SCR in Table 3-2 of the 2015 LADCO Four-Factor Analysis (Appendix 2), however the report also indicates that \$8,600 is the upper end cost for industrial coal boilers specifically.

[c] See Appendix 4 for how G-P BART analyses were used to estimate costs for the A-M Kaukauna mill and A-M Rhinelander mill boilers.

Table 15B – Summary of Results from Four-Factor Analysis for SO_2

Analysis	Control Category	Cost-effectiveness (2019 $/ton)
Amec/LADCO 2015 Analysis[a]	Clean fuels	Not included
	DSI	\$440-\$1,310
	Post-combustion	\$1,640-\$5,130
WDNR 2020 Analysis based on G-P Green Bay mill BART[b]	Clean fuels	Not included
	DSI	\$2,466-\$3,850
	Post-combustion	\$1,968-\$5,460

G-P = Georgia Pacific

[a] Costs (\$/ton) from 2015 LADCO Four-Factor Analysis were adjusted to 2019 \$/ton by multiplying by a factor 1.09, based on the 2020 Chemical Engineering Plant Cost Index (CEPCI). Also see Tables 1-1 and 3-4 of the 2015 LADCO Four-Factor Analysis (Appendix 2), which include details on compliance timeframe, energy and non-air quality environmental impacts, and remaining useful life.

[b] See Appendix 4 for how the G-P Green Bay mill BART analyses were used to estimate costs for A-M Kaukauna and A-M Rhinelander mill boilers.

Fifth Factor of Visibility Improvement

The following visibility improvement estimates are provided to demonstrate that additional SO_2 or NOx controls at the A-M Kaukauna mill or A-M Rhinelander mill would have a negligible impact on visibility at the Northern LADCO Class I Areas (see Appendix 2, Table A2-3 for Visibility Improvement Calculation Table).

The first scenario considers A-M Kaukauna, which accounts for approximately 23% of Wisconsin's total 2028 Modeled SO_2 emission and is expected to still be the largest source of SO_2 emissions in the state in 2028 (Tables 6 and 12). Considering Wisconsin's 1.0 Mm^{-1} particulate sulfate contribution to visibility impairment at Seney, the Class I Area most impacted by Wisconsin emissions (Table 8-6 of LADCO TSD, Appendix 2), it can be estimated that A-M Kaukauna is responsible for approximately 0.23 Mm^{-1} (~0.04 dv) of light extinction. Extending this calculation, A-M Kaukauna would similarly have a cumulative particulate sulfate contribution impact on the Northern LADCO Class I Areas of approximately 0.44 Mm^{-1} (~0.09 dv) (Table 8-6 of LADCO TSD, Appendix 2). Therefore, installation of a high-end SO_2 control (i.e., scrubbers) at A-M Kaukauna would not be expected to achieve a cumulative visibility improvement greater than ~0.09 dv at the Class I areas Wisconsin impacts.

A similar hypothetical scenario which considers additional SO_2 controls at A-M Rhinelander, which accounts for 6% of Wisconsin's SO_2 emissions (Tables 6 and 12), demonstrates that the maximum cumulative visibility improvement that could be achieved at Northern LADCO Class I Areas is 0.11 Mm^{-1} (~0.03 dv). Given that A-M Kaukauna and A-M Rhinelander each account for 1% of the state's 2028 NOx emissions (Tables 6 and 12), hypothetical NOx controls at A-M Kaukauna and A-M Rhinelander would achieve a maximum, cumulative visibility improvement through reduction in particulate nitrate contributions of 0.09 Mm^{-1} (~0.02 dv) at Northern LADCO Class I Areas.

Taken altogether, hypothetical, additional SO_2 and NOx controls that eliminated all of A-M Kaukauna's and A-M Rhinelander's emissions that contribute to particulate sulfate and nitrate would yield a cumulative visibility improvement of 0.65 Mm^{-1} (~0.14 dv), which accounts for approximately 9% of Wisconsin's cumulative contribution to visibility impairment to the Northern LADCO Class I Areas or only 0.3% of the total combined light extinction at the four Class I areas.

3.5. Consideration of the Five Additional Factors

Section 51.308(f)(2)(iv) of the Haze Rule requires that when developing its LTS, a state must consider five additional factors. However, the rule does not specify that these factors be considered at any particular step of developing the LTS. EPA's Guidance (Step 3(e)) says that as part of meeting the requirement to consider these five additional factors, a state may take one or more of them into consideration when it selects sources (see Section 3.4.1 of this haze SIP). Then if a state decides not to consider these factors during source selection, the subsequent analysis of control options provides another opportunity for states to meet the rule requirement to consider the five factors.

The five additional factors required for consideration under the Haze Rule are addressed below. These five factors are then considered further in Section 3.6, along with the information on the four statutory factors (Section 3.4) and other factors, to determine what control measures are reasonable to meet the requirements for a LTS.

3.5.1 Emission Reductions Due to Ongoing Air Pollution Control Programs

There are several ongoing federal and state air pollution control programs that have, and will continue to, contribute to Wisconsin's emission reductions (Section 3.3) and associated visibility improvements at the Northern LADCO Class I areas (Section 3.5.5) for Round 2. These programs are described below for the different sectors.

Point Sources

Ongoing point source control programs are particularly important to account for alongside the consideration of the four-factor information (Section 3.4) when making decisions on what control measures may be necessary to make reasonable progress for Round 2 (Section 3.6). Wisconsin point source emission reductions of NOx and SO_2 – the priority emissions from point sources being evaluated for Round 2 – are occurring from the Round 1 2018 Targets into the Round 2 timeframe due to various federal and state regulations or other permitting actions. Several important permanent and enforceable NOx and SO_2 emission control programs implemented in Wisconsin for point sources are listed here and discussed in more detail below:

- Federal transport rules for NOx and SO_2
- Wisconsin NOx Reasonably Available Control Technology (RACT) and NOx Reasonably Available Control Measures (RACM)
- Boiler Maximum Achievable Control Technology (MACT) and Title V permitting actions
- 2010 SO_2 NAAQS requirements

Federal Transport Rules for NOx and SO_2

Wisconsin EGU emission reductions of NOx and SO_2 from the Cross-State Air Pollution Rule (CSAPR) and its predecessor the Clean Air Interstate Rule are already included in the Round 1 2018 Target emissions. CSAPR implemented a first phase of NOx and SO_2 emission budgets in 2015 and 2016. However, the CSAPR Update Rule finalized in 2016 further reduced Wisconsin EGU NOx emissions during the ozone season starting in 2017. EPA also continues to evaluate non-EGUs for NOx emission reduction requirements under federal transport rules.

Wisconsin NOx RACT and NOx RACM

Wisconsin NOx RACT – Wisconsin has implemented NOx RACT for major NOx sources located in several southeast counties of Wisconsin as part of compliance requirements for the 2008 ozone NAAQS. The NOx RACT requirements are codified under ss. NR 428.20 to 428.25, Wis. Adm. Code and became applicable May 1, 2009. Specific lbs/mmBtu NOx emission limits apply to both new and existing NOx emission units located in Kenosha, Milwaukee, Ozaukee, Racine, Sheboygan, Washington, and Waukesha counties of Wisconsin that meet the applicability criteria listed in s. NR 428.21, Wis. Adm. Code. The applicable NOx emission limit for a specific NOx emitting unit is determined based on the type and the size of combustion unit and the type of fuel used.

Wisconsin NOx RACM – Wisconsin implemented RACM for NOx sources in the state's nonattainment areas for the 1997 ozone NAAQS. The NOx RACM requirements are codified under ss. NR 428.04 to 428.12, Wis. Adm. Code and became applicable in January 2001. Specific lbs/mmBtu NOx emission limits apply to both new and existing NOx emission units located in several southeast counties of Wisconsin, including Kenosha, Manitowoc, Milwaukee, Ozaukee, Racine, Sheboygan, Washington, and Waukesha counties, that meet the applicability criteria listed in ss. NR 428.04 and 428.05, Wis. Adm. Code.

The current version of chapter NR 428, Wis. Adm. Code was approved by EPA as the Wisconsin SIP revision in 75 FR 64155 on October 19, 2010. Therefore, the requirements in this chapter are considered federally enforceable and permanent.

Boiler MACT and Title V Permitting Actions

Compliance with the National Emission Standards for Hazardous Air Pollutant (NESHAP) for Industrial, Commercial, and Institutional Boilers and Process Heaters (Boiler MACT) has led to significant reductions in NOx and SO_2 for Wisconsin non-EGUs, due to control measures such as converting/repowering from coal to natural gas or process gas, boiler heat input limitations, and installation of DSI equipment. Additional permitting actions not necessarily associated with any state or federal regulation have also led to significant reductions of NOx and SO_2 emissions. Some Wisconsin EGUs have recently retired or are scheduled for early retirement within the Round 2 timeframe (see Section 3.5.3), achieving emission reductions beyond those required to comply with CSAPR and the CSAPR Update or other federal regulations. These additional reductions in NOx and SO_2 emissions have further improved visibility at the Northern LADCO Class I areas for Round 2. These reductions are reflected partially in LADCO's 2016 Base emissions, and more fully in the 2019 actual emissions and LADCO's 2028 Modeled (and WDNR 2028 Adjusted) projections (see Section 3.3). Appendix 3 provides the most recent committed control measures and emission limitations that have contributed to emission reductions from Round 1 into Round 2 at these sources.

2010 SO_2 NAAQS Requirements

In 2010, the EPA revised the primary SO_2 NAAQS, setting a 1-hour standard of 75 ppb. EPA then undertook a multi-round process to make initial area designations for this NAAQS. In August 2013, in Round 1 of its designations, EPA designated a portion of Oneida County as nonattainment for this NAAQS, with the AM-Rhinelander mill being a primary source of SO_2 emissions in that area. In December 2020, in Round 4 of its designations, EPA finalized a designation of nonattainment for part of Outagamie County, identifying the A-M Kaukauna mill as the primary SO_2 source in that area. Based on certified 2018-2020 SO_2 monitoring data that demonstrates attainment of the 2010 SO_2 NAAQS, EPA changed the designation of this area to "attainment" effective April 30, 2021 (86 FR 19576). In part as a response to these actions, both sources have demonstrated reduced SO_2 emissions from both the Round 1 2018 Target emissions and the Round 2 2016 Base emissions, and both of the areas designated by EPA are now meeting the 2010 SO_2 NAAQS. A number of Wisconsin facilities are also subject to required SO_2 modeling in air permits to demonstrate compliance with this NAAQS (see Appendix 3), pursuant to Ch. NR 404, Wis. Adm. Code.

A-M Rhinelander Mill

As mentioned above, A-M Rhinelander has made significant SO_2 reductions from the Round 1 2018 Target emissions and Round 2 2016 Base year emissions. The mill decommissioned four coal-fired stoker boilers in 2016, representing a permanent and enforceable reduction of 326 mmBtu/hr and permitted 1,780 tons/yr SOx. The mill has shut down coal boiler B26 for five consecutive months out of the year, and essentially replaced the steam demand with increased operation of the natural gas boilers, each year since 2016 (which has also achieved significant NOx reductions). The mill has also fired slightly lower sulfur coal in recent years. These actions have resulted in significant emission reductions (shown in Section 3.6.1).

The WDNR has been actively engaged with A-M Rhinelander and EPA to resolve approvability issues related to WDNR's attainment SIP for this NAAQS, submitted to EPA in January 2016 (see WDNR's Sept. 10, 2020 letter to EPA Region 5, found in Appendix 5). The 2010 SO_2 NAAQS emission requirements for A-M Rhinelander were made permanent and federally enforceable through Construction Permit Revision 15-DMM-128-R1 and the supplemental attainment plan SIP revision submitted to EPA on March 29, 2021.[26] Permit 15-DMM-128-R1 was issued on March 25, 2021, with an effective date of December 31, 2021. The proposed SIP includes a permanent and enforceable reduction in allowable SOx of 1,232 tons/yr. The new 2.38 Lbs/mmBtu 24-hr SO_2 limit in the permit for coal boiler B26 is a 32% reduction from the 3.50 Lbs/mmBtu 24-hr SO_2 permitted limit associated with the Round 1 target. Together, these two additional pieces of information support that projected 2028 emissions similar to the demonstrated 2017-2019 emissions are more reasonable to expect than the 2028 Modeled emissions.

Since EPA determined that both RACT and RACM are the levels of emission reduction necessary to demonstrate attainment with this NAAQS, these emission requirements will also fulfill RACT and RACM obligations for the facility.

A-M Kaukauna Mill

As mentioned above, A-M Kaukauna has significantly reduced SO_2 from the Round 1 2018 Target emissions and Round 2 2016 base year emissions. The mill has not fired high-sulfur petroleum coke in coal boilers B09 and B11 since 2016, and petroleum coke is currently not on site at the facility.[27] The mill also has fired only natural gas in boiler B09 since April 2019. These emission reductions are shown in Section 3.6.1, and are also reflected in the stack S09 (i.e., B09+B11) SO_2 average daily maximum emission rate being reduced from 4.58 Lbs/mmBtu

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[26] EPA proposed approval of the supplemental attainment plan for the Rhinelander 2010 SO_2 NAAQS nonattainment area on July 22, 2021 (86 FR 38643).

[27] See Permit 445031180-P22 (pp 74-76) which includes a consent order with EPA (EPA-5-16-113(a)-WI-01) regarding fugitive dust from petroleum products, and requires that the mill will not have petroleum coke delivered to the mill after Sept 2016 unless an appropriate wind fence or PM_{10} monitor is installed.

in 2016 to 3.11 Lbs/mmBtu in 2019 (annual average rate was reduced from 3.57 (calc.) to 2.85 (calc.) over the same period).

A-M Kaukauna is also scheduled to have its Title V operation permit renewed in 2021. This permit renewal will require SO_2 NAAQS attainment modeling, along with associated permit emission limitations. The permit renewal application includes significantly lower coal sulfur content and significantly lower PTE emission estimates compared to the current permit. These anticipated reductions were not incorporated into the 2028 Modeled emissions, and this supports that projected 2028 emissions similar to or below the demonstrated 2017-2019 emissions are more reasonable to expect than the 2028 Modeled emissions.

Mobile Sources – Onroad

Both NOx and VOC emissions from onroad mobile sources are substantially controlled through federal new vehicle emission standards programs and fuel standards. These regulations have continued to reduce emissions nationwide as fleets turn over to newer vehicles. The federal onroad control programs are listed in Table 16.

Table 16 – Federal Onroad Mobile Source Regulations

On-road Control Program	Pollutants	Model Year[a]	Regulation
Passenger vehicles, SUVs, and light duty trucks – emissions and fuel standards	VOC & NOx	2004 – 2009+ (Tier 2) 2017+ (Tier 3)	40 CFR Part 85 & 86
Light-duty trucks and medium duty passenger vehicle – evaporative standards	VOC	2004 - 2010	40 CFR Part 86
Heavy-duty highway compression engines	VOC & NOx	2007+	40 CFR Part 86
Heavy-duty spark ignition engines	VOC & NOx	2005 – 2008+	40 CFR Part 86
Motorcycles	VOC & NOx	2006 – 2010 (Tier 1 & 2)	40 CFR Part 86
Mobile Source Air Toxics – fuel formulation, passenger vehicle emissions, and portable container emissions	Organic Toxics & VOC	2009 – 2015[b]	40 CFR Part 59, 80, 85, & 86
Light duty vehicle corporate average fuel economy (CAFE) standards	Fuel efficiency (VOC and NOx)	2012 – 2016 & 2017 – 2025	40 CFR Part 600

[a] The range in model years affected can reflect phasing of requirements based on engine size or initial years for replacing earlier tier requirements.
[b] The range in model years reflects phased implementation of fuel, passenger vehicle, and portable container emission requirements as well as the phasing by vehicle size and type.

The Wisconsin-administered inspection and maintenance (I/M) program also limits on-road VOC and NOx emissions from onroad sources and is required for southeastern counties of the state. The Wisconsin I/M program was first implemented in 1984 and has gone through several modifications and enhancements since that time. The I/M program requirements are codified in chs. NR 485 and Trans 131, Wis. Adm. Code. The I/M program reduces average vehicle VOC and NOx emissions and garners some level of continued incremental reduction as fleets turn over to new vehicles.

The CAA has required the use of reformulated gasoline (RFG) in the southeast Wisconsin counties of Kenosha, Milwaukee, Ozaukee, Racine, Washington, Waukesha since 1995 [42 U.S.C. 7545(k)(10)(D)]. Wisconsin counties are in Phase II of the RFG program, which began in 2000, and builds upon the initial phase of the RFG program to further improve air quality. As with the I/M program, the RFG program reduces average vehicle NOx and VOC emissions and offers some level of continued incremental reduction as fleets turn over to new vehicles.

Mobile Sources – Nonroad

Similar to onroad sources, VOC and NOx emitted by nonroad mobile sources are significantly controlled via federal standards for new engines. These programs reduce emissions nationwide. Table 17 lists the nonroad source categories and applicable federal regulations. The nonroad regulations continue to slowly lower average unit and total sector emissions as equipment fleets are replaced each year (often 20 years or longer for complete fleet turnover) pulling the highest emitting equipment out of circulation or substantially reducing its use. The new engine tier requirements are implemented in conjunction with fuel programs regulating fuel sulfur content. The fuel programs enable achievement of various new engine tier VOC and NOx emission limits. The RFG program noted in the onroad control measures subsection also contributes to lower NOx and VOC emissions from the nonroad mobile sector.

Table 17 – Federal Nonroad Mobile Source Regulations

Nonroad Control Program	Pollutants	Model Year[a]	Regulation
Aircraft	HC & NOx	2000 – 2005+	40 CFR Part 87
Compression Ignition[b]	NMHC & NOx	2000 – 2015+ (Tier 4)	40 CFR Parts 89 & 1039
Large Spark Ignition	HC & NOx	2007+	40 CFR Part 1048
Locomotive Engines	HC & NOx	2012 – 2014 (Tier 3) 2015+ (Tier 4)	40 CFR Part 1033
Marine Compression Ignition	HC & NOx	2012 – 2018	40 CFR Part 1042
Marine Spark Ignition	HC & NOx	2010+	40 CFR Part 1045
Recreational Vehicle[c]	HC & NOx	2006 – 2012 (Tier 1 – 3) (phasing dependent on vehicle type)	40 CFR Part 1051
Small Spark Ignition Engine[d] < 19d Kw – emission standards	HC & NOx	2005 – 2012 (Tier 2 & 3)	

HC – Hydrocarbon (VOCs)
NMHC – Non-Methane Hydrocarbon (VOCs)
[a] The range in model years affected can reflect phasing of requirements based on engine size or initial years for replacing earlier tier requirements.
[b] Compression ignition applies to diesel non-road compression engines including engines operated in construction, agricultural, and mining equipment.
[c] Recreational vehicles include snowmobiles, off-road motorcycles, and ATVs.
[d] Small spark ignition engines include engines operated in lawn and hand-held equipment.

Area Sources

Wisconsin has implemented many VOC RACT/Control Techniques Guidelines (CTGs) rules under chs. NR 419 through 424, Wis. Adm. Code. A number of these rules limit VOC emissions from area sources. There are also a number of federal programs in place which reduce area source VOC emissions. VOC emission standards for consumer and commercial products were promulgated under 40 CFR Part 59. This program will continue to limit VOCs emitted from this source category. Another federal rule, the area source hazardous air pollutant control rule, also controls area source VOC emissions associated with fuel storage and transfer activities (40 CFR 63, Subparts R, BBBBBB, and CCCCCC).

3.5.2 Measures to Mitigate the Impacts of Construction Activities

In consideration of construction activities and their effect on regional haze, construction activities in Wisconsin are subject to federal non-road standards for construction equipment and vehicles. The impact of construction activities will continue to be mitigated through the federal general conformity and transportation conformity rules. For the construction of new major sources, the visibility impacts of such sources will continue to be managed in conformance with existing requirements pertaining to New Source Review (NSR) and Prevention of Significant Deterioration (PSD). This involves analysis of visibility impacts and consultation with FLMs in determining if a new major source or major modification is installing Best Available Control

Technology, and if it may have an adverse impact on visibility in Class I areas. The WDNR commits to ensuring that permitting of new and modified sources through Wisconsin's NSR program is consistent with making reasonable progress toward the visibility goals of the Round 2 haze SIP. Source retirement and replacement schedules, which must be considered by a state when developing its LTS (40 CFR § 51.308(f)(2)(iv)(C)), will be managed to comply with existing requirements under the PSD program.

Additionally, WDNR has authority to regulate and enforce fugitive dust and particulate matter emissions from direct and portable sources and construction areas within the state. Section NR 415.03, Wis. Adm. Code, contains general limitations for particulate matter emissions and s. NR 415.04, Wis. Adm. Code, contains fugitive dust requirements that apply to all sources, regardless of if the code sections are referenced in a source's air permit, if the source is not required to have an air permit, or if the source is already subject to PSD.

3.5.3 Source Retirement and Replacement Schedules

Information on recent and upcoming Wisconsin point source EGU and non-EGU retirements/replacements is provided in Appendix 3. This information is also reflected in Section 3.3 for Wisconsin point source emission reductions trends. Most of the known Wisconsin EGU retirements have been included in LADCO's 2028 Modeled emissions, with the exception of the recently announced shutdowns of We Energies South Oak Creek power plant and Alliant Energy Columbia power plant.[28,29] Several non-EGU coal boilers have also been retired and in some cases replaced by gas boilers. These shutdowns and replacements continue to contribute to Wisconsin's emission reductions and the associated visibility improvements at the affected LADCO Northern Class I areas for Round 2.

3.5.4 Basic Smoke Management Practices for Prescribed Fire Burns

The WDNR has worked with land managers in the state to prepare a plan to address controllable fire activities that can impact visibility locally. Appendix 6 contains the "Wisconsin Smoke Management Plan: Best Management Practices for Prescribed Burns" (April 2021).

3.5.5 Anticipated Net Effect on Visibility

The visibility improvement at the Northern LADCO Class I Areas expected during Round 2 is calculated from LADCO's 2028 modeling (Appendix 2), which accounts for on-the-books and on-the-way controls, and include scheduled EGU shutdowns that were publicly announced as of September 2020. Current visibility conditions at the Northern LADCO Class I Areas on the most impaired days are below their respective glidepaths (Figure 3). LADCO's 2028 projections are similarly below the glidepath at the end of Round 2 (Figure 3). Current visibility conditions on the clearest days have also shown continued improvement relative to baseline conditions (Figure

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[28] See https://www.jsonline.com/story/money/business/energy/2020/11/06/we-energies-plans-shut-down-oak-creek-power-plant-2024/6191575002/.

[29] See https://madison.com/wsj/news/local/environment/columbia-power-plant-to-close-by-2025-ending-coal-fired-power-in-portage/article_14aa87c2-7984-5ff6-9815-a7fd1eb7d65c.html#tracking-source=home-top-story-1.

2). Table 18 lists the expected improvement in visibility on the most impaired days over the course of Round 2 at the Northern LADCO Class I Areas. As noted in Section 3.7, an even larger improvement in visibility will be achieved by the end of Round 2 than is presented in Table 18, due to the implementation of additional control measures in Wisconsin that are not included in LADCO's 2028 Modeled emissions.

Table 18 – Anticipated Improvement in Visibility (in deciviews) over Round 2 on the Most Visibly Impaired Days

Northern LADCO Class I Areas	Current (2014-2018) Visibility	Modeled 2028 Visibility	Expected Round 2 Improvement
Isle Royale	15.54	14.97	0.57
Seney	17.57	16.94	0.63
Boundary Waters	13.96	13.46	0.50
Voyageurs	14.18	13.74	0.44

3.6. Decisions on Control Measures Necessary to Make Reasonable Progress

Section 51.308(f)(2) of the Haze Rule requires that each state must submit an LTS that addresses regional haze visibility impairment for each Class I area within the State and for each Class I area located outside the State that may be affected by emissions from the State. The LTS must include the enforceable emissions limitations, compliance schedules, and other measures that are necessary to make reasonable progress, as determined pursuant to (f)(2)(i) through (iv).

After considering information for the four statutory factors (Section 3.4), the required additional five factors (Section 3.5), and other factors as described below, WDNR has determined that the following measures – which are beyond those included for the Round 1 SIP – are reasonable to meet the requirements for an LTS for Round 2. This determination is further discussed below.

- On-the-books retirements at Wisconsin coal EGUs
- On-the-books controls affecting Wisconsin mobile sources
- Permitted control requirements and shutdowns at non-EGU point sources
- SO_2 NAAQS requirements for A-M Kaukauna, A-M Rhinelander and other Wisconsin non-EGU point sources

3.6.1 Consideration of Four-Factor Analyses and Required Additional Five Factors

The initial results of the four-factor analyses for NOx and SO_2 at A-M Kaukauna and A-M Rhinelander are provided in Section 3.4. These results indicate that for SO_2, additional controls in the range of operation of the existing DSI equipment at full capacity, up to installation of

Advanced FGD, could be cost-effective for addressing visibility impairment.[30] The results also indicate that for NOx, additional controls in the range of combustion modifications, up to SNCR, could be cost-effective for addressing visibility impairment. (As noted in Section 3.4.2, while determined to be potentially cost-effective, public comment has been received indicating that many of these NOx and SO_2 control technologies may not be affordable to facilities and could force facility closures if required – see Appendix 8.) However, the cost-effectiveness of any additional control measures based on the four-factor analyses is only one element to consider for what additional measures, if any, should be required for Round 2 reasonable progress. Before considering cost-effectiveness any further, weight should first be given to the following factors and considerations, as allowed for in the Haze Rule and discussed previously (Sections 3.2, 3.3 and 3.5) and further below:

- Emission reductions from the Round 1 2018 Target emissions through the Round 2 2028 Modeled and 2028 Adjusted projections for the point source sector
- Potential future projects and impacts during the Round 2 timeframe
- The Round 2 URPs already being met for 2028, and even the Round 3 URPs already being met for 2038 according to the LADCO modeling "adjusted" glidepaths
- Fifth factor of visibility improvement estimates from additional controls

As detailed in Section 3.5.1, the primary emissions for the A-M Kaukauna and A-M Rhinelander mills – SO_2 – are already being addressed under the 2010 1-hour SO_2 NAAQS (to be implemented during the Round 2 time period), and these facilities have already demonstrated SO_2 (and NOx) reductions from their Round 1 2018 Targets as well as from the Round 2 2016 Base year emissions. Tables 19A and 19B show the historic and 2028 Modeled emission reductions for these facilities from Round 1 through Round 2. Emissions of NOx and SO_2 at A-M Rhinelander are expected to decrease by more than 48% and 56%, respectively, from the Round 1 2018 Targets through 2028, based on recent demonstrated emissions. Facility emissions of NOx and SO_2 at A-M Kaukauna are expected to decrease by more than 23% and 46%, respectively (32% and 48% for the B09+B11 stack), from the Round 1 2018 Targets through 2028, based on recent demonstrated emissions. The recent demonstrated emissions at A-M Rhinelander and A-M Kaukauna are more reasonable to expect than the 2028 Modeled emissions, as shown in Section 3.5.1. As shown in Tables 19A and 19B, these emission reductions are expected to occur with only a slight decrease (or even a slight increase) in heat input, demonstrating that the reductions are not due to decreased operation at the facilities. Moreover, WDNR provided visibility improvement estimates in Section 3.4.2 to demonstrate that any additional SO_2 or NOx controls at A-M Kaukauna or A-M Rhinelander would have a negligible impact on visibility at the Northern LADCO Class I Areas. Finally, a number of other Wisconsin facilities are also subject to required SO_2 modeling in their air permits to demonstrate compliance with the 2010 SO_2 NAAQS, as mentioned in Section 3.5.1.

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[30] Although WDNR did not find it necessary to determine a threshold for what could be deemed "cost-effective" for point sources for this Round 2 haze SIP, some possible reference points from other CAA requirements for similar existing point sources could be: CSAPR Update proposed revisions ($1,600/ton); CSAPR ($500 – $1,300/ton), Wisconsin BART for NOx and SO2 ($1,200 – $1,900/ton); Wisconsin NOx RACT ($1,200 – $2,500/ton).

The WDNR concludes that, when weighing the four-factor analyses against the consideration of the five additional required factors, it is unnecessary to require any additional controls at A-M Kaukauna or A-M Rhinelander to meet Round 2 regional haze SIP requirements.

Table 19A – Comparison of Round 1 and Round 2 Operation and Emissions for A-M Rhinelander Mill

Unit	Round 1 SIP (2005-2018)		Round 2 SIP (2019-2028)		
	2005 Base	2018 Target	2016 Base[a]	2019 Actual	2028 Modeled[a,b]
	NOx (annual tons)				
B26	1,562	1,562	1,145	811	1,145
Facility total	**1,618**	**1,618**	**1,168**	**847**	**1,168**
Facility Progress from Round 1 2018 Target (% Change)	**---**	**---**	**-28%**	**-48%**	**-28%**
	SO_2 (annual tons)				
B26	2,354	2,354	1,596	1,067	1,596
Facility total	**2,451**	**2,451**	**1,596**	**1,067**	**1,596**
Facility Progress from Round 1 2018 Target (% Change)	**---**	**---**	**-35%**	**-56%**	**-35%**
	Facility Heat Input (1,000 mmBtu)				
Coal	2,405	2,405	1,688	1,196	1,688
Natural gas	297	297	836	1,370	836
Total	**2,702**	**2,702**	**2,525**	**2,566**	**2,525**
% Change from Round 1 2018 Target	**---**	**---**	**-6.6%**	**-5.0%**	**-6.6%**

[a] Boiler B26 did not operate for two months during 2016 due to a facility project, therefore operation and emissions for B26 are underestimated by about 20% for 2016 Base and 2028 Modeled.

[b] 2028 Modeled emissions are conservative. 2028 actual emissions are expected to be at or below 2019 operation and emissions (2017 and 2018 were similar to 2019 as well, therefore these lower emissions are well demonstrated).

Table 19B – Comparison of Round 1 and Round 2 Operation and Emissions for A-M Kaukauna Mill

Unit	Round 1 SIP (2005-2018)		Round 2 SIP (2019-2028)		
	2005 Base	2018 Target	2016 Base	2019	2028 Modeled[a]
	NOx (annual tons)				
B09	551	551	239	219	239
B11	1,218	1,218	1,070	990	1,070
Facility total	**2,019**	**2,019**	**1,578**	**1,560**	**1,578**
Facility Progress from Round 1 2018 Target (% Change) (B09+B11 % Change)	---	---	**-22%** (-26%)	**-23%** (-32%)	**-22%** (-26%)
	SO_2 (annual tons)				
B09	2,726	2,726	920	570	920
B11	6,040	6,040	5,213	3,971	5,213
Facility total	**9,090**	**9,090**	**6,532**	**4,898**	**6,532**
Facility Progress from Round 1 2018 Target (% Change) (B09+B11 % Change)	---	---	**-28%** (-30%)	**-46%** (-48%)	**-28%** (-30%)
	Facility Heat Input (1,000 mmBtu)				
Coal + petroleum coke	3,486	3,486	2,837	2,341	2,837
Coal throughput (1,000 tons)	*(119)*	*(119)*	*(99)*	*(111)*	*(99)*
Coke throughput (1,000 tons)	*(30)*	*(30)*	*(21)*	*(0)*	*(21)*
Natural gas	93	93	932	744	932
Black liquor solids	2,856	2,856	3,537	3,682	3,537
Bark/paper broke	849	849	475	692	475
Total	**7,283**	**7,283**	**7,781**	**7,460**	**7,781**
% Change from Round 1 2018 Target	**---**	**---**	**+6.8%**	**+2.4%**	**+6.8%**

[a] 2028 Modeled emissions are conservative. 2028 actual emissions are expected to be at or below 2019 operation and emissions (2017 and 2018 were similar to 2019 as well, therefore these lower emissions are well demonstrated). The 2019 operation includes no high-sulfur petroleum coke in B09 and B11 (pet coke has not been fired since 2016, and pet coke is not currently on site at the facility). Also, B09 has only fired natural gas since April 2019.

3.6.2 Consideration of Other Factors

Section 51.308(f)(2)(ii) of the Haze Rule requires that a State must consult with those States that have emissions that are reasonably anticipated to contribute to visibility impairment in the Class I area to develop coordinated emission management strategies containing the emission reductions necessary to make reasonable progress.

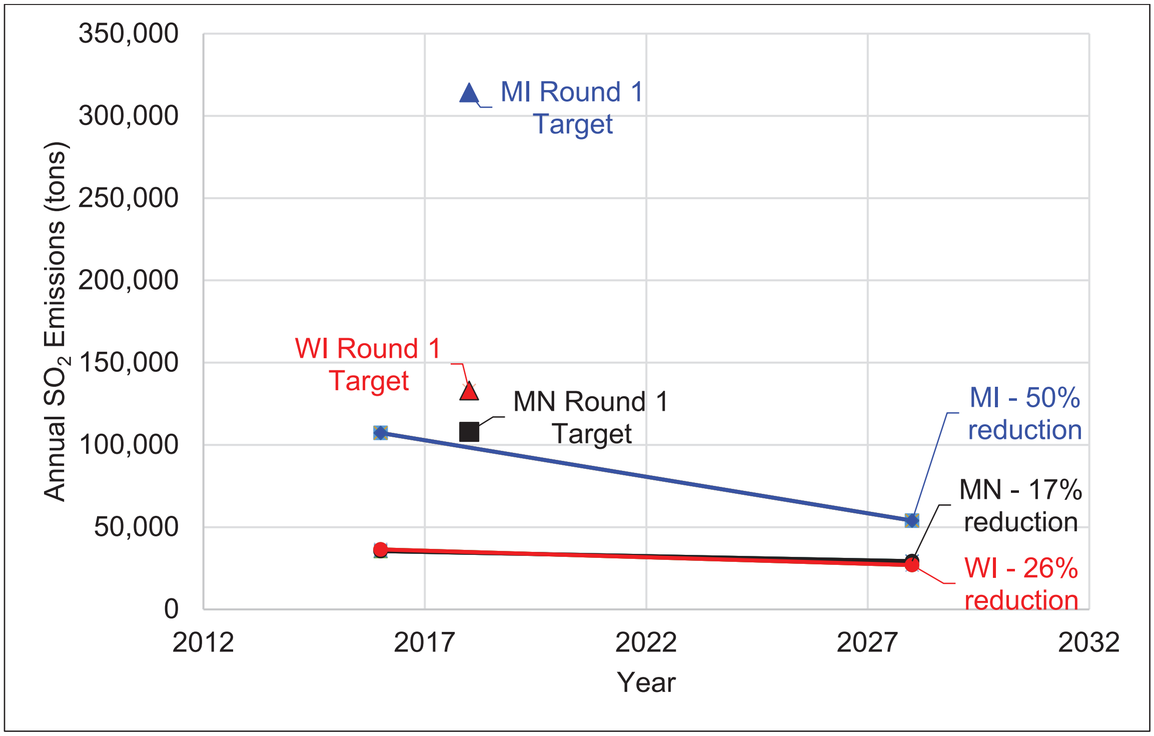
Meeting Identified Contribution and Reduction Obligations

To determine Wisconsin's share of visibility improvement needed to make reasonable progress in the Northern LADCO Class I Areas, WDNR considered the magnitude of, and expected reduction in, Wisconsin's SO_2 and NOx emissions over the second planning period relative to those from Michigan and Minnesota. Additionally, WDNR considered the relative impact of emissions from the three states on visibility impairment in the Northern LADCO Class I Areas (Table 2). Minnesota emissions contribute significantly more than do Michigan's and Wisconsin's to visibility impairment at its Class I areas, Boundary Waters and Voyageurs. Wisconsin, Illinois, and Michigan's emissions contribute approximately equally to Michigan's Class I area, Seney. Wisconsin and Minnesota approximately equally contribute to visibility impairment at Michigan's Class I area, Isle Royale.

Figure 6A shows that the magnitude of Wisconsin SO_2 emissions are comparable to Minnesota and are expected to decrease at a slightly faster rate than Minnesota's emissions. Michigan's SO_2 reductions are expected to outpace those of Minnesota and Wisconsin; however, Michigan's total SO_2 emissions are over two times greater than Minnesota's and Wisconsin's emissions at the beginning of the second planning period. All three state's 2016 SO_2 emissions are significantly lower than the 2018 emissions targets set in their respective Round 1 haze SIPs. Figure 6B shows that Wisconsin's 2016 NOx emissions are approximately 50,000 tons and 100,000 tons lower than NOx emissions from Minnesota and Michigan, respectively. NOx emissions in all three states are expected to decrease at approximately the same rate over the second planning period. Further, as previously identified in Sections 3.3.3 and 3.6.1, Wisconsin's point source emissions are expected to be significantly lower than those shown in Figures 6A and 6B.

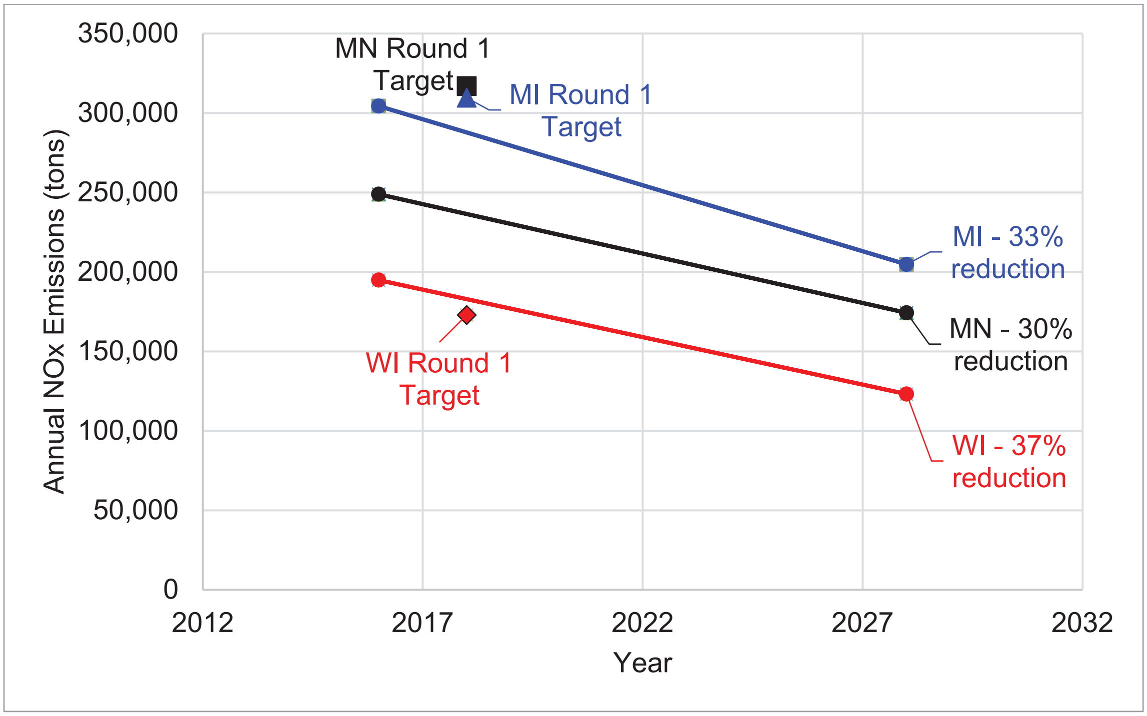
Considering Wisconsin's relative contribution to visibility impairment at the Northern LADCO Class I Areas and the magnitude and expected reduction in its SO_2 and NOx emissions, WDNR determined that Wisconsin is meeting its share of emission reductions needed to make reasonable progress for the second planning period.

Figure 6A – SO_2 Emissions in 2016 and 2028 for MI, MN, and WI[a,b]



[a] MI, MN, and WI SO_2 emissions for the 2016 and 2028 inventory years are from the LADCO TSD (Appendix 2).
[b] Round 1 2018 emissions targets are from MI, MN, and WI's Round 1 haze SIPs.

Figure 6B – NOx Emissions in 2016 and 2028 for MI, MN, and WI[a,b]



[a] MI, MN, and WI SO_2 emissions for the 2016 and 2028 inventory years are from the LADCO TSD (Appendix 2).
[b] Round 1 2018 emissions targets are from MI, MN, and WI's Round 1 haze SIPs.

Meeting "Asks" by Other States

As noted in Section 3.1, LADCO states provided updates on progress made in preparing their regional haze SIP revisions for the second implementation period during monthly LADCO Regional Haze Workgroup calls. These updates covered topics such as, states' SIP development timelines and four factor analysis progress, including source screening criteria and sources brought forward for analysis. The WDNR also notified LADCO states when Wisconsin's proposed Round 2 haze SIP was posted for public comment (Section 4.2). The WDNR did not receive any emissions reduction "asks" by another state in which a Class I area is located.

The WDNR had a conversation with Minnesota on June 8, 2021. Minnesota stated that any "ask" to states would likely be based on the results of Minnesota's source apportionment modeling, which has not yet been completed. Minnesota indicated a potential "ask" might be to request that states evaluate large, industrial coal-fired emissions units. Although Minnesota has not provided such an "ask," WDNR notes that this SIP revision contains four-factor analyses for emissions units that would likely fall into the category identified by Minnesota.

3.6.3 Conclusion and Long-term Strategy Requirements

Based on the information provided in this submittal, additional controls of emissions at Wisconsin sources are not necessary to meet regional haze progress for the second planning period. WDNR's demonstration of reasonable progress is based on measures that go beyond those included for the first planning period. Therefore, to fulfill its long-term strategy requirements, WDNR will continue to require the emission limits, averaging periods, monitoring and record keeping requirements, and compliance deadlines associated with regulations and permitting requirements already in place for Wisconsin's emission sources.

3.7. Reasonable Progress Goals

Section 51.308(f)(3)(ii)(B) of the Haze Rule requires that a state containing sources which are reasonably anticipated to contribute to visibility impairment in a Class I area in another State for which a demonstration by the other State is required under section 51.308(f)(3)(ii)(A), the State must demonstrate that there are no additional emission reduction measures for anthropogenic sources or groups of sources in the State that may reasonably be anticipated to contribute to visibility impairment in the Class I area that would be reasonable to include in its own long-term strategy. A demonstration is required under section 51.308(f)(3)(ii)(A) if a State in which a Class I area is located establishes a reasonable progress goal for the most impaired days that provides for a slower rate of improvement in visibility than the uniform rate of progress calculated under section 51.308(f)(2)(vi).

Under section 51.308(f)(3)(ii)(B) of the Haze Rule and Step 7B of the EPA Guidance, states that contain sources which are reasonably anticipated to contribute to visibility impairment in a Class I area in another state must conduct a "URP glidepath check" to determine if the RPG provide for a rate of improvement in visibility that is consistent with the 2028 point on the URP glidepath. Table 20 lists RPGs for the Northern LADCO Class I Areas. The RPGs are based on LADCO's 2028 visibility projections, which account for on-the-books and on-the-way controls, which include scheduled EGU shutdowns that were publicly announced as of September 2020. The RPGs for the most impaired days provide for a faster rate of improvement than that established by the URP glide paths (Table 20); thus, a demonstration is not required under section 51.308(f)(3)(ii). Additionally, visibility conditions on the clearest days have continued to improve since the baseline period (Figure 2).

Table 20 – Comparison of the Uniform Rate of Progress with Reasonable Progress Goals (in deciviews) for Northern LADCO Class I Areas for the Second Implementation Period.

Northern LADCO Class I Areas	URP at 2028	RPG based on 2028 Visibility Modeling	RPG – URP for 2028
Isle Royale	15.85	14.97	-0.88
Seney	18.59	16.94	-1.65
Boundary Waters	14.69	13.46	-1.23
Voyageurs	14.48	13.74	-0.74

The 2028 URP points presented in Table 20 correspond to the unadjusted URP glidepaths (Figure 3). As mentioned in Section 3.2.4 of this SIP, the Northern LADCO Class I Areas are expected to meet URP conditions for Round 2 regardless of whether the unadjusted or adjusted glidepaths are considered (Figure 3, Table 20), and as such, glidepath adjustments for Round 2 are not necessary. If the adjusted URP glidepaths are considered, however, the Round 2 RPGs for the Northern LADCO Class I Areas also meet the 2038 URP glidepath points, which correspond to the end of the third implementation period (Figure 3).

Furthermore, it is likely that actual visibility conditions at the end of Round 2 will be better than the RPGs listed in Table 20. Additional reductions are expected from the point source sector, as described in Section 3.3.3 of this SIP, which were not considered by LADCO when simulating Wisconsin's Round 2 LTS. Section 51.308(f)(3)(i) of the Haze Rule says that emission control measures implemented to meet other requirements of the CAA may be considered in a state's LTS. Emissions reductions are expected to result from permanent and enforceable control measures implemented within the state to meet nonattainment area requirements under the SO_2 NAAQS. These control measures were not identified at the time LADCO conducted 2028 visibility modeling for the region. The WDNR's LTS is sufficient for meeting the RPGs for the four Northern LADCO Class I Areas.

3.8. Periodic Implementation Planning and Adequacy

Section 51.308(f) of the Haze Rule requires states to revise their regional haze implementation plan and submit a plan revision to the EPA by July 31, 2021, and every ten years thereafter. Approximately halfway through each implementation period, section 51.308(g) requires periodic reports evaluating progress towards the RPGs established for each Class I area, with potential follow-up actions listed in section 51.308(h).

Wisconsin's LTS contains enforceable emission reduction measures that are expected to achieve the Round 2 RPGs identified for 2028 (Table 20). To comply with section 51.308(f) of the Haze Rule, WDNR commits to reassessing and revising its RPGs in 2028 and every 10 years thereafter. The WDNR will also continue to maintain its monitoring networks, develop emissions inventories, and submit the required progress reports and SIP revisions for future implementation periods of the Regional Haze Program. The next progress report, due by January 31, 2025, will evaluate the progress made towards meeting the RPGs set for the Northern LADCO Class I Areas. The WDNR will continue to have periodic calls as needed with the LADCO regional haze work group including Region 5 states, tribes, FLMs, and EPA Region 5. The LADCO states will continue to conduct technical evaluations necessary to determine if the Northern LADCO Class I Areas are on track to meet their RPGs. In the next progress report, WDNR will evaluate if emission reductions associated with Wisconsin's LTS are on track to, or have already, occurred. The review will also look at what new emission sources have begun operation. The WDNR will evaluate what actions, if any, are appropriate and necessary based on the findings of the next progress report.

3.9. Monitoring Strategy

Section 51.308(f)(6)(iii) of the Haze Rule requires that a State with no Class I areas must include in its haze SIP 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 Class I areas in other States.

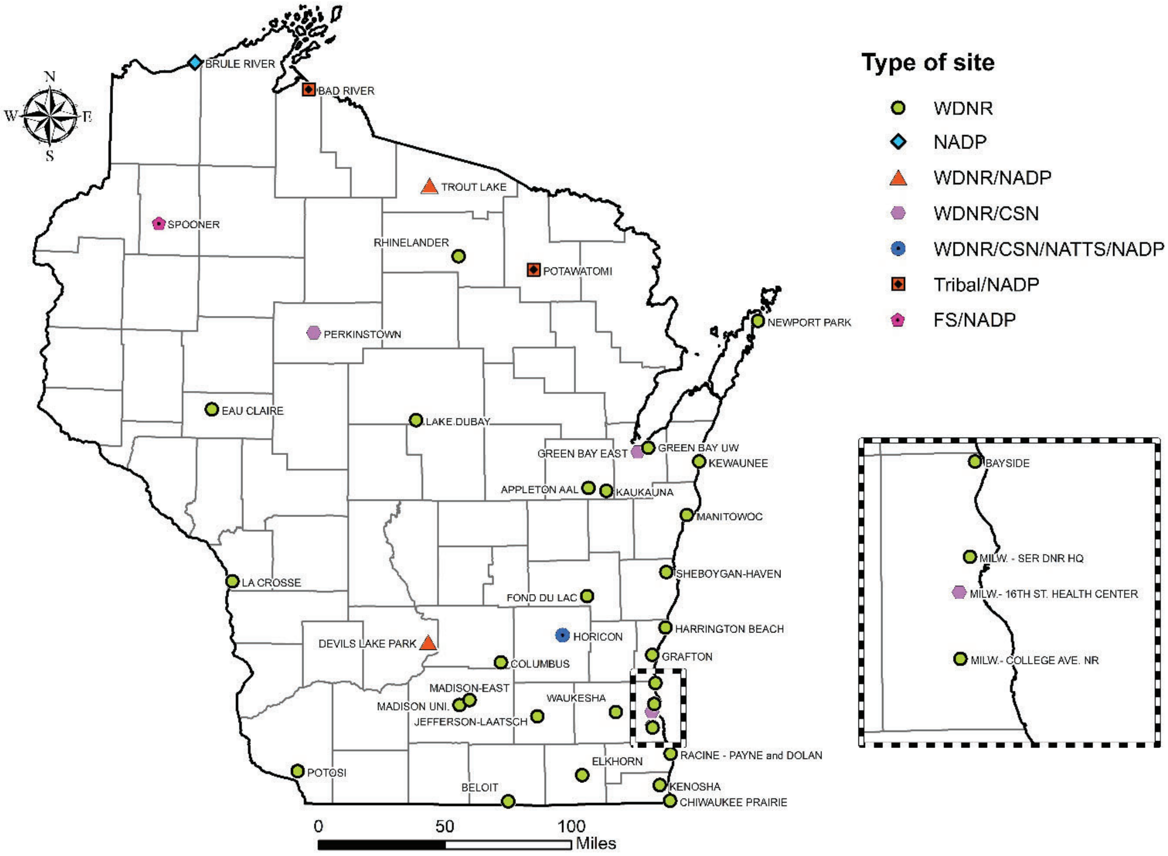
The WDNR, along with its tribal and FLM partners, maintains a statewide monitoring network to measure and report levels of various air pollutants (Figure 7), including those that contribute to impairment of visibility in Class I areas. Because no Class I areas are in Wisconsin, WDNR does not operate any monitoring sites under the federal Interagency Monitoring of Protected Visual Environments (IMPROVE) program, and therefore, does not require approval of its monitoring network under the Haze Rule. If deemed appropriate, Wisconsin's ongoing monitoring efforts and resulting data are available to support modeling efforts to evaluate visibility impacts at the Northern LADCO Class I Areas via the LADCO Regional Haze Workgroup.

Wisconsin's air monitoring network consists of State and Local Air Monitoring Stations (SLAMS), which are a network of monitoring sites whose size and distribution is largely determined by the monitoring requirements for the NAAQS and the needs of monitoring organizations to meet their respective tribal/state implementation plan (TIP/SIP) requirements, which include National Core Monitoring Network (NCore), Photochemical Assessment

Monitoring Stations (PAMS), and all other state or locally operated sites that have not been designated as Special Purpose Monitoring (SPM) sites. The WDNR also operates additional sites not required under SLAMS that support the following networks: the Chemical Speciation Network (CSN), SPM sites, National Air Toxics Trends Network Sites (NATTS), and the National Atmospheric Deposition Program (NADP). The U.S. Forest Service (FS) also maintains and operates an NADP site in Spooner, WI.

Specific site information about Wisconsin's air monitoring network (Figure 7), including the pollutants measured, sampling schedules, and site locations (address and latitude/longitude) can be found in the Wisconsin Department of Natural Resources 2022 Air Monitoring Network Plan.[31]

Figure 7 – Wisconsin's Air Monitoring Network



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[31] "Wisconsin Department of Natural Resources 2022 Air Monitoring Network Plan," WDNR, June 2021. https://dnr.wisconsin.gov/sites/default/files/topic/AirQuality/2022AnnualNetworkPlan0629.pdf.

4. Procedural Requirements

4.1 Federal Land Manager Consultation

The WDNR shared the February 2021 draft of the Round 2 haze SIP with the U.S. Forest Service, the National Park Service, and the U.S. Fish and Wildlife Service on February 22, 2021. FLMs and representatives of the WDNR held a conference call on March 23, 2021, as required in 40 CFR § 51.308 (i)(2). Written comments received from the FLMs are available at https://dnr.wisconsin.gov/topic/AirQuality/Particles.html under the "Regional Haze – Round 2" tab. Appendix 7 contains WDNR's responses to the FLM comments. The WDNR received additional written comments from the National Park Service during the public comment period (Section 4.2), which are addressed in Appendix 8.

Wisconsin has not received a certification from an FLM that there exists Reasonably Attributable Visibility Impairment (RAVI) in any Class I area for a Wisconsin source. Until the state receives such a certification, the provisions in 40 CFR § 51.302 do not apply to Wisconsin.

4.2. Public Participation

On April 28, 2021, WDNR posted the April 2021 draft of the Round 2 haze SIP for public review through June 2, 2021. The public comment period was scheduled following the FLM comment period to meet the minimum 60-day FLM consultation period required under 40 CFR § 51.308 (i)(2).The virtual public hearing was held on June 1, 2021 at 3:00 PM CDT online via Zoom and open conference call and was attended by six members of the public and four EPA Region 5 personnel. No verbal comments were received at the public hearing. Appendix 8 contains WDNR's responses to the written comments received during the public comment period from EPA, the National Park Service, and the A-M Rhinelander paper mill on the April 2021 draft of the Round 2 haze SIP. The WDNR considered input from FLMs and the public when finalizing this SIP revision.

5. List of Appendices

Appendix 1. Regional Haze Second Implementation Period: Checklist for Early Engagement

Appendix 2. Supplemental Technical Analyses for the Wisconsin Regional Haze State Implementation Plan Revision for the Second Implementation Period

Appendix 3. Information for Wisconsin Point Source Facilities Over Q/d = 1

Appendix 4. Supplemental Information for WDNR Round 2 Four-Factor Analysis

Appendix 5. WDNR Sept 10, 2020 letter to EPA Region 5, "Attainment SIP for the Oneida County 2010 1-hour SO_2 NAAQS Nonattainment Area."

Appendix 6. Wisconsin Smoke Management Plan: Best Management Practices for Prescribed Burns, April 2021

Appendix 7. WDNR Responses to Federal Land Manager Consultation Comments

Appendix 8. WDNR Responses to Public Comments

APPENDIX 1

Regional Haze Second Implementation Period: Checklist for Early Engagement

REGIONAL HAZE SECOND IMPLEMENTATION PLANNING PERIOD: MILESTONES FOR EARLY ENGAGEMENT DRAFTS FOR INFORMAL REVIEW

Based on US Environmental Protection Agency's "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period", August 20, 2019.[1]

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
01/01/2018 – 11/30/2018	1	**40 CFR 51.308(f)(1)** ***Ambient Data Analysis*** *(Applies only to a state with a Class I area – not required for WI, but included for background)* Identify the 20 percent most anthropogenically impaired days and the 20 percent clearest days and determine baseline, current, and natural visibility conditions for each Class I area within the state.	6	Analysis of visibility monitoring data Determine the baseline (2000-2004) visibility condition and the current visibility condition (as defined in section 51.301) for the 20 percent most anthropogenically impaired days and for the 20 percent clearest days, for each in-state Class I area. This must be done based on using available monitoring data. Determine the natural visibility condition (as defined in section 51.301) for the 20 percent most anthropogenically impaired days and for the 20 percent clearest days, for each in-state Class I area. This must be done based on using available monitoring data and appropriate data analysis techniques. Determine the difference between the baseline period visibility condition and the current visibility condition, for both sets of days. This is the "actual	40 CFR 51.308(f)(1)	Section 3.2, Table 3, Figure 2, Figure 3

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[1] "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period", US EPA, August 2019. https://www.epa.gov/sites/production/files/2019-08/documents/8-20-2019_-_regional_haze_guidance_final_guidance.pdf

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
				progress made towards the natural visibility condition since the baseline period.” Determine the difference between the average visibility condition in the period of 2003-2007 and the average visibility condition for each subsequent 5-year period, up to and including the 5-year period that determines current visibility conditions, for both sets of days. This is the “actual progress made during the previous implementation period up to and including the period for calculating current visibility conditions.” Determine the difference between the current visibility conditions and natural visibility conditions, for both sets of days.		
01/01/2018 – 11/30/2018	2	**40 CFR 51.308(f)(2)** ***Determination of Affected Class I Areas in Other States*** Determine which Class I area(s) in other states may be affected by the state’s own emissions.	2	Determine Class I areas in other states that may be affected by emission sources in the state.	40 CFR 51.308(f)(2)	Section 2; Table 2
			3	Determine which other states have sources that may be reasonably anticipated to affect in-state Class I areas.	40 CFR 51.308(f)(2)(ii)	N/A
			4	Consult with these states, through multi-state organizations and directly.	40 CFR 51.308(f)(2)(ii)	Sections 3.1, 3.6.2
			5	Consult with FLMs for all in-state Class I areas and affected out-of-state Class I areas on an ongoing basis.	40 CFR 51.308(i)(4)	Sections 3.1, 4.1
			7	Develop current extinction budgets for each Class I area.	Not explicitly addressed.	Addressed in LADCO

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
						TSD (Appendix 2)
01/01/2018 – 11/30/2019	3	**40 CFR 51.308(f)(2)** ***Selection of sources for analysis*** Select the emission sources for which an analysis of emission control measures will be completed in the second implementation period and explain the bases for these selections. For the purpose of this source selection step, a state may consider estimated visibility impacts (or surrogate metrics for visibility impacts), the four statutory factors, the five required factors listed in section 51.308(f)(2)(iv), and other factors that are reasonable to consider.	11	(Optional) Estimate baseline visibility impacts for source selection purposes.	40 CFR 51.308(f)(2)	N/A
			12	Select sources for analysis of control measures.	40 CFR 51.308(f)(2)(i)	Section 3.4.1
			16	Consider evaluating major and minor stationary sources or groups of sources, mobile sources, and area sources.	40 CFR 51.308(f)(2)(i)	Sections 3.3.3, 3.4.1
			17	Document the criteria used to determine the sources or groups of sources that have been evaluated and how the four factors were taken into consideration in selecting the measures for inclusion in the long-term strategy (LTS).	40 CFR 51.308(f)(2)(i)	Sections 3.3.3, 3.4.1, 3.4.2, 3.6.1, and 3.6.3
01/01/2020 – 05/31/2020	4	**40 CFR 51.308(f)(2)** ***Characterization of factors for emission control measures*** Identify potential emission control measures for the selected sources,	13	Identify emission control measures to be considered for these sources.	40 CFR 51.308(f)(2)(i)	Section 3.4.2

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
		develop data on the four statutory factors and on visibility benefits if they will be considered.				
02/01/2020 – 06/30/2020	5	**40 CFR 51.308(f)(2)** ***Decisions on what control measures are necessary to make reasonable progress*** Consider the four statutory factors, the five required factors listed in section 51.308(f)(2)(iv) (if not already considered when selecting sources), and, optionally, visibility benefits, and decide on emission controls for incorporation into the LTS. Consider measures adopted by other contributing states, including all measures that have been agreed upon through interstate consultation.	14	Characterize the four factors for these sources and measures.	40 CFR 51.308(f)(2)(i)	Section 3.4.2
			15	Quantify visibility benefits for these sources and measures.	Not explicitly addressed.	Section 3.5.5 reports general expected benefits by end of Round 2
			18	Document the technical basis, including information on the four factors and modeling, monitoring, and emissions information on which the state is relying to determine the emission reductions from anthropogenic sources in the state that are necessary for achieving reasonable progress towards natural visibility conditions in each Class I area it affects.	40 CFR 51.308(f)(2)(iii)	Sections 3.2, 3.3.1, 3.3.3, 3.4.2, 3.5, and 3.6
			19	Identify the emissions information on which the state's strategies are based and explain how this information meets the Regional Haze Rule's requirements regarding the year(s) represented in the information, i.e., the tie to the submission of information to the NEI.	40 CFR 51.308(f)(2)(iii)	Section 3.3, particularly 3.3.2 and 3.3.3
			20	Consult with those states that have emissions that are reasonably anticipated to contribute to	40 CFR 51.308(f)(2)(ii)	Sections 3.1, 3.6.2

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
				visibility impairment in the in-state Class I areas to develop coordinated emission management strategies containing the emission reductions necessary to make reasonable progress. This consultation could include the exchange of relevant portions of analyses of control measures and associated technical information.		
			21	Include in the SIP all measures agreed to during state-to-state consultations or a regional planning process, or measures that will provide equivalent visibility improvement.	40 CFR 51.308(f)(2)(ii)(A)	Section 3.6.2
			22	Consider the emission reduction measures identified by other states for their sources as being necessary to make reasonable progress in the Class I area.	40 CFR 51.308(f)(2)(ii)(B)	Section 3.6.2
			23	Include in the SIP a description of the actions taken to resolve any disagreements with other states regarding measures that are necessary to make reasonable progress at jointly affected Class I areas.	40 CFR 51.308(f)(2)(ii)(C)	Section 3.6.2 [N/A – no disagreements]
			24	Consider emission reductions due to ongoing air pollution control programs, including measures to address RAVI.	40 CFR 51.308(f)(2)(iv)(A)	Section 3.5.1
			25	Consider measures to mitigate the impacts of construction activities.	40 CFR 51.308(f)(2)(iv)(B)	Section 3.5.2

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
			26	Consider source retirement and replacement schedules.	40 CFR 51.308(f)(2)(iv)(C)	Section 3.5.3
			27	Consider basic smoke management practices for prescribed fire used for agricultural and wildland vegetation management purposes and smoke management programs. After consideration of basic smoke management practices, states have the option to include the practices into their SIP submittal, but it is not required.	40 CFR 51.308(f)(2)(iv)(D)	Section 3.5.4; Appendix 6
			28	Consider the anticipated net effect on visibility due to projected changes in point, area, and mobile source emissions over the period addressed by the LTS.	40 CFR 51.308(f)(2)(iv)(E)	Section 3.5.5
			29	Select measures for inclusion in the LTS.	40 CFR 51.308(f)(2)	Section 3.6.3
			30	Set emission limits, averaging periods and monitoring and record keeping requirements.,	40 CFR 51.308(f)(2) – opening text	Sections 3.5, 3.6.3 (citing existing regs)
			31	Set compliance deadlines.	40 CFR 51.308(f)(2) – opening text	Sections 3.5, 3.6.3 (citing existing regs)
06/01/20 – 08/30/20	6	**40 CFR 51.308(f)(3)**	8	Identify significant future trends in emissions.	40 CFR 51.308(f)(2)(iv)(A)	Section 3.3

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
		Regional scale modeling of the LTS to set the RPGs for 2028 *(Applies only to a state with a Class I area)* Determine the visibility conditions in 2028 that will result from implementation of the LTS and other enforceable measures to set the RPGs for 2028. Typically, a state will do this through regional scale modeling, although the Regional Haze Rule does not explicitly require regional scale modeling.	9	(Optional) Conduct source apportionment modeling and/or review available results from such modeling by other parties. (Optional) Conduct modeling to predict visibility levels for the 20 percent most impaired and 20 percent clearest days as of the end of the implementation period assuming already adopted emissions controls and/or review available results from such modeling by other parties. A comparison of these projected levels to current visibility conditions is a factor that may be considered in the source selection step (step 12 on this list).	40 CFR 51.308(f)(3)	Addressed in LADCO TSD (Appendix 2)
			32	Project the 2028 RPGs for the 20 percent most anthropogenically impaired and 20 percent clearest days.	40 CFR 51.308(f)(3)	Section 3.7; Table 20; Figure 2 (clearest days)
06/01/2020 – 08/30/2020	7A	**40 CFR 51.308(f)(3)(ii)(A)** ***Progress, degradation, and URP glidepath checks*** *(Applies only to a state with a Class I area)* • Demonstrate that there will be an improvement on the 20 percent most anthropogenically impaired	33	URP Glidepath Check		Section 3.2; Figure 3; Table 20
			33A	Determine the URP using the baseline period visibility condition value and the natural visibility conditions value for the 20 percent most anthropogenically impaired days. The URP may be adjusted for impacts from anthropogenic sources outside the U.S. and from certain types of	40 CFR 51.308(f)(1)(vi)	Section 3.2.4; Table 4; Figure 3; Figure 2 (clearest days)

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
		days in 2028 at the in-state Class I area, compared to 2000-2004 conditions. 40 CFR 51.308(f)(3). • Demonstrate that there will be no degradation on the 20 percent clearest days in 2028 at the in-state Class I area, compared to 2000-2004 conditions. 40 CFR 51.308(f)(3). • Determine the URP that would achieve natural conditions at the in-state Class I area in 2064. The URP may be adjusted for international anthropogenic impacts and certain wildland prescribed fires subject to EPA approval as part of EPA's action on the SIP submission. 40 CFR 51.308(f)(1). • Compare the 2028 RPG for the 20 percent most anthropogenically impaired days to the 2028 point on the URP glidepath for the in-state Class I area. If the RPG is above the URP glidepath, demonstrate that there are no additional		prescribed fires, subject to EPA approval as part of EPA's action on the SIP submission.		

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
		emission reduction measures for anthropogenic sources or groups of sources in the state that may reasonably be anticipated to contribute to visibility impairment in the Class I area that would be reasonable to include in the LTS. If the RPG is above the URP glidepath, also provide the number of years needed to reach natural conditions.				
06/01/2020 – 08/30/2020	7B	**40 CFR 51.308(f)(3)(ii)(B)** ***URP glidepath check*** *(Applies to a state only with respect to an out-of-state Class I area to which sources in the state may reasonably be anticipated to contribute to visibility impairment.)* If the RPG for the 20 percent most anthropogenically impaired days for the affected Class I area in another state is above the URP glidepath, the state preparing the SIP must demonstrate that there are no additional emission reduction measures for anthropogenic sources or groups of sources in the state	33B	Compare 2028 RPG for the 20 percent most anthropogenically impaired days to the 2028 point on the URP glidepath. If the 2028 point is above the glidepath demonstrate that there are no additional emission reduction measures for anthropogenic sources or groups of sources in the state that may reasonably be anticipated to contribute to visibility impairment in the Class I area that would be reasonable to include in the LTS.	40 CFR 51.308(f)(3)(ii)(A)	Section 3.7; Table 20
			33C	If the 2028 RPG for the 20 percent most anthropogenically impaired days is above the 2028 point on the URP glidepath, Calculate the number of years it would take to reach natural conditions at the rate of progress provided by the SIP for the implementation period.	40 CFR 51.308(f)(3)(ii)(A)	N/A (2028 projections are below URPs)
			34	Compare the 2028 RPG for the 20 percent clearest days to the 2000-2004 conditions for the same	40 CFR 51.308(f)(3)(i)	N/A (no degradation

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
		whose emissions may reasonably be anticipated to contribute to visibility impairment in the Class I area that would be reasonable to include in the LTS.		days, and strengthen the LTS if there is degradation. Also, compare the 2028 RPG for the 20 percent most anthropogenically impaired days to the 2000-2004 conditions for the same days, and strengthen the LTS if the RPG does not show an improvement.		in visibility on clearest days)
02/01/2021 – 07/31/2021	8	**40 CFR 51.308(f)(4), (5), and (6)** ***Additional requirements for SIPs*** Provide additional information necessary to ensure that other requirements of the Regional Haze Rule are met.	35	Submit a monitoring strategy for measuring, characterizing, and reporting of regional haze visibility impairment that is representative of all Class I areas within the state.	40 CFR 51.308(f)(6)	N/A
			36	Provide for the establishment of any additional monitoring sites or equipment needed to assess whether reasonable progress goals to address regional haze for all Class I areas within the state are being achieved.	40 CFR 51.308(f)(6)(i)	N/A
			37	Provide for 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 Class I areas both within and outside the state.	40 CFR 51.308(f)(6)(ii)	Section 3.9
			38	For a state with no Class I areas, provide for 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 Class I areas in other states.	40 CFR 51.308(f)(6)(iii)	Section 3.9
			39	Provide for reporting of all visibility monitoring data to the Administrator at least annually for each	40 CFR 51.308(f)(6)(iv)	N/A

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
				Class I area in the state. To the extent possible, the state should report visibility monitoring data electronically.		
			40	Provide for a statewide inventory of emissions of pollutants that are reasonably anticipated to cause or contribute to visibility impairment in any Class I area. The inventory must include emissions for the most recent year for which data are available, and estimates of future projected emissions. The state must also include a commitment to update the inventory periodically.	40 CFR 51.308(f)(6)(v)	Sections 3.3.1, 3.3.2
			41	Provide other elements, including reporting, recordkeeping, and other measures, necessary to assess and report on visibility.	40 CFR 51.308(f)(6) (vi)	Section 3.8
			42	Commit to submit the January 31, 2025, progress report.	40 CFR 51.308(f) opening Text	Section 3.8
02/01/2021 – 04/30/2021		***Consult with FLMs.***	43	Offer an in-person consultation meeting with responsible FLMs at a point early enough in the state's policy analyses of its LTS emission reduction obligation so that information and recommendations provided by the Federal Land Manager can meaningfully inform the state's decisions on the LTS. "Early enough" is considered at least 120 days prior to holding any public hearing or public comment opportunity. Consultation must be provided no less than 60	40 CFR 51.308(i)(2)	Section 4.1

DATES	2019 GUIDANCE STEP	DESCRIPTION	2019 GUIDANCE APPENDIX D TASK	DESCRIPTION	CITATION	PAGE # or SECTION # in SIP
				days before any public hearing or public comment opportunity.		
			44	Include in the SIP submission a description of how the state addressed any comments provided by the FLMs.	40 CFR 51.308(i)(3)	Section 4.1; Appendix 7
04/01/2021 – 06/30/2021		***Provide Public Comment Period***				Section 4.2; Appendix 8
07/01/2021 – 07/31/2021		***Respond to public comments.***				Section 4.2; Appendix 8
07/01/2021 – 07/31/2021		***Receive final state approval.***				
07/01/2021 – 07/31/2021		***Submit Final SIP to USEPA***				

APPENDIX 2

Supplemental Technical Analyses for the Wisconsin Regional Haze State Implementation Plan Revision for the Second Implementation Period

Table of Contents

Table A2-1. Wisconsin Process Level Emissions Summary (supports Section 3.4.1 of the Round 2 haze SIP). The table below summarizes 2028 emissions projections (in tons per year, TPY) based on 2016 emissions data from LADCO's "Process level report of Q/d sources" spreadsheet (Haze_Control_Sheet_V6.9.xlsx) for Wisconsin point source processes.

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH$_3$	2028 NOx	2028 PM$_{2.5}$	2028 SO$_2$	Total Emissions	Q/d
111003090	B20	S10	1	WPL - COLUMBIA ENERGY CENTER	0	1.25833	0.0657873	0.011168	1.335285	0.003218
111003090	B21	S11	1	WPL - COLUMBIA ENERGY CENTER	0	1667.912	18.0831123	643.302	2329.298	5.613469
111003090	B21	S01	1	WPL - COLUMBIA ENERGY CENTER	0	16.8476	0.1826577	6.498	23.52826	0.056702
111003090	B22	S12	1	WPL - COLUMBIA ENERGY CENTER	0	1777.951	23.7749985	736.065	2537.791	6.115926
111003090	B22	S02	1	WPL - COLUMBIA ENERGY CENTER	0	17.9591	0.2401515	7.435	25.63425	0.061777
111003090	F21	F21	1	WPL - COLUMBIA ENERGY CENTER	0	0	22.66613	0	22.66613	0.054624
111003090	P21	P21	1	WPL - COLUMBIA ENERGY CENTER	0	0	29.16212	0	29.16212	0.070279
111003090	P22	P22	1	WPL - COLUMBIA ENERGY CENTER	0	0	8.009658	0	8.009658	0.019303
111071180	P10	S10	0	CARDINAL FG	0	1425.58	21.74246	62.488	1509.81	3.654637
122003640	B21	S11	3	E J STONEMAN STATION	9.323	197.82	27.1039	137.262	371.5089	0.658339
122003640	B22	S11	1	E J STONEMAN STATION	8.95695	189.984	29.7409	131.873	360.5549	0.638927
122003640	F04	F04	1	E J STONEMAN STATION	0	0	3.81702	0	3.81702	0.006764
122003640	F08	F08	2	E J STONEMAN STATION	0	3.536	0.0741909	0	3.610191	0.006398
230006260	B20	S20	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	341.5625	1265.41	1.741929	574.963	2183.677	4.902219
230006260	B21	S21	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	275.2225	948.84	1.731574	512.03	1737.824	3.901307
230006260	B22	S11	2	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0.077247	6.7591	0.072419	0.014484	6.923249	0.015542
230006260	B23	S11	2	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0.058632	5.13025	0.054967	0.010993	5.254842	0.011797
230006260	F01	F01	2	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0	0	2.4893	0	2.4893	0.005588
230006260	P14	S14	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0	0	1.979765	0	1.979765	0.004444
230006260	P14	S14	2	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0	0	5.905574	0	5.905574	0.013258
230006260	P16	S16	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PLEASANT PRAIRIE	0	0	4.57725	0	4.57725	0.010276
241007690	B18	S18	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	273.9105	1109.98	6.721531	334.8	1725.412	4.195862
241007690	B19	S19	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	280.029	1107.79	7.057782	282.36	1677.237	4.078709
241007690	B25	S05A	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0.217974	532.05	4.956985	13.9	551.125	1.340227
241007690	B26	S05A	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0.156885	386.87	3.568514	10.29	400.8854	0.974874
241007690	B27	S05B	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0.090266	195.09	1.279989	27.35	223.8103	0.544262
241007690	B28	S05B	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0.162643	342.22	2.303881	37.58	382.2665	0.929597
241007690	F148	F148	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0	0	1.32	0	1.32	0.00321
241007690	F600	F600	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0	0	1.191176	0	1.191176	0.002897

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH$_3$	2028 NOx	2028 PM$_{2.5}$	2028 SO$_2$	Total Emissions	Q/d
241007690	P66	S66	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-OAK CREEK STATION	0	0	1.044118	0	1.044118	0.002539
246004000	P11	S11	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PORT WASHINGTON	49.95395	61.91	15.66695	3.36	130.8909	0.366598
246004000	P12	S12	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PORT WASHINGTON	49.9571	60	8.39355	3.36	121.7107	0.340886
246004000	P19	S19	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PORT WASHINGTON	0.05605	1.75155	0.1113456	0.010509	1.929454	0.005404
246004000	P21	S21	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PORT WASHINGTON	39.72355	50.96	5.74945	2.65	99.083	0.27751
246004000	P22	S22	1	WISCONSIN ELECTRIC POWER COMPANY D/B/A WE ENERGIES-PORT WASHINGTON	41.4237	53.23	5.0731	2.77	102.4968	0.287072
265006830	B10	S11	1	USG INTERIORS LLC	0.033186	1.03705	0.078816	0.006222	1.155274	0.002469
265006830	P30	S12	1	USG INTERIORS LLC	0	34.7791	0.0311911	406.2635	441.0738	0.942719
265006830	P31	S24	0	USG INTERIORS LLC	0	0	5.118088	4.623609	9.741697	0.020821
265006830	P31	S21	0	USG INTERIORS LLC	0	0	4.967556	4.487621	9.455177	0.020209
265006830	P31	S22	0	USG INTERIORS LLC	0	0	4.967556	4.487621	9.455177	0.020209
265006830	P32	S13	2	USG INTERIORS LLC	0	10.359	0.768587	0.062154	11.18974	0.023916
405031990	B26	S13	1	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	93.075	1.324179	156.6745	251.0737	0.993916
405031990	B26	S13	2	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	5.7249	0.021265	0.025397	5.771562	0.022848
405031990	B27	S14	1	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	290.2415	6.317295	590.545	887.1038	3.511746
405031990	B27	S14	2	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	11.85855	0.044045	0.05266	11.95525	0.047327
405031990	F47	F47	1	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	0	11.26893	0	11.26893	0.04461
405031990	P32	S32	0	WI PUBLIC SERVICE CORP - JP PULLIAM PLANT	0	12.1	2.90047	0.2	15.20047	0.060174
405032100	B26	S16	1	GREEN BAY PACKAGING INC MILL DIVISION	0.010343	201.377	1.05078	751.32	953.7581	3.766526
405032100	B33	S23	1	GREEN BAY PACKAGING INC MILL DIVISION	0.098736	1.63532	0.058625	0.018515	1.811196	0.007153
405032210	B05	S01	3	PROCTER & GAMBLE PAPER PRODUCTS CO	0.61149	36.3073	1.45229	0	38.37108	0.151212
405032210	B06	S01	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0.643805	28.1664	1.529035	0	30.33924	0.11956
405032210	B07	S04	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0.907625	53.8905	2.155615	0	56.95374	0.224442
405032210	B08	S05	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	1.78903	0.114498	0	1.903528	0.007501
405032210	P11	S11	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	6.63424	0	6.63424	0.026144
405032210	P11A	S11	2	PROCTER & GAMBLE PAPER PRODUCTS CO	0.281104	17.22	0.263535	0	17.76464	0.070007
405032210	P12	S12	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	25.50477	0	25.50477	0.100509
405032210	P12A	S12	2	PROCTER & GAMBLE PAPER PRODUCTS CO	0.62981	60.6	0.590445	0	61.82026	0.24362
405032210	P13	S13	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	22.60229	0	22.60229	0.089071
405032210	P13A	S13	2	PROCTER & GAMBLE PAPER PRODUCTS CO	0.490928	67.67	0.460245	0	68.62117	0.270421
405032210	P14	S14	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	30.51574	0	30.51574	0.120256
405032210	P14A	S14	2	PROCTER & GAMBLE PAPER PRODUCTS CO	0.603585	18.862	0.56586	0	20.03145	0.07894

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
405032210	P15	S15	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	33.93873	0	33.93873	0.133745
405032210	P15A	S15	1	PROCTER & GAMBLE PAPER PRODUCTS CO	0.81587	89.29	0.76488	0	90.87075	0.358102
405032210	P30	S30	0	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	11.36043	0	11.36043	0.044769
405032210	P40	S40	0	PROCTER & GAMBLE PAPER PRODUCTS CO	0	0	16.8088	0	16.8088	0.06624
405032650	B23	S11	1	EXPERA SPECIALTY SOLUTIONS INC	0	35.0288	0.9687309	130.378	166.3755	0.631394
405032650	B23	S11	4	EXPERA SPECIALTY SOLUTIONS INC	0	0.33915	0	1.17895	1.5181	0.005761
405032650	B24	S11	1	EXPERA SPECIALTY SOLUTIONS INC	0	26.37625	0.7294417	98.173	125.2787	0.475432
405032650	B24	S11	4	EXPERA SPECIALTY SOLUTIONS INC	0	0.2604	0	0.9052	1.1656	0.004423
405032650	B25	S12	1	EXPERA SPECIALTY SOLUTIONS INC	0	36.15	2.298078	0.2169	38.66498	0.146733
405032870	B02	S22	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	30.9575	0.854	0.6405	32.452	0.12586
405032870	B10	S08	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	3.6	54.184	0.8334167	0	58.61742	0.227338
405032870	B26	S10	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0.014992	371.483	4.264173	583.76	959.5222	3.721353
405032870	B28	S10	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0.012127	210.352	3.449404	472.219	686.0325	2.660667
405032870	B29	S11	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	118.393	0.8202859	229.0795	348.2928	1.350798
405032870	P01	S01	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	6.65	0.1783765	0.0399	6.868277	0.026638
405032870	P01B	S01	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.188443	0	1.188443	0.004609
405032870	P02	S02	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	7.9	0.2119059	0.0474	8.159306	0.031645
405032870	P02A	S02	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.359967	0	1.359967	0.005274
405032870	P03	S03	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	3.5	0.09388235	0.021	3.614882	0.01402
405032870	P03B	S03	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.682668	0	1.682668	0.006526
405032870	P04	S04	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	2.15	0.05767059	0.0129	2.220571	0.008612
405032870	P04A	S04	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.623039	0	1.623039	0.006295
405032870	P05	S05	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	14.925	0.2668941	0.0597	15.25159	0.059151
405032870	P05B	S05	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	3.136394	0	3.136394	0.012164
405032870	P15	S21	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	4.284	0.3192	0.0714	4.6746	0.01813
405032870	P15B	S21	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	4.590706	0	4.590706	0.017804
405032870	P29	S46	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.716645	0	1.716645	0.006658
405032870	P33	S33	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	14.325	0.2561647	0.0573	14.63846	0.056773
405032870	P33B	S33	2	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	4.119441	0	4.119441	0.015977
405032870	P37	P37	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	4.701212	0	4.701212	0.018233
405032870	P38	P38	1	GEORGIA-PACIFIC CONSUMER PRODUCTS LP	0	0	1.431886	0	1.431886	0.005553
436034390	P33	S11	0	CARMEUSE LIME AND STONE - ROCKWELL OPERATION	0	15.525	0.1794002	41.07915	56.78355	0.207872

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
436034390	P36	S11	0	CARMEUSE LIME AND STONE - ROCKWELL OPERATION	0	288.799	2.860494	668.86	960.5195	3.51625
436034390	P36A	S11	1	CARMEUSE LIME AND STONE - ROCKWELL OPERATION	0	5.145	0.000116735	0.02205	5.167167	0.018916
436035930	B09	S10	1	MANITOWOC PUBLIC UTILITIES	0	49	3.684231	194.5	247.1842	0.883538
436035930	B28	S20	1	MANITOWOC PUBLIC UTILITIES	0	26.5	0.21479	68	94.71479	0.33855
436035930	B28	S20	2	MANITOWOC PUBLIC UTILITIES	0	0	1.492179	0	1.492179	0.005334
436035930	B28	S20	3	MANITOWOC PUBLIC UTILITIES	0	0	1.555286	0	1.555286	0.005559
445031180	B07	S07	1	EXPERA SPECIALTY SOLUTIONS LLC	0	31.52625	22.09034	0.42035	54.03694	0.188045
445031180	B07	S07	4	EXPERA SPECIALTY SOLUTIONS LLC	0.36363	31.81755	0.2159045	0.068181	32.46527	0.112977
445031180	B08	S08	1	EXPERA SPECIALTY SOLUTIONS LLC	0.051623	4.516975	0.03065075	7.75E-06	4.599256	0.016005
445031180	B08	S10	1	EXPERA SPECIALTY SOLUTIONS LLC	0.051623	4.516975	0.03065075	7.75E-06	4.599256	0.016005
445031180	B08A	S08	1	EXPERA SPECIALTY SOLUTIONS LLC	0	34.2425	11.000815	83.1605	128.4038	0.446836
445031180	B08A	S10	1	EXPERA SPECIALTY SOLUTIONS LLC	0	34.2425	11.000815	83.1605	128.4038	0.446836
445031180	B09	S09	1	EXPERA SPECIALTY SOLUTIONS LLC	0.0042	147.131	6.037219	762.495	915.6674	3.186458
445031180	B09	S09	2	EXPERA SPECIALTY SOLUTIONS LLC	0.656205	57.418	0.3896235	0	58.46383	0.20345
445031180	B09	S09	3	EXPERA SPECIALTY SOLUTIONS LLC	0	30.3387	0.970705	157.228	188.5374	0.656097
445031180	B09	B09	7	EXPERA SPECIALTY SOLUTIONS LLC	0	4.435025	0.1929208	0	4.627946	0.016105
445031180	B10	S08	2	EXPERA SPECIALTY SOLUTIONS LLC	0.02972	2.6005	0.01764625	5.58E-06	2.647872	0.009214
445031180	B10	S10	2	EXPERA SPECIALTY SOLUTIONS LLC	0.02972	2.6005	0.01764625	5.58E-06	2.647872	0.009214
445031180	B10A	S08	1	EXPERA SPECIALTY SOLUTIONS LLC	0	47.6395	15.30479	115.6963	178.6405	0.621656
445031180	B10A	S10	1	EXPERA SPECIALTY SOLUTIONS LLC	0	47.6395	15.30479	115.6963	178.6405	0.621656
445031180	B11	S09	1	EXPERA SPECIALTY SOLUTIONS LLC	0.023595	826.82	35.97588	4284.945	5147.764	17.91386
445031180	B11	S09	5	EXPERA SPECIALTY SOLUTIONS LLC	0	180.0395	8.605696	928.455	1117.1	3.887429
445031180	B11	B11	6	EXPERA SPECIALTY SOLUTIONS LLC	0	25.87425	1.210384	0	27.08463	0.094253
445031180	B11	S09	7	EXPERA SPECIALTY SOLUTIONS LLC	0.29419	25.7418	0.1746765	0	26.21067	0.091211
445031180	B11A	S09	1	EXPERA SPECIALTY SOLUTIONS LLC	0	10.814	0	0	10.814	0.037632
445031180	P08	S05	0	EXPERA SPECIALTY SOLUTIONS LLC	5.0069	0.152509	5.744327	0	10.90374	0.037944
445031180	P10	S06	1	EXPERA SPECIALTY SOLUTIONS LLC	6.9658	0.212177	9.603515	0	16.78149	0.058398
445031180	P11	S11	0	EXPERA SPECIALTY SOLUTIONS LLC	0	0	1.21422	0	1.21422	0.004225
445031180	P12	S12	2	EXPERA SPECIALTY SOLUTIONS LLC	0.374215	11.694	0.888745	0	12.95696	0.045089
445031180	P12A	S12	1	EXPERA SPECIALTY SOLUTIONS LLC	0	13.6399	5.125837	0.075777	18.84151	0.065567
445031180	P13A	S13	1	EXPERA SPECIALTY SOLUTIONS LLC	0	0	2.096632	0	2.096632	0.007296
445031180	P14A	S14	1	EXPERA SPECIALTY SOLUTIONS LLC	0	0	1.219911	0	1.219911	0.004245

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
445031180	P15A	S15	1	EXPERA SPECIALTY SOLUTIONS LLC	0	0	2.116473	0	2.116473	0.007365
445031180	P16	S16	1	EXPERA SPECIALTY SOLUTIONS LLC	0	0	1.52127	0	1.52127	0.005294
445031180	P19	S19	0	EXPERA SPECIALTY SOLUTIONS LLC	0.378885	0	0.7545463	0	1.133431	0.003944
445031290	B05	S05	1	APPLETON COATED LLC	1.83298	25.719	3.00723	0.446789	31.006	0.106793
445031290	B22	S12	1	APPLETON COATED LLC	0.640145	56.0125	1.52034	0.120027	58.29301	0.200778
445031290	B23	S15	1	APPLETON COATED LLC	0.007611	153.029	0.3450324	145.542	298.9236	1.029578
445031290	B23	S15	2	APPLETON COATED LLC	0	0	12.9398	0	12.9398	0.044568
445031290	B23	S15	5	APPLETON COATED LLC	0	0	2.037843	0	2.037843	0.007019
445031290	F04	F04	1	APPLETON COATED LLC	0	0	2.006674	0	2.006674	0.006912
445031290	P51	P51	2	APPLETON COATED LLC	0.15417	6.7449	0.3574569	0.037579	7.294105	0.025123
445031290	P52	P52	1	APPLETON COATED LLC	0.02323	1.01633	0.04867344	0.005662	1.093896	0.003768
445031290	P54	S54	1	APPLETON COATED LLC	0	0	1.826436	0	1.826436	0.006291
445031290	P62	S62	0	APPLETON COATED LLC	0	0	2.018066	0	2.018066	0.006951
445031290	P62A	S62A1	1	APPLETON COATED LLC	0	0	3.199168	0	3.199168	0.011019
445031290	P62A	S62A1	2	APPLETON COATED LLC	0.056696	2.48045	0.131455	0.01382	2.682421	0.009239
445031290	P63	S63	0	APPLETON COATED LLC	0	0	5.698477	0	5.698477	0.019627
445031290	P63	S63	1	APPLETON COATED LLC	0.096328	4.21435	0.2233455	0.02348	4.557503	0.015697
460033090	B24	S11	1	WPL - EDGEWATER GENERATING STATION	0	821.015	62.21588	2983.475	3866.706	12.16497
460033090	B25	S12	1	WPL - EDGEWATER GENERATING STATION	0	485.687	17.4165	2997.85	3500.954	11.01428
460033090	F21	F21	1	WPL - EDGEWATER GENERATING STATION	0	0	5.59009	0	5.59009	0.017587
460033090	P30	P30	1	WPL - EDGEWATER GENERATING STATION	0	0	6.37425	0	6.37425	0.020054
460033090	P31	P31	1	WPL - EDGEWATER GENERATING STATION	0	0	1.6857	0	1.6857	0.005303
471034960	B01	S01	2	THEDA CLARK MEDICAL CENTER	30.16745	**905.025***	47.31203	0	982.5045	3.217183
471034960	B06	S01	1	THEDA CLARK MEDICAL CENTER	0	4.42555	0.385023	0	4.810573	0.015752
606034110	B25	S11	1	DAIRYLAND POWER COOP ALMA SITE	4.426855	1237.3	5.028513	919.5	2166.255	5.331512
606034110	B25	S11	2	DAIRYLAND POWER COOP ALMA SITE	0.077375	2.32123	0.001193874	0.020601	2.420399	0.005957
606034110	F74	F74	1	DAIRYLAND POWER COOP ALMA SITE	0	0	2.685691	0	2.685691	0.00661
617049840	P01	S01	1	CARDINAL FG CO	0	1573.465	31.29112	57.637	1662.393	4.896449
617049840	P08	S08	1	CARDINAL FG CO	0	0	0	3.75589	3.75589	0.011063
649014410	P30	S10	0	Viking Gas Transmission Co #2222	0	70.19671	1.03301038	0.013042	71.24276	0.233498
649014410	P31	S11	0	Viking Gas Transmission Co #2222	0	93.18562	1.3713079	0.017283	94.57421	0.309967
649014410	P32	S12	0	Viking Gas Transmission Co #2222	0	76.75055	1.12945672	0.014235	77.89424	0.255298

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
663020930	B20	S10	1	DAIRYLAND POWER COOP GENOA STATION-EOP	0	577.03	11.2878	253.005	841.3228	1.721062
663020930	B25	S15	1	DAIRYLAND POWER COOP GENOA STATION-EOP	0	16.09585	0.2494267	0.007607	16.35288	0.033452
663020930	B35	S16	1	DAIRYLAND POWER COOP GENOA STATION-EOP	0	1.362835	0.02111902	0.000644	1.384598	0.002832
663020930	F07	F07	1	DAIRYLAND POWER COOP GENOA STATION-EOP	0	0	1.153106	0	1.153106	0.002359
735008010	B12	S12	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	2.9048	23.74675	0.98037	0.54465	28.17657	0.110409
735008010	B24	S15	2	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	196.938	33.56081	50.407	280.9058	1.100718
735008010	B24	S15	7	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0.55264	31.086	0.186515	0.10362	31.92878	0.125112
735008010	B25	S11	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0.11744	10.276	0.0016515	0.02202	10.41711	0.040819
735008010	B25	S11	3	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	14.1502	0	2.30302	16.45322	0.064471
735008010	B29	S14	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0.08464	2.72435	0.050255	0.01587	2.875115	0.011266
735008010	B29	S14	3	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0.20896	6.7259	0.1959	0.03918	7.16994	0.028095
735008010	B30	S16	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0.1224	3.1365	0.04131	0.02295	3.32316	0.013022
735008010	F05	F05	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	0	16.63059	0	16.63059	0.065166
735008010	F08	F08	1	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	0	2.563059	0	2.563059	0.010043
735008010	P32	S52	0	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	0	4.723291	0	4.723291	0.018508
735008010	P73	S73	0	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	0	0	1.4286	0	1.4286	0.005598
737009020	B02	S02	2	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.112415	4.7	1.288895	0	6.10131	0.019563
737009020	B03	S03	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.1068	297.9465	13.48082	762.065	1073.599	3.442365
737009020	B03	S03	2	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.1772	7.7535	0.02879865	0.033905	7.993403	0.02563
737009020	B04	S04	0	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.1198	5.2413	0.01946775	0.0232	5.403767	0.017327
737009020	B04	S04	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	7.9945	694.16	66.29155	575.075	1343.521	4.307837
737009020	B12	S12	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	35.2	0.660575	0	35.86058	0.114983
737009020	B13	S13	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	36.1	0.64149	0	36.74149	0.117807
737009020	B22	S22	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.032837	1.02615	0.005336	0.006381	1.070704	0.003433
737009020	B25	S25	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0.087791	3.840865	0.0142661	0.016951	3.959873	0.012697
737009020	F24	F24	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	2.334688	0	2.334688	0.007486
737009020	F26	F26	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	1.315359	0	1.315359	0.004218
737009020	P36	S36	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	1.823083	0	1.823083	0.005845
737009020	P43	S43	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	2.833721	0	2.833721	0.009086
737009020	P56	P56	1	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	1.992131	0	1.992131	0.006388
737009020	P56	P56	2	WISCONSIN PUBLIC SERVICE CORPORATION- WESTON PLANT	0	0	1.399293	0	1.399293	0.004487
737009570	B20	S10	1	EXPERA SPECIALTY SOLUTIONS LLC	0.016393	219.5475	0.04444134	1112.375	1331.983	4.160344

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
737009570	B21	S11	2	EXPERA SPECIALTY SOLUTIONS LLC	0.047324	2.78031	0.002699594	6.68695	9.517284	0.029726
737009570	B21	S11	3	EXPERA SPECIALTY SOLUTIONS LLC	0	5.205	0.0019779	0	5.206978	0.016264
737009570	B21A	S11	1	EXPERA SPECIALTY SOLUTIONS LLC	0	149.3025	26.66303	2.14652	178.1121	0.556319
737009570	B24	S10	1	EXPERA SPECIALTY SOLUTIONS LLC	0.004236	83.2095	0.000637326	287.451	370.6654	1.157744
737009570	B24	S10	2	EXPERA SPECIALTY SOLUTIONS LLC	0	58.218	1.228093	15.788	75.23409	0.234988
737009570	B24	S10	3	EXPERA SPECIALTY SOLUTIONS LLC	0	61.009	0.04718831	3.26835	64.32454	0.200913
737009570	F102	F102	1	EXPERA SPECIALTY SOLUTIONS LLC	0	0	3.687367	0	3.687367	0.011517
737009570	P30	S12	0	EXPERA SPECIALTY SOLUTIONS LLC	6.17675	2.575825	2.961251	0.381604	12.09543	0.037779
737009570	P35	S52	0	EXPERA SPECIALTY SOLUTIONS LLC	2.939545	0	0	0	2.939545	0.009181
737009570	P36	S53	0	EXPERA SPECIALTY SOLUTIONS LLC	0	47.7005	0.2949779	40.2592	88.25468	0.275656
737009570	P36A	S53	1	EXPERA SPECIALTY SOLUTIONS LLC	0	10.00345	0.003177565	0.048617	10.05524	0.031407
744008100	B26	S09	1	EXPERA SPECIALTY SOLUTIONS	0.019131	1144.5	13.12	1595.53	2753.169	12.24114
744008100	B28	S08	1	EXPERA SPECIALTY SOLUTIONS	1.128235	11.4586	2.67955	0.211544	15.47793	0.068818
744008100	B30	B30	1	EXPERA SPECIALTY SOLUTIONS	0.20995	6.56095	0.498632	0.039366	7.308898	0.032497
744008100	F96	F96	1	EXPERA SPECIALTY SOLUTIONS	23.446	0	0	0	23.446	0.104246
744008100	F98	F98	1	EXPERA SPECIALTY SOLUTIONS	0.015415	3.14597	0.094379	0.018876	3.27464	0.01456
744008100	P30A	P30A	1	EXPERA SPECIALTY SOLUTIONS	0	1.568485	0.01660751	0.009411	1.594503	0.007089
772009370	B01	S01	1	WISCONSIN RAPIDS WWTF	0	2861.3	20.2608	0	2881.561	7.83925
772009370	B02	S02	1	WISCONSIN RAPIDS WWTF	0	2859.88	20.25075	0	2880.131	7.83536
772009370	B03	S03	2	WISCONSIN RAPIDS WWTF	0	139.16	0.98539	0	140.1454	0.381264
772009480	B20	S10	1	CATALYST PAPER - BIRON MILL	0	1.23545	0.093894	0.007413	1.336757	0.003712
772009480	B22	S10	1	CATALYST PAPER - BIRON MILL	0	1.55905	0.118488	0.009354	1.686892	0.004684
772009480	B23	S11	1	CATALYST PAPER - BIRON MILL	0	647.775	29.29628	1823.4	2500.471	6.942649
772009480	B24	S12	1	CATALYST PAPER - BIRON MILL	0	655.5	28.97698	571.6	1256.077	3.487543
772009480	B24	S12	2	CATALYST PAPER - BIRON MILL	0	126.7	3.903578	110.5	241.1036	0.669433
772009480	P01	S01a	1	CATALYST PAPER - BIRON MILL	0	0	1.117744	0	1.117744	0.003103
772009480	P02	S02a	1	CATALYST PAPER - BIRON MILL	0	0	2.793688	0	2.793688	0.007757
772009480	P05	S05a	1	CATALYST PAPER - BIRON MILL	0	0	1.751	0	1.751	0.004862
772009480	P05	P05	4	CATALYST PAPER - BIRON MILL	0	0	1.296959	0	1.296959	0.003601
772009480	P50	S50a	1	CATALYST PAPER - BIRON MILL	0	0	2.15953	0	2.15953	0.005996
772009480	P51A	S51a	1	CATALYST PAPER - BIRON MILL	0	0.958635	0.1904735	0.042606	1.191715	0.003309
772009480	P60	S60c	1	CATALYST PAPER - BIRON MILL	0	0	5.846349	0	5.846349	0.016233

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
772009480	P60A	S60c	1	CATALYST PAPER - BIRON MILL	0	1.18797	0.2124371	0.047519	1.447926	0.00402
772010030	B20FE	S10FE	1	WISCONSIN RAPIDS PAPER MILL	0	418.9785	0.01296086	789.4	1208.391	3.313025
772010030	B20FE	S10FE	2	WISCONSIN RAPIDS PAPER MILL	0	109.0275	1.05285	12.30055	122.3809	0.335529
772010030	B21FE	S11FE	1	WISCONSIN RAPIDS PAPER MILL	0	406.868	0.01258623	766.585	1173.466	3.217269
772010030	B21FE	B21FE	2	WISCONSIN RAPIDS PAPER MILL	0	127.0245	246.0351	14.40485	387.4645	1.062304
772010030	B24FE	S26FE	1	WISCONSIN RAPIDS PAPER MILL	0	24.0418	1.019955	0.437124	25.49888	0.06991
772010030	P14	S14	1	WISCONSIN RAPIDS PAPER MILL	0	0	4.248843	0	4.248843	0.011649
772010030	P30AFE	S13FE	1	WISCONSIN RAPIDS PAPER MILL	0	26.01645	0.000705882	0.1561	26.17326	0.071759
772010030	P30FE	S13FE	1	WISCONSIN RAPIDS PAPER MILL	0	93.869	0.8021884	2.23495	96.90614	0.265686
772010030	P32FE	S15FE	1	WISCONSIN RAPIDS PAPER MILL	6.00375	66.2175	4.831338	2.157455	79.21004	0.217169
772010030	P35	S35	1	WISCONSIN RAPIDS PAPER MILL	0	0	10.8542	0	10.8542	0.029759
772010030	P35A	S35	1	WISCONSIN RAPIDS PAPER MILL	0	5.038	0.1351369	0.030228	5.203365	0.014266
772010030	P35FE	S19FE	1	WISCONSIN RAPIDS PAPER MILL	3.96685	64.133	5.613191	1.477155	75.1902	0.206148
772010030	P36AFE	S18FE	1	WISCONSIN RAPIDS PAPER MILL	0	2.3848	0.000255875	0.014309	2.399365	0.006578
772010030	P36FE	S18FE	1	WISCONSIN RAPIDS PAPER MILL	1.6538	152.112	4.687015	9.64155	168.0944	0.460861
772010030	P37FE	S20FE	1	WISCONSIN RAPIDS PAPER MILL	1.7539	139.8385	13.00204	11.50285	166.0973	0.455386
772010030	P37SFE	S20FE	1	WISCONSIN RAPIDS PAPER MILL	0	2.9427	0.000631468	0.017656	2.960988	0.008118
772010030	P38FE	S21FE	1	WISCONSIN RAPIDS PAPER MILL	5.08975	66.8905	0.3660088	0.70886	73.05512	0.200294
772010030	P39AFE	S20FE	1	WISCONSIN RAPIDS PAPER MILL	0	2.40085	0.000321997	0.014405	2.415577	0.006623
772010030	P39FE	S20FE	1	WISCONSIN RAPIDS PAPER MILL	1.745	160.736	14.29471	2.32277	179.0985	0.491031
772010030	P40FE	S27FE	1	WISCONSIN RAPIDS PAPER MILL	0	0	2.28326076	4.373577	6.656838	0.018251
772010030	P41FE	S27FE	1	WISCONSIN RAPIDS PAPER MILL	0	0	1.45867788	4.438818	5.897496	0.016169
772010030	P44FE	S29FE	1	WISCONSIN RAPIDS PAPER MILL	11.41545	0	0.2713118	0	11.68676	0.032041
772010030	P45FE	S30FE	1	WISCONSIN RAPIDS PAPER MILL	12.4532	0	0.2462735	0	12.69947	0.034818
772010030	P49FE	S34FE	1	WISCONSIN RAPIDS PAPER MILL	0	0	1.101779	0	1.101779	0.003021
772010030	P51FE	S36FE	1	WISCONSIN RAPIDS PAPER MILL	0	0	8.42295	0	8.42295	0.023093
772010030	P64	S64	1	WISCONSIN RAPIDS PAPER MILL	0	0	6.870472	0	6.870472	0.018837
772010030	P64A	S64	1	WISCONSIN RAPIDS PAPER MILL	0	5.65	0.1515529	0.0339	5.835453	0.015999
772010030	P82	S82	1	WISCONSIN RAPIDS PAPER MILL	0	0	12.74404	0	12.74404	0.03494
772010140	B20	S10	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	453.068	0.0140154	885.245	1338.327	3.674918
772010140	B20	S10	2	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	128.8695	1.24446	14.53915	144.6531	0.397204
772010140	B21	S11	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	425.4415	0.0131608	831.265	1256.72	3.450832

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
772010140	B21	S11	2	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	95.946	0.971359	10.83265	107.75	0.295871
772010140	B24	S26	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	13.3145	0.56486	0.242082	14.12144	0.038776
772010140	F06	F06	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	1.74006	0	1.74006	0.004778
772010140	P30	S13	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	55.812	0.53374	2.0912	58.43694	0.160462
772010140	P30A	S13	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	19.0615	0.000511765	0.11435	19.17636	0.052656
772010140	P32	S15	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	6.4262	70.029	5.10944	2.281645	83.84629	0.230234
772010140	P35	S19	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	4.3376	70.0275	6.12909	1.612915	82.10711	0.225458
772010140	P36	S18	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	1.8084	166.092	5.11778	10.52765	183.5458	0.503999
772010140	P36A	S18	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	1.73935	0.000186621	0.010436	1.749973	0.004805
772010140	P37	S20	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	1.8046	141.9325	13.1968	11.6751	168.609	0.462984
772010140	P37S	S20	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	3.145	0.00067488	0.01887	3.164545	0.00869
772010140	P38	S21	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	5.23715	67.892	0.371491	0.719475	74.22012	0.203801
772010140	P39	S20	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	1.8678	169.9885	15.1175	2.45648	189.4303	0.520158
772010140	P39A	S20	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	2.0785	0.000278764	0.012471	2.09125	0.005742
772010140	P40	S27	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	2.84221	4.405855	7.248065	0.019902
772010140	P41	S27	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	1.56706	4.42	5.98706	0.01644
772010140	P44	S29	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	10.6812	0	0.28611	0	10.96731	0.030115
772010140	P45	S30	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	11.6522	0	0.259706	0	11.91191	0.032709
772010140	P49	S34	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	1.08542	0	1.08542	0.00298
772010140	P51	S36	1	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	8.8958	0	8.8958	0.024427
772010140	P51	P51	2	WISCONSIN RAPIDS FIBER AND ENERGY MILL	0	0	1.8955	0	1.8955	0.005205
772010690	B14	S20	2	DOMTAR A W LLC-NEKOOSA	0.290677	25.4342	0.00490517	0.054502	25.78428	0.068693
772010690	B14A	S20	1	DOMTAR A W LLC-NEKOOSA	0	115.4485	9.107485	4.901735	129.4577	0.344895
772010690	B20	B20	2	DOMTAR A W LLC-NEKOOSA	1.1205	15.97765	0.1820815	0.210094	17.49033	0.046597
772010690	B20	B20	3	DOMTAR A W LLC-NEKOOSA	0	1.20E-05	0	12.0849	12.08491	0.032196
772010690	B21	B21	2	DOMTAR A W LLC-NEKOOSA	1.159915	24.82945	0.188486	0.217484	26.39534	0.070321
772010690	B21	B21	3	DOMTAR A W LLC-NEKOOSA	0	0.000429	0	431.4975	431.4979	1.149576
772010690	B24	B24	3	DOMTAR A W LLC-NEKOOSA	0	0.000429	0	431.4975	431.4979	1.149576
772010690	B24	S10	4	DOMTAR A W LLC-NEKOOSA	3.691585	81.4225	0.599885	0.69217	86.40614	0.230199
772010690	F91	F91	1	DOMTAR A W LLC-NEKOOSA	0	0	1.5525	0	1.5525	0.004136
772010690	P21	S21	1	DOMTAR A W LLC-NEKOOSA	10.8354	4.25677	10.72889	6.19165	32.01271	0.085287
772010690	P22	S22	1	DOMTAR A W LLC-NEKOOSA	0	41.9786	0.9762643	0.853505	43.80837	0.116712

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
772010690	P51	P51	1	DOMTAR A W LLC-NEKOOSA	0	0	1.323311	0	1.323311	0.003526
772010690	P61	S61	0	DOMTAR A W LLC-NEKOOSA	7.40285	0	1.445365	0	8.848215	0.023573
802033320	B20	S10	1	XCEL ENERGY BAY FRONT GENERATING STATION	0	154.7	0.0516017	44.9	199.6516	1.264953
802033320	B21	S11	1	XCEL ENERGY BAY FRONT GENERATING STATION	0	164.6	0.10482	51.7	216.4048	1.371098
802033320	B24	S13	4	XCEL ENERGY BAY FRONT GENERATING STATION	0	1.6	0.0513645	0	1.651365	0.010463
802033320	F04	F04	1	XCEL ENERGY BAY FRONT GENERATING STATION	0	0	2.810614	0	2.810614	0.017807
816009590	B27	S17	1	CALUMET SUPERIOR LLC	0	4.6425	0.6756847	0.37316	5.691345	0.038892
816009590	I10	S12	1	CALUMET SUPERIOR LLC	0	125.04	0.1046585	0.14	125.2847	0.856135
816009590	P19	S19	1	CALUMET SUPERIOR LLC	0	13.482	1.962216	1.083685	16.5279	0.112944
816009590	P20	S14	1	CALUMET SUPERIOR LLC	0	2.04	0.05092941	10.01	12.10093	0.082692
816009590	P31	S15	0	CALUMET SUPERIOR LLC	6.5871	13.43435	0.8873888	9.72	30.62884	0.209303
816009590	P32	S16	1	CALUMET SUPERIOR LLC	0	5.50425	0.9099727	0.44	6.854223	0.046838
816009590	P77	S16	1	CALUMET SUPERIOR LLC	0	200.862	10.44077	5.77	217.0728	1.483371
816036430	F01	F01	1	GRAYMONT (WI) LLC	0	0	2.039691	0	2.039691	0.01433
816036430	F02	F02	1	GRAYMONT (WI) LLC	0	0	5.226765	0	5.226765	0.036721
816036430	F05	F05	1	GRAYMONT (WI) LLC	0	0	1.111928	0	1.111928	0.007812
816036430	F07	F07	1	GRAYMONT (WI) LLC	0	0	6.998118	0	6.998118	0.049165
816036430	P30A	S10	1	GRAYMONT (WI) LLC	0	0	0	52.3	52.3	0.367432
816036430	P30A	S10	2	GRAYMONT (WI) LLC	0	64.169	1.522714	0	65.69171	0.461515
816036430	P31A	S11	1	GRAYMONT (WI) LLC	0	0	0	7	7	0.049178
816036430	P31A	S11	2	GRAYMONT (WI) LLC	0	13.9818	0.2806789	0	14.26248	0.100201
816036430	P33A	S14	1	GRAYMONT (WI) LLC	0	0	0	138.4	138.4	0.972326
816036430	P33A	S14	2	GRAYMONT (WI) LLC	0	98.7015	1.39991	0	100.1014	0.70326
816036430	P40A	S40	1	GRAYMONT (WI) LLC	0	0	0	247	247	1.735292
816036430	P40A	S40	2	GRAYMONT (WI) LLC	0	40.4263	1.816396	0	42.2427	0.296775
816036430	P50	S50	1	GRAYMONT (WI) LLC	0	235.3	4.186952	8.8	248.287	1.744334
816036430	P52	S52	1	GRAYMONT (WI) LLC	0	0	1.175351	0	1.175351	0.008257
851009390	B23	S23	1	FLAMBEAU RIVER PAPERS LLC	0	27.4905	1.1622	0.1341	28.7868	0.121169
851009390	B24	S24	1	FLAMBEAU RIVER PAPERS LLC	0	15.912	2.008808	41.42445	59.34526	0.249796
851009390	B24	S24	2	FLAMBEAU RIVER PAPERS LLC	0	194.2475	34.64796	3.439925	232.3354	0.977945
851009390	B24	S24	3	FLAMBEAU RIVER PAPERS LLC	0	8.41535	2.169323	0.153768	10.73844	0.0452
851009390	B25	S25	B25	FLAMBEAU RIVER PAPERS LLC	0	9.45	0.7182	0	10.1682	0.0428

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
851009390	B26	S26	1	FLAMBEAU RIVER PAPERS LLC	0	6.95	0.5282	0	7.4782	0.031477
851009390	B90	S90	1	FLAMBEAU RIVER PAPERS LLC	0	1.515	0.11514	0.00909	1.63923	0.0069
851009390	P110	S110	1	FLAMBEAU RIVER PAPERS LLC	0	0	0	32.0398	32.0398	0.134862
851009390	P130	S130	1	FLAMBEAU RIVER PAPERS LLC	0	0	0	74.7595	74.7595	0.314677
851009390	P140	S140	1	FLAMBEAU RIVER PAPERS LLC	0	0	0	5.36965	5.36965	0.022602
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	124.81	1.83645	14.3794	141.0259	0.350732
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	46.0897	0.765488	4.42366	51.27885	0.127531
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	24.1304	0.852138	5.11157	30.09411	0.074844
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	23.4406	1.37039	3.83145	28.64244	0.071234
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	21.4726	0.442599	2.48065	24.39585	0.060673
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	20.5386	0.267524	2.38841	23.19453	0.057685
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	21.0867	0.402619	1.31002	22.79934	0.056702
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	16.6531	0.280886	2.34411	19.2781	0.047945
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	16.5428	0.553451	0.519924	17.61618	0.043812
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	14.7146	0.272319	1.78062	16.76754	0.041701
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	14.2941	0.142885	1.13561	15.5726	0.038729
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	12.032	0.732502	1.13625	13.90075	0.034571
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	11.418	0.230906	1.7324	13.38131	0.033279
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	11.3788	0.131967	1.14928	12.66005	0.031486
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	5.81528	4.41643	1.21866	11.45037	0.028477
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	9.88145	0.120196	1.33432	11.33597	0.028193
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	8.54889	0.103367	1.13278	9.785037	0.024335
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	6.05499	0.0728048	0.585673	6.713468	0.016696
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	5.59211	0.0725099	0.575363	6.239983	0.015519
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	5.05611	0.0616364	0.55987	5.677616	0.01412
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	3.9148	0.474039	0.589542	4.978381	0.012381
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	3.47932	0.116403	0.109351	3.705074	0.009215
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	1.57525	0.0312347	0.154572	1.761057	0.00438
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	0.369705	0.974096	0.035099	1.3789	0.003429
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	1.24378	0.0119888	0.121636	1.377405	0.003426
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	0.956046	0.115767	0.143974	1.215787	0.003024
241870530				GENERAL MITCHELL INTERNATIONAL AIRPORT	0	0.929407	0.0304706	0.189402	1.14928	0.002858

Facility ID	Unit ID	Process Code	Process ID	Facility Name	2028 NH_3	2028 NOx	2028 $PM_{2.5}$	2028 SO_2	Total Emissions	Q/d
				POKEGAMA	0.058768	152.448	3.9938	0.063796	156.5644	1.025585

[*] NOx emissions (identified in red text) from the B01--2 process at Theda Clark Medical Center reported in LADCO's "Process level report of Q/d sources" (Haze_Control_Sheet_V6.9.xlsx) spreadsheet as 905.025 TPY are incorrect. NOx emissions for this process totaled 4.65 pounds in 2016. The WDNR did not correct this error in order to ensure consistency with the LADCO spreadsheet.

Table A2-2. Wisconsin Q/d > 10 Emissions Summary (supports Section 3.4.1 of the Round 2 haze SIP). The table below summarizes 2016 emissions (TPY) data from LADCO's "Process level report of Q/d sources" spreadsheet (Haze_Control_Sheet_V6.9.xlsx) for Wisconsin processes with a Q/d greater than 10.

	NH_3	NOx	$PM_{2.5}$	SO_2	Total Emissions[a]	Q/d
Processes with Q/d > 10 [N=4][b] (Units with Q/d > 10)	0 (0)	3,278 (3,510)	129 (139)	11,862 (12,790)	15,269 (16,439)	53 (57)
	Relative to Wisconsin Point Source Processes with Q/d > 1 [N = 45][b]					
Processes with Q/d > 1[c]	1,214	24,902	780	31,075	57,970	179
% contribution for processes with Q/d > 10[d] (for units with Q/d > 10)	0% (0%)	13% (14%)	17% (18%)	38% (41%)	26% (28%)	30% (32%)
	Relative to All Wisconsin Point Source Processes Analyzed [N = 350]					
All processes	1,597	32,298	1,766	33,870	69,531	216
% contribution for processes with Q/d > 10[d] (for units with Q/d > 10)	0% (0%)	10% (11%)	7% (8%)	35% (38%)	22% (24%)	25% (26%)

[a] Total emissions refer to the sum of NH_3, NOx, $PM_{2.5}$, and SO_2 emissions for each category.

[b] Wisconsin selected the four units with Q/d>10 for further evaluation (see Section 3.4.1 of the SIP), which in addition to the four processes with Q/d>10 here, also include the petroleum coke process (Q/d = 3.9) and two smaller processes (Q/d = 0.2) for A-M Kaukauna B11. Therefore, the percentage contributions for the units with Q/d>10 are even higher. (**Note:** the additional selection of A-M Kaukauna coal boiler B09 (Q/d=4.1) in Section 3.4.2 of the SIP is also not reflected in the percentage contributions reported for Q/d>10 units.)

[c] NOx emissions at Theda Clark Medical Center were over-reported by 905 TPY in 2016 (see Appendix 2, Table A2-1); accounting for this error would make the NOx and Total Emissions percentage contributions for Q/d>10 processes and units even higher.

[d] These percentage contributions are also higher when using 2028 Modeled or 2028 Adjusted point source emissions, because the selected units represent a larger portion of the NOx and SO_2 emission inventories.

Table A2-3. Visibility Improvement Calculation Table (supports Section 3.4.2 of the Round 2 haze SIP).

	% of Wisconsin Emissions				**Reference**
Source / State	**SO_2**	**NOx**			
A-M Kaukauna	23%	1.2%			Tables 6, 12 of Wisconsin Round 2 haze SIP
A-M Rhinelander	6.0%	1.1%			
	Source Region Contributions (Mm-1)				**Reference**
Source / State	**particulate sulfate**	**particulate nitrate**			
WI contribution to Seney	**1.0**	2.1			Table 8-6 of LADCO TSD, Tables 6, 12 of Wisconsin Round 2 haze SIP
A-M Kaukauna contribution to Seney	**0.23**	0.03			
WI cumulative contribution to Northern LADCO Class I Areas	1.9	4.1			
A-M Kaukauna cumulative contribution to Northern LADCO Class I Areas	**0.44**	**0.05**			
A-M Rhinelander cumulative contribution to Northern LADCO Class I Areas	**0.11**	**0.04**			
	Source Region Contributions (dv approximation[*])		**Total Beta extinction for dv approximation**		
Source / State	**particulate sulfate**	**particulate nitrate**	**Mm^{-1}**	**dv[*]**	**Beta extinction notes**
WI contribution to Seney	**0.17**	0.37	57.4	17.47	Seney, Table 8.5 of LADCO TSD
A-M Kaukauna contribution to Seney	**0.04**	0	57.4	17.47	
WI cumulative contribution to Northern LADCO Class I Areas	0.41	0.92	46.9	15.45	Average of the Northern LADCO Class I Areas, Table 8.5 of LADCO TSD
A-M Kaukauna cumulative contribution to Northern LADCO Class I Areas	**0.09**	**0.01**	46.9	15.45	
A-M Rhinelander cumulative contribution to Northern LADCO Class I Areas	**0.03**	**0.01**	46.9	15.45	
Cumulative A-M Kaukauna and Rhinelander nitrate, sulfate contributions (Mm^{-1})	**0.65**				
Cumulative A-M Kaukauna and Rhinelander nitrate, sulfate contributions (dv[*])	**0.14**				

Total combined light extinction at Northern LADCO Class I Areas on Most Impaired Days (Mm^{-1}) **[Reference:** Table 8.5 of LADCO TSD]	**187.53**	
Cumulative A-M Kaukauna and Rhinelander nitrate, sulfate contributions (% of total Northern LADCO Class I Area Light Extinction)	**0.3%**	
Wisconsin cumulative anthropogenic contribution to light extinction at Northern LADCO Class I Areas (Mm^{-1}) **[Reference:** Table 8.5 of LADCO TSD]	**7.21**	
Cumulative A-M Kaukauna and Rhinelander nitrate, sulfate contributions (% of WI contribution to Northern LADCO Class I Area Light Extinction)	**8.9%**	

*Mm^{-1} to deciview (dv) conversion was determined using the IMPROVE Haze Metric Converter, https://vista.cira.colostate.edu/Improve/haze-metrics-converter/.

LADCO | LAKE MICHIGAN AIR DIRECTORS CONSORTIUM

Modeling and Analysis for Demonstrating Reasonable Progress for the Regional Haze Rule 2018 - 2028 Planning Period

Technical Support Document

Lake Michigan Air Directors Consortium
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June 17, 2021

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Contents

Document Change Log

Version	Date	Comments/Changes
1	January 11, 2021	First draft to LADCO states
2	January 15, 2021	Updates to sections 2, 4, and 6
3	January 19, 2021	Updates to sections 4, 7, 8, and 8; grammatical/style edits throughout
4	January 27, 2021	Draft for comments to the LADCO regional haze workgroup; incorporated comments from WI DNR and MPCA
5	April 15, 2021	Draft final that integrated comments through March from LADCO states, EPA, and the Federal Land Managers; includes copy editing by LADCO staff
6	May 5, 2021	Removed references to LADCO 2016-based PSAT simulation
7	June 6, 2021	Added results from LADCO 2016abc and 2028abc PSAT simulations
8	June 17, 2021	Added a line to Table 8-1 providing a sum of other lines (contribution to b_{ext} on the most impaired days)

Errata/Known Issues

#	Description

Support Materials

Supplementary Materials

Electronic Docket

Figures

Tables

Executive Summary

LADCO prepared this Technical Support Document to support the development of regional haze state implementation plans (SIPs) for the second haze implementation period. The approaches documented here include emissions inventory processing; chemical transport modeling and evaluation; analysis of ambient monitoring data for haze species; and the calculation of reasonable progress metrics for comparison to regional haze goals. LADCO presents the modeling and analysis results for two base years (2011 and 2016), both projected to 2028, in order to provide robust assessment of expected future year air quality. LADCO also analyzed the stationary point source emission inventory to screen sources for their potential contribution to haze in downwind Class I areas. LADCO calculated distance weighted emissions (Q/d) for the 2028 stationary point inventories.

Analysis of observed ambient fine particle concentrations ($PM_{2.5}$) at surface monitors in the LADCO region in 2019 shows that the 24-hour design values are at least five $\mu g/m^3$ below the level of the NAAQS. The highest concentrations are in the urban areas, and the lowest concentrations are in the far northern parts of the region, including near LADCO's Class I areas, and in the Appalachian portions of Ohio and eastern Kentucky. The annual and 24-hour $PM_{2.5}$ design values for all LADCO states decreased by 33% to 51% between 2002 and 2019. The chemical composition of the $PM_{2.5}$ in the region has changed as concentrations have decreased. Fine particles have transitioned from containing primarily ammonium sulfate aerosols in 2001 to containing similar proportions of ammonium nitrate, ammonium sulfate, and organic carbon at the more rural IMRPOVE monitoring sites in 2018. The reductions in PM concentrations produced significant improvements to regional haze. Total light extinction from haze decreased by roughly 40 percent from 2000-2004 to 2014-2019 at all LADCO-region Class I monitors, with similar reductions on the clearest and most impaired days.

LADCO selected 2011 and 2016 as modeling years because they were available in U.S. EPA modeling platforms that included projections to 2028, the last year of the current regional haze implementation period. The U.S. EPA modeling platforms represented the state-of-the-science for the modeling software, and emissions and meteorology data. U.S. EPA used both platforms for regional haze modeling studies, providing further justification for selecting these years. LADCO chose to model two different base years to provide additional weight of evidence for our member states to use in their RHR reasonable progress SIPs. LADCO used the CAMx regional air quality model to estimate base and future year PM concentrations and haze conditions. We configured CAMx with the Particulate Matter Source Apportionment Tool (PSAT) to calculate emissions tracers for identifying upwind sources of haze at downwind Class I areas.

Starting in March 2018, LADCO produced a series of Q/d analyses for use by the LADCO member states for regional haze planning. LADCO used a cumulative Q/d threshold of 80% to identify sources for possible for-factor analysis. We provided the results of the Q/d analysis to the LADCO-member states in a spreadsheet to use to screen sources for further analysis.

LADCO's projections of haze in 2028 for both modeling platforms show that all of the LADCO-region Class I areas are predicted to be ahead of the uniform rate of progress (URP) toward natural visibility conditions. Predicted 2028 visibility conditions based on the 2016 modeling platform shows that the visibility in the Class I areas in Minnesota and Michigan is about 1 deciview below the unadjusted glidepath line (i.e., URP). Accounting for the adjustment due to international anthropogenic contributions, LADCO estimated 2028 visibility on the 20% most impaired days to be about 2.5 dv below the URP line.

1 Introduction

The Lake Michigan Air Directors Consortium (LADCO) was established by the states of Illinois, Indiana, Michigan, and Wisconsin in 1989. The four states and EPA signed a Memorandum of Agreement (MOA) that initiated the Lake Michigan Ozone Study and identified LADCO as the organization to oversee the study. Additional MOAs were signed by the states in 1991 (to establish the Lake Michigan Ozone Control Program), January 2000 (to broaden LADCO's responsibilities), and June 2004 (to update LADCO's mission and reaffirm the commitment to regional planning). In March 2004, Ohio joined LADCO. Minnesota joined the Consortium in 2012. LADCO consists of a Board of Directors (i.e., the State Air Directors), a technical staff, and various workgroups. The main purposes of LADCO are to provide technical assessments for and assistance to its member states, to provide a forum for its member states to discuss regional air quality issues, and to facilitate training for staff in the member states.

One of LADCO's responsibilities is to provide technical air quality modeling guidance and support to the LADCO states. LADCO prepared this Technical Support Document (TSD) to support our member-states' Regional Haze State Implementation Plans (SIPs) for the second haze implementation period. The approaches documented here include emissions inventory processing; chemical transport modeling and evaluation; analysis of ambient monitoring data for haze species; and the calculation of reasonable progress metrics for comparison to regional haze goals. LADCO presents the modeling and analysis results for two base years (2011 and 2016), both projected to 2028, in order to provide robust assessment of expected future year air quality.

1.1 Regional Haze

Particulate matter (PM) impairs visible light in the atmosphere either as distinct pollution plumes or as more uniformly distributed "regional haze". Regional haze is defined at 40 CFR 51.301 as "visibility impairment that is caused by the emission of air pollutants from numerous anthropogenic sources located over a wide geographic area. Such sources include, but are not limited to, major and minor stationary sources, mobile sources, and area sources." Fine particles less than 2.5 μm in diameter ($PM_{2.5}$) exist in the atmosphere as either primary emitted species or secondary species formed through chemical reactions. When these particles absorb and scatter light they alter the "clarity, color, and visible distance" in the atmosphere. The important PM species for visibility impairment include sulfate, nitrate, ammonium, elemental carbon, organic carbon and soil dust particles. (U.S. EPA 82 FR 3278 January 2017).

Section 169A of the 1977 amendments to the Clean Air Act (CAA) established a visibility protection program for the nation's areas of "great scenic importance", otherwise known as Class I areas. CAA Section 169A established 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 manmade air pollution" (U.S. EPA 82 FR 3278 January 2017).

In 1999, U.S. EPA promulgated the Regional Haze Rule (RHR) to establish more comprehensive visibility protections in the nation's Class I areas (Figure 1-1). There are 156 Class I areas, including four in the LADCO region[1]: Isle Royale National Park and Seney National Wildlife Refuge in Michigan; and Boundary Waters Canoe Area and Voyageurs National Park in Minnesota. EPA's visibility rule (64 FR 35714, July 1, 1999) requires reasonable progress in achieving "natural conditions" in all Class I areas by the year 2064.

For haze SIPs, the Clean Air Act sets "as a national goal the prevention of any future, and the remedying of any existing, impairment of visibility in Class I areas which impairment results from manmade air pollution." The RHR required that all states submit regional haze SIPs every 10 years and review these SIPs every 5 years. Requirements for regional haze SIPs (pursuant to 40 CFR 51.308(d)) include setting reasonable progress goals, determining baseline conditions, determining natural conditions, providing a long-term control strategy, providing a monitoring strategy (air quality and emissions), and establishing best available retrofit technology (BART) emissions limitations and associated compliance schedule. During the first regional haze implementation period, which culminated with regional haze SIPs that were due on December 17, 2007, LADCO effectively served as a Regional Planning Organization (RPO) for its member states[2]. These first regional haze SIPs addressed the initial 10-year implementation period (i.e., reasonable progress by the year 2018).

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[1] Although Rainbow Lake in northern Wisconsin is also a Class I area, the visibility rule does not apply because the Federal Land Manager determined that visibility is not an air quality related value there, meaning that….

[2] A sub-entity of LADCO, known as the Midwest Regional Planning Organization (MRPO), was responsible for the regional haze activities of the multi-state organization during the first RHR planning period.

Figure 1-1. Class I areas by Federal Land Manager

In January 2017, US EPA issued a final rule updating the regional haze program, including revising portions of the visibility protection rule promulgated in 1980 and the Regional Haze Rule promulgated in 1999 (U.S. EPA 82 FR 3278 January 2017). This rule clarifies the obligations of the states and U.S. EPA during the second haze implementation period, which tracks progress in improving visibility out to the year 2028. To aid states in developing second round regional haze SIPs, U.S EPA issued their “Guidance on Regional Haze State Implementation Plans for the Second Implementation Period” (U.S. EPA, 2019a).

LADCO followed the recommendations in the aforementioned Regional Haze SIP guidance document (U.S. EPA, 2019a) and referred to the U.S. EPA (2019b) Technical Support Document for EPA’s Updated 2028 Regional Haze Modeling and the U.S. EPA (2018) Modeling Guidance for Demonstrating Air Quality Goals for Ozone, PM2.5, and Regional Haze to inform the development of this document.

1.2 Project Overview

LADCO conducted emission inventory analysis and regional air quality modeling to support the development of Regional Haze SIPs**.** These SIP revisions are plans that describe how states will make reasonable progress toward meeting the visibility goals of the RHR. LADCO used the Comprehensive Air Quality Model with Extensions (CAMx[3]) to simulate PM and haze for two base years, 2011 and 2016. LADCO used CAMx to forecast haze conditions at the end of the second RHR planning period (2028) with emissions inventories projected to 2028 from each of these base years.

LADCO also performed analysis on the stationary point source emission inventory to screen sources for their potential contribution to haze in downwind Class I areas. LADCO calculated distance weighted emissions (Q/d)[4] for the 2028 stationary point inventories. LADCO worked with the states to apply these Q/d estimates for screening sources to subject to the four-factor analysis required by the RHR.

This document describes how LADCO used CAMx modeling to simulate base and future year air quality, and to evaluate if the Class I areas in and near the LADCO region are projected to meet or exceed the uniform rate of progress toward natural visibility conditions in 2064. The CAMx modeling outputs of this work are being provided to the LADCO state air programs to support their RHR SIP revisions that are due to EPA on July 31, 2021.

1.3 Organization of the Technical Support Document

This technical support document (TSD) is organized into the following sections.

- Section 2: Current and historical PM and haze conditions in the LADCO region
- Section 3: CAMx 2011 and 2016 modeling platforms; the platforms include base and future year (2028) emissions inventories, photochemical modeling data and configurations, and model performance evaluation methods
- Section 4: Emissions summaries of the 2011, 2016, and 2028 data used for the modeling in this TSD.
- Section 5: Q/d methods and results used to screen stationary point sources for four factor analysis.

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[3] www.camx.com

[4] where Q = emissions in tons/year and d = distance from the Class I areas in km

- Section 6: CAMx model performance evaluation results for both 2011 and 2016.
- Section 7: Second RHR planning period reasonable progress results and analysis.
- Section 8: CAMx source apportionment modeling results and analysis.
- The TSD concludes with a summary of significant findings and observations from the LADCO modeling.

A Supplemental Materials document includes supporting figures and tables for the results presented in this TSD.

An Electronic Docket on the LADCO website includes supporting spreadsheets, memos, and additional figures produced by LADCO during the second regional haze implementation period.

2 Ambient Air Quality Data and Visibility Analysis

In this section LADCO presents an analysis of the historical and current PM and haze conditions at monitors in the Great Lakes region. The goals of this section are to show the current status of ambient PM air quality and haze in the LADCO region and to illustrate the progress with these air quality indicators over time.

The primary contributor to reduced visibility is $PM_{2.5}$. An extensive network of regulatory and special-purpose monitors around the country measure ambient $PM_{2.5}$ concentrations. Measurements of speciated $PM_{2.5}$ components are made at a smaller network of sites. In particular, $PM_{2.5}$ composition measurements are used to track haze at the mostly rural Class I areas in the Interagency Monitoring of Protected Visual Environments (IMPROVE) network. In this section, we discuss the current status of and trends in both haze and $PM_{2.5}$ in the LADCO region, with a focus on the four Class I areas in the region.

2.1 Current $PM_{2.5}$ Conditions and Historical Trends

Concentrations of $PM_{2.5}$ are frequently reported as design values (DVs), which can be compared with the $PM_{2.5}$ National Ambient Air Quality Standard (NAAQS). These DVs are calculated as annual and daily (24-hour) averages.[5] We present both forms of $PM_{2.5}$ DVs in this section, along with a discussion of trends in DVs and $PM_{2.5}$ composition.

Figure 2-1 shows the annual and 24-hour 2019 $PM_{2.5}$ DVs within the LADCO region and neighboring states. $PM_{2.5}$ DVs at all monitors in the LADCO region are below the levels of both $PM_{2.5}$ NAAQS. In particular, all 24-hour DVs are at least five $\mu g/m^3$ below the level of the NAAQS. The highest concentrations are in the urban areas, and the lowest concentrations are in the far northern parts of the region, including near LADCO's Class I areas, and in the Appalachian portions of Ohio and eastern Kentucky.

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[5] The annual $PM_{2.5}$ DV is the three-year average of the annual mean concentration at a monitoring location. The 24-hour $PM_{2.5}$ DV is the three-year average of the 98th percentile of daily average $PM_{2.5}$ at a monitor. Design values are labeled by the last year of the three-year average. For example, the 2019 annual $PM_{2.5}$ DV is the three-year average of the annual average $PM_{2.5}$ concentrations for the years 2017-2019. We downloaded design values from EPA's Air Quality Design Values webpage: https://www.epa.gov/air-trends/air-quality-design-values.

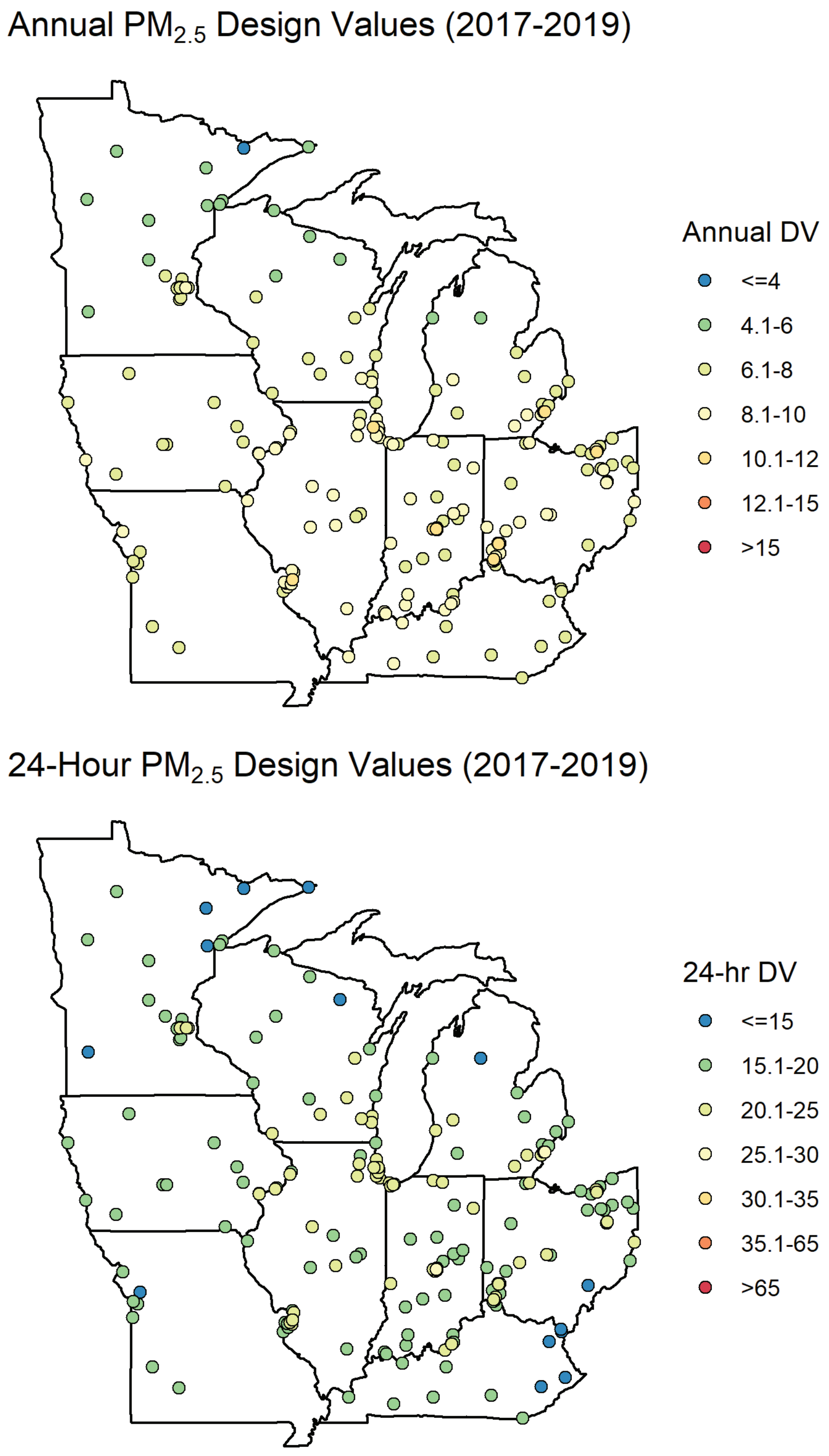

Figure 2-1. 2017-2019 annual (top) and 24-hour (bottom) PM$_{2.5}$ design values (DVs) in μg/m^3. For comparison, the annual PM$_{2.5}$ NAAQS is 12 μg/m^3, and the 24-hour NAAQS is 35 μg/m^3.

$PM_{2.5}$ design values have decreased dramatically in all states in the LADCO region over the last 19 years, as shown in Figure 2-2. The annual and 24-hour $PM_{2.5}$ design values for all states decreased by 33% to 51% since 2002. Ohio started with the highest concentrations and had the largest reductions, whereas Minnesota started with the lowest levels and had the smallest reductions. As a result of these differential changes, $PM_{2.5}$ levels in the six states have converged to much more uniform concentrations among the states. The pace of reduction in $PM_{2.5}$ DVs was especially large after the year 2007. The pace of reductions appears to have decreased somewhat in the last several years. However, state average concentrations are currently at least 14 $\mu g/m^3$ below the level of the 24-hour NAAQS and at least 3 $\mu g/m^3$ below the annual NAAQS.

Figure 2-3 shows how the chemical composition of the $PM_{2.5}$ has changed as its concentrations have decreased. This figure shows the chemical composition of $PM_{2.5}$ at LADCO state monitors in the primarily rural IMPROVE network. Concentrations of all of the major measured $PM_{2.5}$ species have decreased at the regional surface monitors since 2001, with the largest reductions (70%) from ammonium sulfate aerosols and the smallest reductions (7%) from organic carbon.[6] The disproportionately large reductions in ammonium sulfate reflect the dramatic reductions in sulfur dioxide emissions from stationary point sources resulting from regulatory control programs and economically driven shifts away from coal combustion. As a result, the chemical composition of fine particles has transitioned from containing primarily ammonium sulfate aerosols in 2001 to containing similar proportions of ammonium nitrate, ammonium sulfate, and organic carbon at these rural sites in 2018.

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[6] The other components had intermediate levels of reduction. Ammonium nitrate concentrations decreased by 20 percent, elemental carbon by 17 percent, and soil by 44 percent. Sea salt was a very small component but increased during this time by 58 percent.

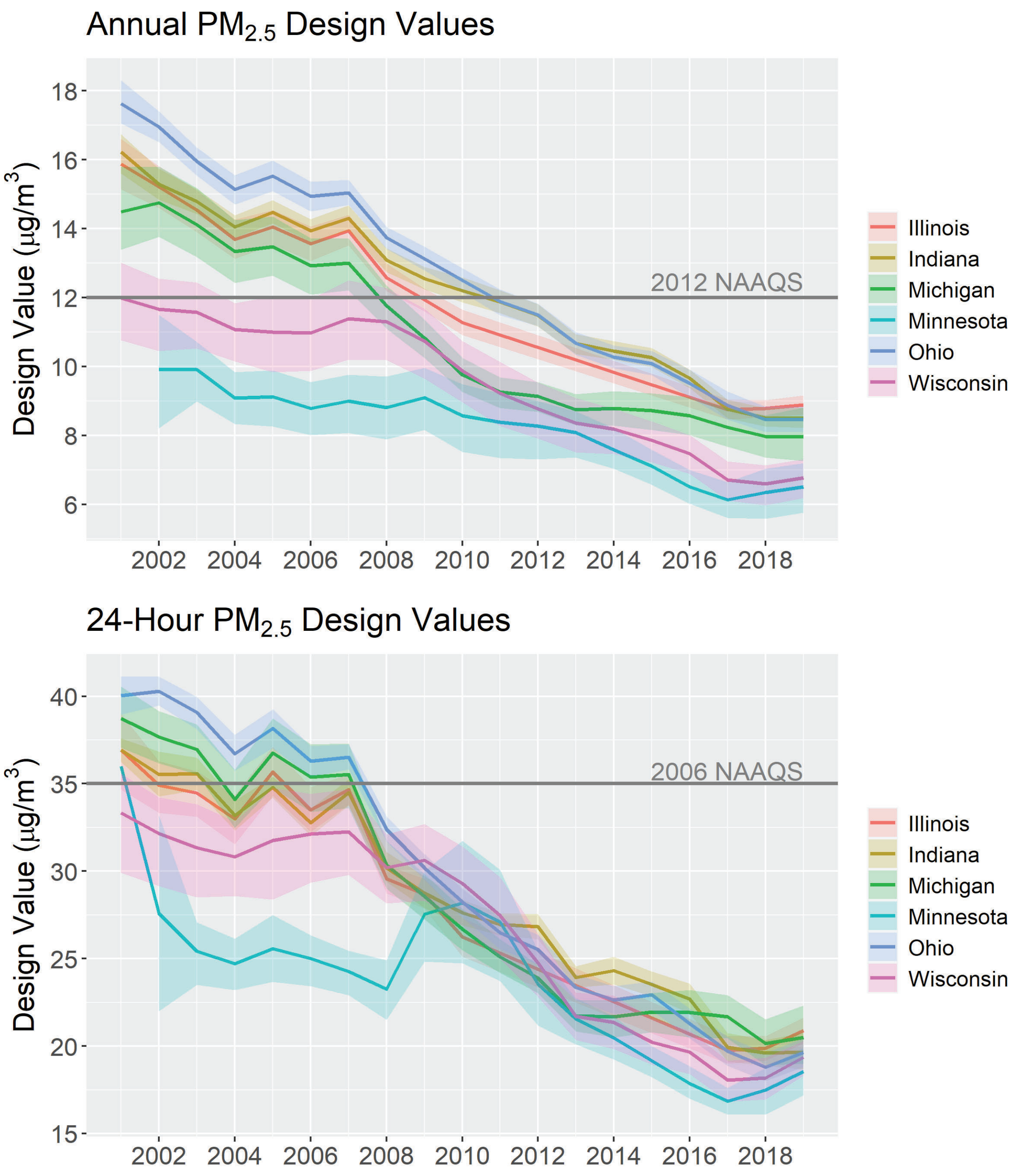

Figure 2-2. Trends in annual (top) and 24-hour (bottom) $PM_{2.5}$ design values in the LADCO states.[7] The levels of the NAAQS are shown for comparison. Dark lines show the state mean, whereas the shaded region shows the 95 percent confidence interval. Plots include monitors with at least six valid design values.

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[7] Note that design values were invalidated for Illinois for the years 2011 through 2016. Illinois values in this figure were interpolated between the preceding and subsequent design values.

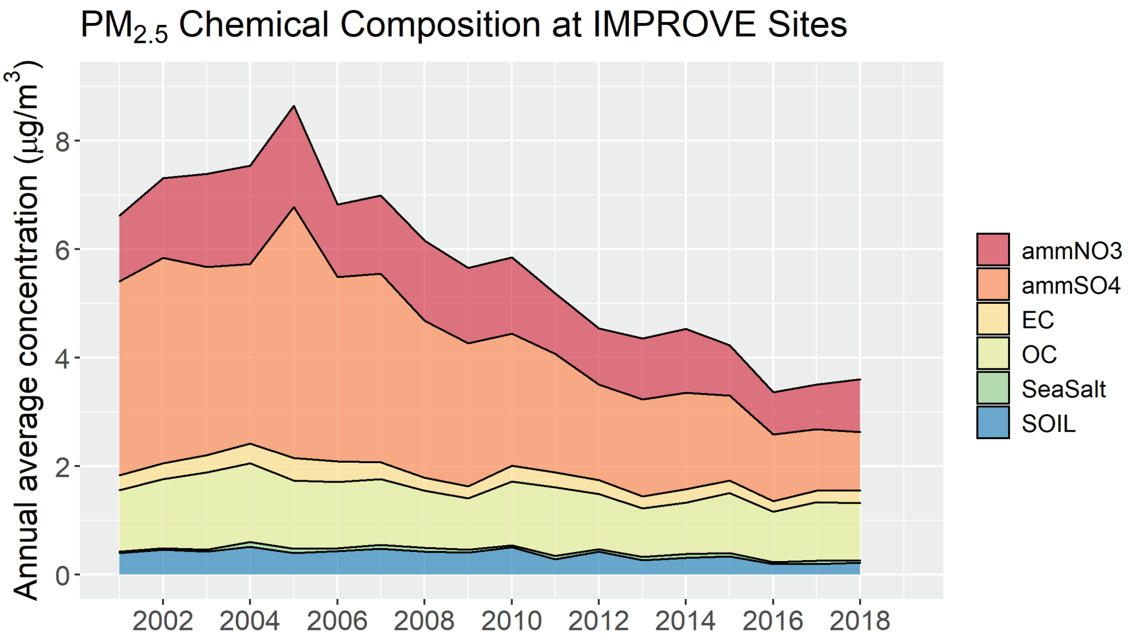

Figure 2-3. Chemical composition of $PM_{2.5}$ at the mostly rural IMPROVE monitoring sites in the LADCO region.[8]

2.2 Current Haze Conditions and Historical Trends

Visibility measurements are reported using either a light extinction coefficient (reported as inverse megameters, Mm^{-1}) or using the deciview haze index. Light extinction represents by how much light is attenuated per unit distance due to a combination of scattering and absorption by gases and particles. The deciview index is a logarithmic transformation of light extinction values[9] and is easier to relate to perceivable changes in visibility. Deciview values would be near zero for a pristine atmosphere and increase with increasing haze. We use both measures in this document. Light extinction is estimated from speciated particle measurements at IMPROVE monitoring sites using the IMPROVE algorithm and then converted to the deciview haze index.[10] We downloaded all visibility data from the Federal Land Manager Environmental Database except as noted.[11]

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[8] Components are: ammNO3 = ammonium nitrate, ammSO4 = ammonium sulfate, EC = elemental carbon, OC = organic carbon, SeaSalt = sea salt, and SOIL = inorganic soil components. Data were downloaded from the Federal Land Manager Environmental Database at http://views.cira.colostate.edu/fed/QueryWizard/.

[9] The relationship is: $dv = 10 \ln (b_{ext} / 10 \text{ Mm-1})$, where dv = deciviews and b_{ext} = the total light extinction coefficient.

[10] These calculations are described in greater detail in Section 7.1.

[11] http://views.cira.colostate.edu/fed/SiteBrowser/Default.aspx?appkey=SBCF_VisSum or http://views.cira.colostate.edu/fed/QueryWizard/.

Visibility at all of the mostly rural IMPROVE monitors in the eastern U.S. improved from 2002 to 2019, as reflected in lower deciview values (Figure 2-4). The haziest areas were located in the middle of this large area, from Iowa and Illinois down to Alabama. The cleanest areas were primarily located along the western and northern parts of this region. The largest reductions in haze over this time period (up to 47%) were found in the southeast and northeast. Reductions at the four LADCO Class I Area monitors were between 27% and 33% during this time. Visibility improvements have been even better than those laid out in the glidepaths for these sites to reach background conditions by 2064, as shown in Section 7.2.

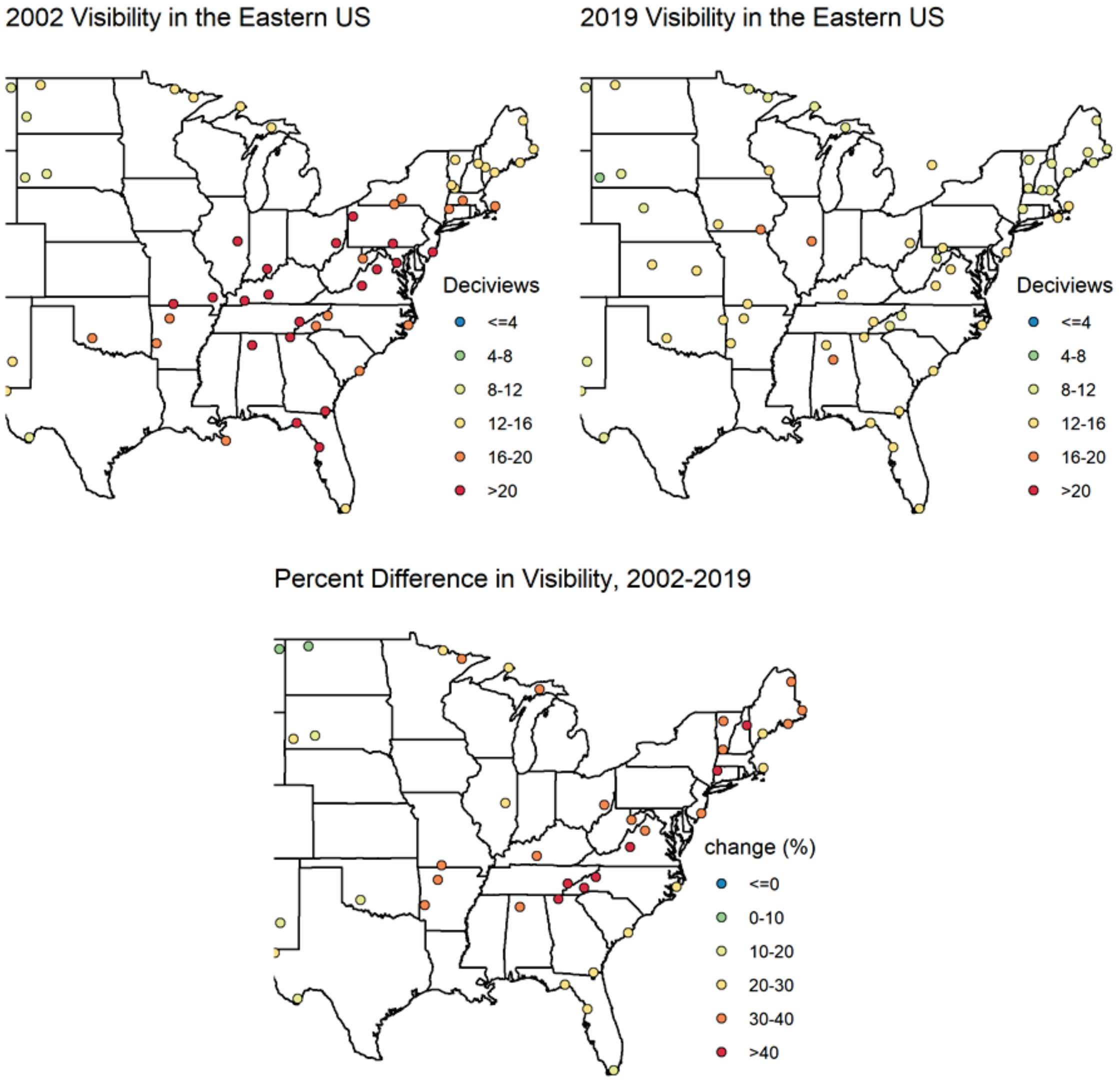

Figure 2-4. Visibility (in deciviews) at sites in the eastern United States in 2002 (left) and 2019 (right), and the percent difference in visibility in these two years (bottom).

Figure 2-5 breaks apart the visibility trends at the four LADCO Class I Area monitors based on the haziness of the day. From 2000 to 2018, visibility on the most impaired days improved by 18% to 26%, with the largest improvements at the Boundary Waters and Seney sites. Visibility improvements were even greater on the clearest days, with improvements of 26% to 34%, with the smallest improvement at Seney.

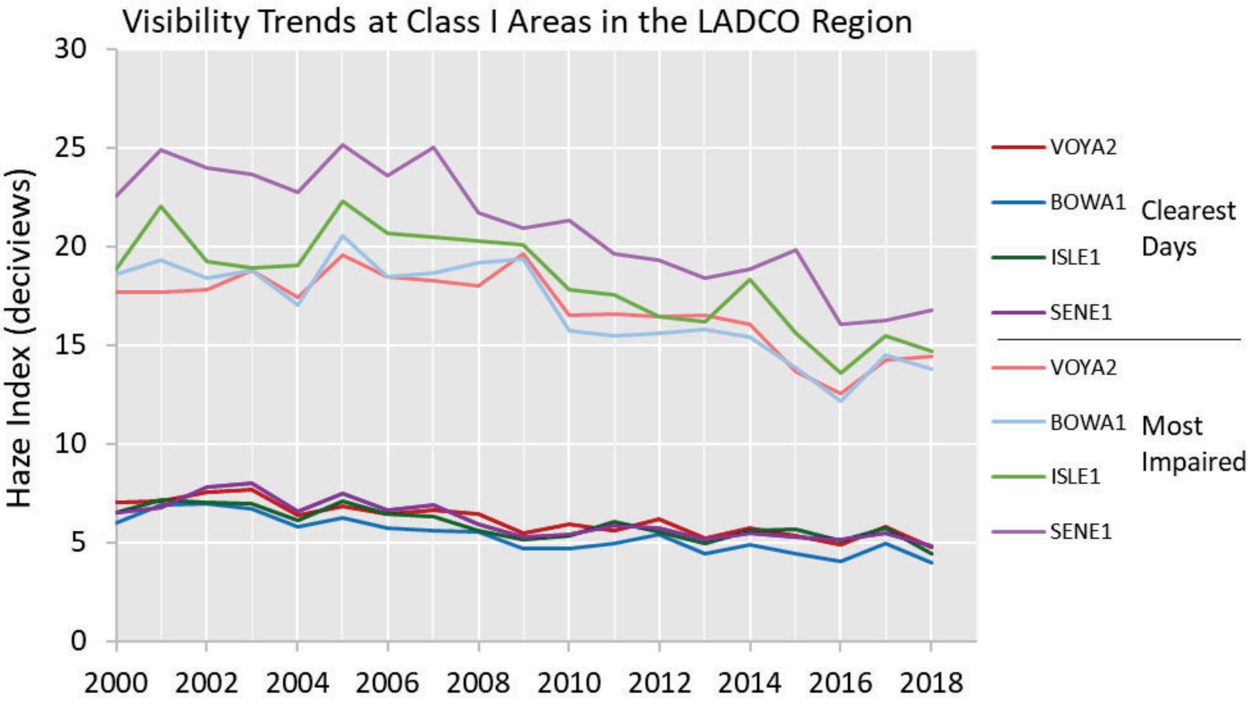

Figure 2-5. Visibility trends (in deciviews) at LADCO Class I Area monitors on the clearest and most impaired days.[12]

Table 2-1 shows the breakdown of the chemical components that contributed to haze at the four LADCO Class I area monitors in the years 2000-2004 and 2014-2019. Figure 2-6 shows the magnitudes and composition of light extinction for every year since 2000 for Minnesota's Voyageurs National Park. Supplemental Materials Section S1 includes comparable figures for the other three LADCO region Class I areas. This chemical speciation of visibility impacts is based upon the $PM_{2.5}$ chemical speciation at these

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[12] Site abbreviations are: VOYA2 = Voyageurs National Park (MN), BOWA1 = Boundary Waters Canoe Area (MN), ISLE1 = Isle Royale National Park (MI), and SENE1 = Seney (MI). Data were downloaded from the WRAP Technical Support System at https://views.cira.colostate.edu/tssv2/Express/HazeAnalysisTools.aspx.

sites (similar to that shown in Figure 2-3) but directly indicates the magnitude of the visibility impacts from each chemical component. The composition of light extinction will be somewhat different than the measured chemical composition of $PM_{2.5}$ because different chemical components have different degrees of impact on light and thus on visibility; for example, elemental carbon (soot) has a disproportionate impact on light and thus on haze.

Light extinction on the most impaired days was 6 to 12 times as large as that on the clearest days. On the clearest days, ammonium sulfate has historically been the largest component of haze, as shown in Table 2-1, Figure 2-6 and Section S1. Ammonium nitrate is a much more important component on the most impaired days than it is on the clearest days; in the years 2014-2018, it was the greatest contributor at all LADCO region Class I area sites.

Total light extinction from haze decreased by roughly 40 percent from 2000-2004 to 2014-2019 at all LADCO Class I monitors, with similar reductions on the clearest and most impaired days. However, different components contributed to these reductions on the different types of days. On the clearest days, there were large reductions in light extinction from all of the major components. On the most impaired days, there were large reductions in light extinction from ammonium sulfate, however, reductions from ammonium nitrate were much smaller, particularly at the Michigan sites. The slow pace of ammonium nitrate reductions led to its being the largest contributor to light extinction in recent years, as mentioned above. In general, haze seems to have peaked in the early- to mid-2000s, then steadily decreased. Total light extinction from haze may have plateaued in the last few years.

Analysis of the back-trajectories of polluted air masses provides insight into potential source locations impacting visibility. Figure 2-7 shows the back-trajectory-based residence times for air masses reaching the LADCO Class I monitors on the 20% most impaired days, weighted for distance from the monitor. For all four areas, the most polluted air masses most frequently arrived from the south and west. Supplemental Materials Section S2 includes similar figures that show how residence times vary based on the trajectory end-point altitude and the weighting of the residence time. All of these analyses show the importance of transport from the south on the most impaired days. This analysis suggests that sources in Minnesota, Wisconsin, Iowa, Illinois and Indiana are most likely to contribute to haze in the LADCO Class I areas. The more westerly source regions contribute more to visibility impairment in the Minnesota

Class I areas, and more easterly source region have a larger contribution to impairment in the Michigan Class I areas.

2.3 Summary

Overall, concentrations of $PM_{2.5}$ and haze have decreased significantly over the last two decades in the LADCO region. As a result, all monitors in the region are meeting the $PM_{2.5}$ NAAQS, and visibility at the regional Class I sites is better than the sites' glide paths. Concentrations of ammonium sulfate, which forms in part from atmospheric sulfur dioxide, have undergone particularly large reductions during this time due to control programs targeting that pollutant. As a result, ammonium nitrate and organic carbon have become relatively more important contributors to fine particulate matter and haze. Air masses on the most impaired days most frequently arrived at LADCO Class I sites from the south, suggesting that emission sources to the south likely contributed most to degraded visibility at these sites.

Table 2-1. Five-year average composition of light extinction (in Mm^{-1}) for LADCO region Class I Area monitors in the years 2000-2004 and 2014-2018.

Parameter	Light Extinction (Mm^{-1})											
	Voyageurs NP			Boundary Waters			Isle Royale NP			Seney		
	2000-2004	2014-2018	Change	2000-2004	2014-2018	Change	2000-2004	2014-2018	Change	2000-2004	2014-2018	Change
Clearest Days												
Ammonium Sulfate	4.2	2.2	-47%	4.1	2.2	-47%	4.6	2.7	-41%	4.8	2.6	-47%
Ammonium Nitrate	0.8	0.4	-46%	0.7	0.4	-42%	0.7	0.4	-41%	0.8	0.5	-40%
Organic Mass	2.1	1.4	-35%	2.0	1.2	-41%	1.2	1.0	-20%	1.6	1.1	-30%
Elemental Carbon	0.6	0.3	-52%	0.6	0.2	-57%	0.4	0.2	-40%	0.5	0.2	-50%
Soil	0.1	0.0		0.1	0.0		0.1	0.1		0.1	0.1	
Coarse Mass	0.7	0.6	-14%	0.7	0.6	-12%	0.7	0.6	-20%	0.7	0.5	-24%
Sea Salt	0.1	0.2		0.1	0.1		0.1	0.2		0.1	0.1	
Total	**8.6**	**5.1**	**-41%**	**8.3**	**4.7**	**-43%**	**7.8**	**5.2**	**-34%**	**8.6**	**5.1**	**-41%**
Most Impaired Days												
Ammonium Sulfate	20.3	11.7	-42%	25.8	11.9	-54%	32.5	15.5	-52%	58.1	18.7	-68%
Ammonium Nitrate	20.7	14.1	-32%	20.1	14.4	-28%	21.3	16.8	-21%	28.1	22.9	-18%
Organic Mass	6.4	3.7	-41%	6.6	3.9	-41%	6.7	4.4	-35%	10.8	5.5	-49%
Elemental Carbon	2.4	1.4	-41%	2.5	1.4	-46%	3.1	1.7	-46%	3.9	2.2	-43%
Soil	0.3	0.2	-33%	0.4	0.2	-53%	0.3	0.2	-33%	0.5	0.2	-57%
Coarse Mass	1.6	1.4	-10%	1.5	1.4	-3%	2.1	1.7	-16%	1.6	1.4	-13%
Sea Salt	0.1	0.3		0.1	0.2		0.1	0.3		0.0	0.2	
Total	**51.7**	**32.9**	**-36%**	**57.0**	**33.4**	**-41%**	**66.1**	**40.6**	**-39%**	**102.9**	**51.2**	**-50%**

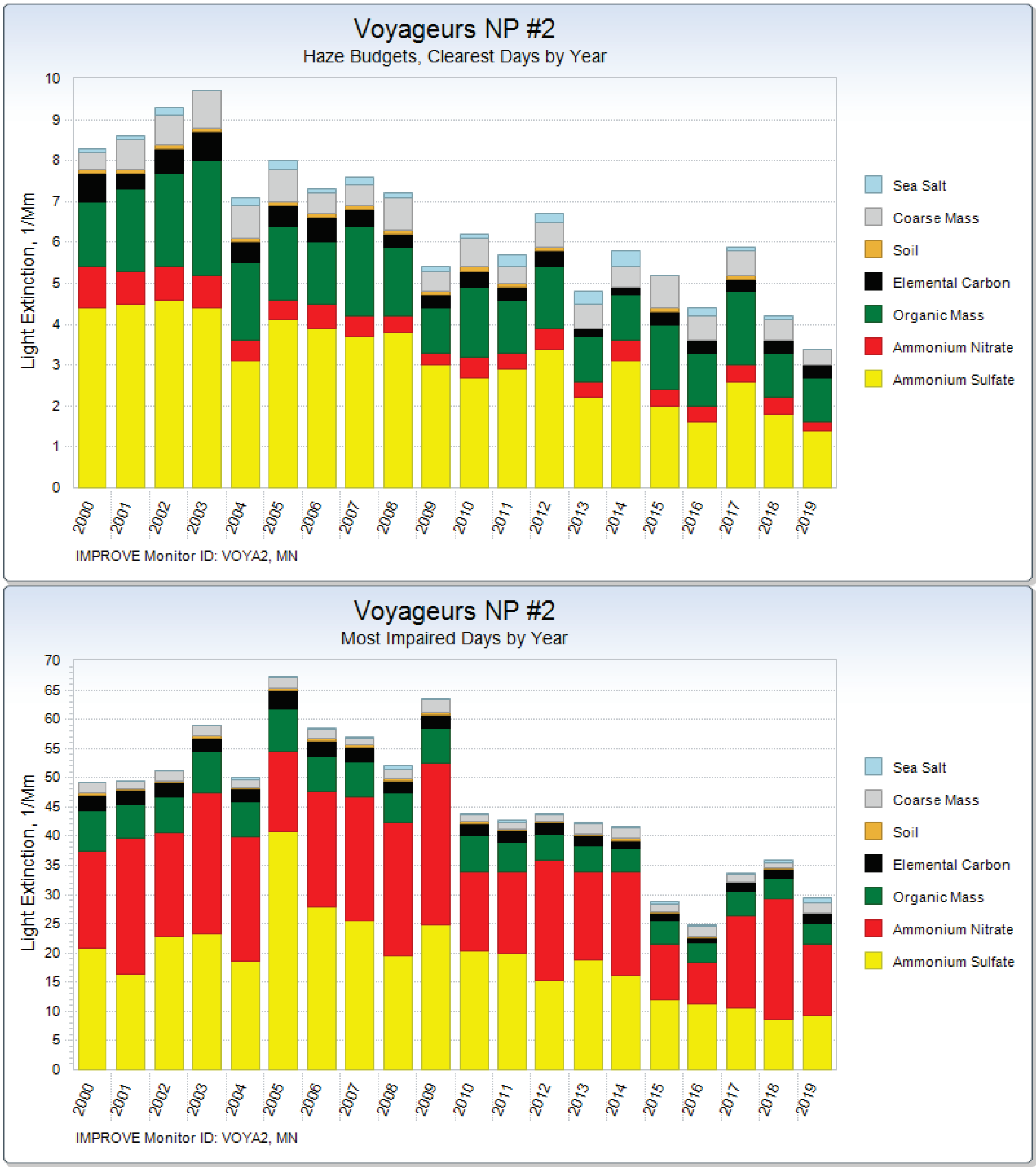

Figure 2-6. Composition of light extinction for Minnesota's Voyageurs National Park, shown for the clearest (top) and most impaired (bottom) days.

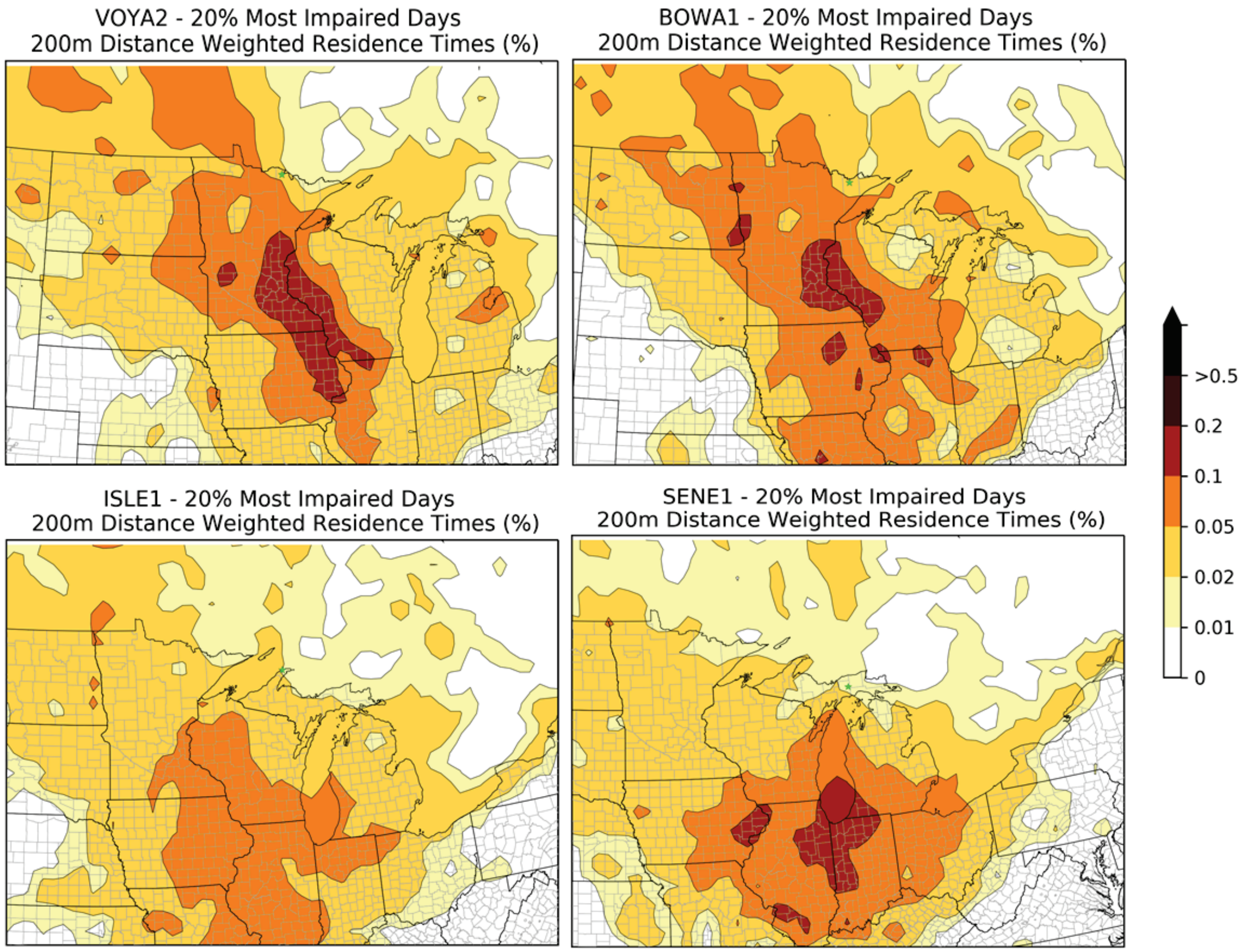

Figure 2-7. Distance weighted residence times for air masses reaching the four LADCO Class I areas on the 20% most impaired days for the years 2012 to 2016. Residence times were determined from 72-hour HYSPLIT back-trajectories ending at 200m altitude.[13]

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[13] Residence time is the normalized cumulative time that trajectories reside in a specific geographic area, weighted by the distance from the receptor (end point). Analyses were conducted by Ramboll for the Central States Air Resource Agencies (CenSARA) using the 12-km North American Model (NAM) meteorology for hours 6, 12, 18 and 24. The project report is available in the electronic docket for this TSD. Additional figures for the LADCO Class I areas are available in the Supplemental Materials document. Complete results and figures are available at https://censara.org/ftpfiles/Ramboll/.

3 Air Quality Modeling Platform

This section describes the details of the regional air quality modeling platforms used by LADCO to estimate haze conditions in 2028. The models described in this section are gridded, Eulerian chemistry-transport models designed to simulate, among other things, the PM species that contribute to regional haze. An air quality modeling platform is the complete collection of data, software, and scripts required for conducting regional modeling simulations. Air quality models are a key decision support tool for air quality planning because they integrate our knowledge of air pollution into software to predict future atmospheric conditions based on forecast changes in emissions.

LADCO selected two base modeling years (2011 and 2016) from which to project visibility conditions in 2028. We used two base years for a few different reasons:

1. The 2011 base year modeling platform was the best available option at the start of the second implementation period
2. When the 2016 base year modeling platform became available in 2020 it represented an improvement to the emissions data, particularly for the stationary source projections to 2028
3. Using two meteorology years for modeling provides additional weight of evidence to the states for use in demonstrating progress under the RHR

The goal of this section is to describe the details of the model simulations, including the input data and software used by LADCO to calculate future year visibility. We will present model emissions summaries, model performance and results in subsequent sections of the document.

3.1 Modeling Years Justification

LADCO selected 2011 and 2016 as modeling years because they were available in U.S. EPA modeling platforms that included projections to 2028, the last year of the current regional haze implementation period. The U.S. EPA modeling platforms represented the state-of-the-science for the modeling software, and emissions and meteorology data. U.S. EPA used both platforms for their preliminary (US. EPA, 2017) and updated (U.S. EPA, 2019) regional haze modeling studies, providing further justification for selecting these years. LADCO chose to model two different base years to provide additional weight of evidence for our member states to use in their RHR reasonable progress SIPs.

The availability of emissions inventories with projections to 2028 was a major factor in selecting these two base years. The triennial National Emissions Inventory (NEI) was conducted for the year 2011. Since its first release in 2014, the NEI2011 underwent several revisions, with the final update to version 6.3 released in October 2017 as part of the U.S. EPA's preliminary regional haze modeling platform (US EPA, 2017). Given the use of 2011-based data for evaluating regional haze progress during this implementation period by the U.S. EPA (2017), Metro4/SESARM (2018), and the Ozone Transport Commission (OTC, 2018), LADCO believes that using 2011-based data and emissions projections is justified.

In 2017 a group of multi-jurisdictional organizations (MJOs), states, and EPA established 2016 as the new base year for a national air quality modeling platform[14]. The group concluded that if only one recent year could be selected, then 2016 would serve as a good base year because of fairly typical O_3 conditions and average wildfire conditions. Following from the base year recommendations from that group, several modeling centers, including U.S. EPA and LADCO, developed data and capabilities for simulating and evaluating air quality in 2016.

Following from the selection of 2016 as the base year for a national modeling platform, starting in late 2017, the MJOs, states, and EPA formed the National Emissions Inventory Collaborative to develop a 2016 emissions inventory and modeling platform. Over 200 participants collaborated across 12 workgroups to develop base and future year emissions to support upcoming regulatory modeling applications. This effort was designed to involve a broad group of air pollution emissions experts in the development of a new national emissions modeling platform. LADCO used the 2016 and 2028 inventories developed by the Collaborative for the modeling presented here because they were the most recent inventory data available at the initiation of this project.

LADCO selected 2028 as the future projection year because it aligns with the end of the second regional haze implementation period and is a comparison point in the uniform rate of progress toward natural visibility in 2064.

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[14] Base Year Selection Workgroup Final Report

3.2 Electricity Generating Unit (EGU) Emissions Forecasts

LADCO relied upon U.S. EPA's inventory estimates from their 2011 and 2016 modeling platforms for most emissions sectors, as described in Sections 3.3.2 and 3.4.2. However, LADCO replaced the Integrated Planning Model (IPM) EGU inventories in the U.S. EPA 2011 and 2016 modeling platforms with inventories derived from the Eastern Regional Technical Advisory Committee (ERTAC) EGU model (MARAMA, 2012). The ERTAC EGU model for growth was developed around activity pattern matching algorithms designed to provide hourly EGU emissions data for air quality planning. The original goal of the model was to create low-cost software that air quality planning agencies could use for developing EGU emissions projections. States needed a model that did not produce large changes to the emissions forecasts with small changes in inputs. A key feature of the model includes data transparency; all of the inputs to the model are publicly available. The open source software includes documentation and a diverse user community to support new users of the software.

The ERTAC EGU model imports base year Continuous Emissions Monitoring (CEM) data for EGUs from U.S. EPA and sorts the data from the peak to the lowest generation hour. It applies hour specific growth rates that include peak and off-peak generation rates. The model then balances the system for all units and hours that exceed physical or regulatory limits by redistributing the power and associated emissions to underutilized units in the system. ERTAC EGU applies future year controls to the emissions estimates and tests for reserve capacity, generates quality assurance reports, and converts the outputs to Sparse Matrix Operator Kernel Emissions model (SMOKE)-ready files.

ERTAC EGU generates hourly future year emissions estimates. The model does not shutdown or mothball existing units because economics algorithms suggest they are not economically viable. Additionally, alternate control scenarios are easy to simulate with the model. Significant effort has been put into the model to prevent simulations from creating new coal plants to meet forecasted power demand. As an alternative, the model now allows portability of generation to different fuels like renewables and natural gas.

Differences between the IPM and ERTAC EGU emissions forecasts arise from alternative forecast algorithms, and from the data used to inform the model predictions.

3.2.1 2011 EGU Emissions Estimates

The 2011 based ERTAC EGU projections were the first year of estimates available from the ERTAC model. There were five different generations of improvements to the inputs, code, and methods in the model before the release of version 2.7 in 2017, which is the version used by LADCO for this application. Between 2011 and 2017 there were widespread shutdowns of coal EGUs across the country as natural gas and renewable generation integrated more widely into the power markets. During this period combined cycle natural gas plants changed from mostly handling peak loads to serving as base load EGUs. ERTAC EGU 2.7 reflected the transformation in the U.S power sector away from coal to less carbon intensive fuels.

3.2.2 2016 EGU Emissions Estimates

The IPM forecasts used for the U.S. EPA “2016fh” modeling platform were updated based on comments from states and stakeholders received through April 2019. LADCO replaced the IPM EGU forecasts in our modeling with ERTAC EGU version 16.1. The ERTAC EGU 16.1 forecasts used CEM data from 2016 and state-reported changes to EGUs received through September 2020. The LADCO-modified ERTAC EGU 16.1 emissions used for this modeling application represent the best available information on EGU forecasts for the Midwest and Eastern U.S. available in September 2020.

3.2.3 2028 EGU Emissions Forecasts

LADCO used ERTAC 16.1 forecasts to estimate 2028 EGU emissions. Figure 3-1 shows the ERTAC 16.1 2028 emissions projections for NOx and SO_2 as a circle plot. The size of the circles in the plot reflect the magnitude of the annual total future year emissions at individual EGU sources in the LADCO region. Figure 3-2 shows the EGU facility specific SO_2 emissions changes between 2016 and 2028 as forecast by ERTAC EGU 16.1. Red bubbles indicate lower emissions in 2028, while blue bubbles indicate higher emissions in 2028. The emissions increases are projected to occur primarily at natural gas EGUs to offset the lost generation capacity from the coal unit shutdowns. There were no new coal units in the LADCO region forecast by ERTAC EGU from 2016 to 2028.

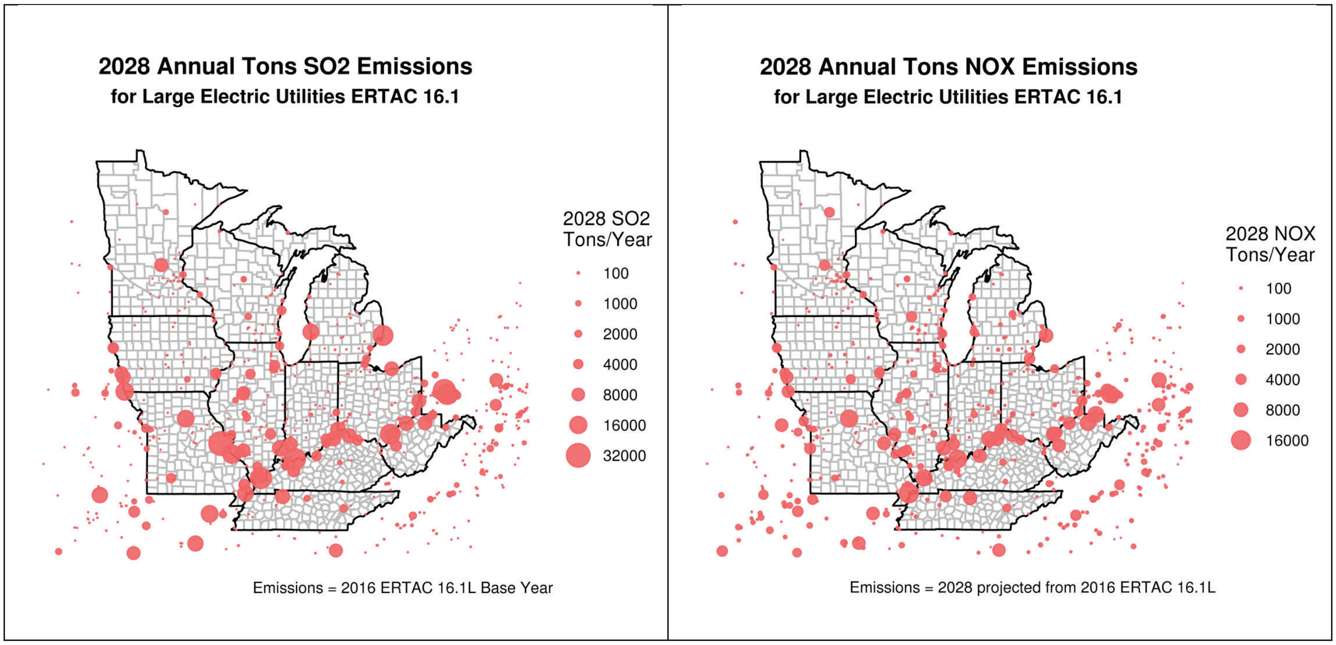

Figure 3-1. ERTAC EGU 16.1 2028 SO_2 (l) and NOx (r) emissions bubble plots

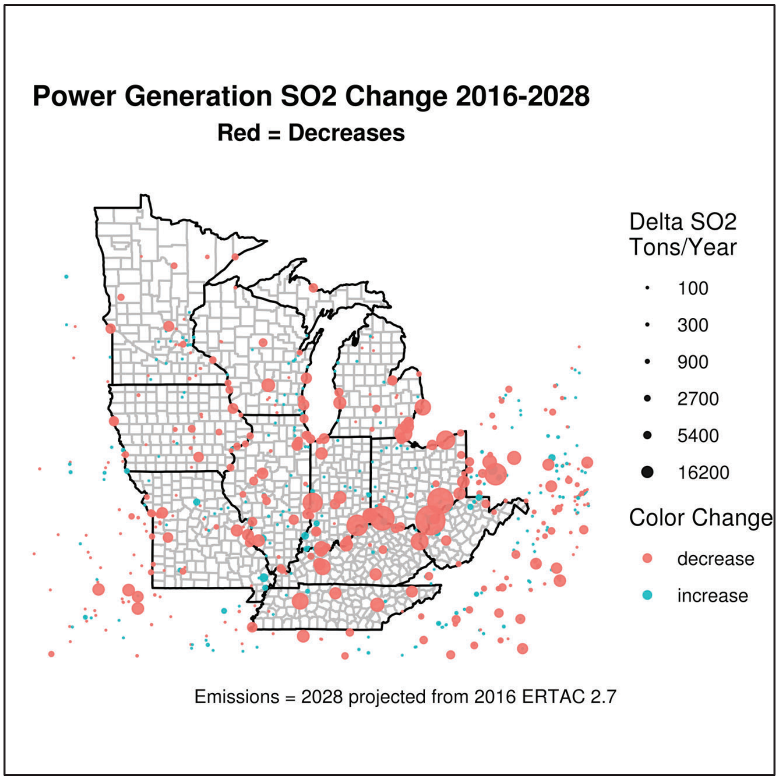

Figure 3-2. ERTAC EGU 16.1 SO_2 emissions difference (2016-2028) bubble plot

3.3 2011 Modeling Platform

LADCO based our 2011 modeling platform on the data and software used by the U.S. EPA for their Preliminary 2028 Regional Haze Modeling (U.S. EPA, 2017). EPA projected the 2011 base year emissions to 2028 to forecast regional haze conditions in the Class I areas. The components of the 2011 modeling platform are described below and in greater detail by U.S. EPA (2016a; 2016b).

3.3.1 Air Quality Model Configuration

LADCO used CAMx 6.40 (Ramboll, 2018) as the photochemical grid model for this application. CAMx is a three-dimensional, Eulerian air quality model that simulates the chemical transformation and physical transport processes of air pollutants in the troposphere. It includes capabilities to estimate the concentrations of primary and secondary gas and particle phase air pollutants, and dry and wet deposition, from urban to continental spatial scales. As CAMx associates source-level air pollution emissions estimates with air pollution concentrations, it can be used to design and assess emissions reduction strategies pursuant to NAAQS attainment goals.

LADCO selected CAMx for this study because it is a component of recent U.S. EPA modeling platforms for investigating the drivers of regional haze in the U.S. As CAMx is a component of U.S. EPA studies with a similar scope to this project (e.g., U.S. EPA, 2017), LADCO was able to leverage the data and software elements that are distributed with recent U.S. EPA regulatory modeling platforms. Using these elements saved LADCO significant resources relative to building a modeling platform from scratch.

Figure 3-3 shows the U.S. EPA modeling domain for the continental U.S. A 12-km uniform grid (12US2) covers all of the continental U.S. and includes parts of Southern Canada and Northern Mexico. The domain has 35 vertical layers with a model top at about 17,550 meters (50 mb). LADCO used the same 12US2 domain for this project because it supported the use of meteorology, initial and boundary conditions, and emissions data that were readily available from U.S. EPA.

Table 3-1 summarizes the CAMx science configurations and options LADCO used for the 2011 and 2028 CAMx modeling for this application. We used the Piecewise Parabolic Method (PPM) advection solver for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. We used K-theory for vertical diffusion using the CMAQ-like vertical diffusivities from WRFCAMx. The CB6r4 gas-phase chemical mechanism was selected because it includes the latest chemical kinetic rates and represents improvements over the other alternative CB05 and SAPRC chemical mechanisms as well as active methane chemistry. Additional CAMx inputs were as follows:

> Meteorological Inputs: LADCO used the U.S. EPA 2011 WRF data for this study (US EPA, 2014). The U.S. EPA used version 3.4 of the WRF model, initialized with the 12-km North American Model (NAM) from the National Climatic Data Center (NCDC) to simulate 2011 meteorology. U.S. EPA prepared the WRF data for input to CAMx with version 4.3 of the WRFCAMx software.
>
> Initial/Boundary Conditions: LADCO used 2011 initial and boundary conditions for CAMx generated by the U.S. EPA from the GEOS-Chem Global Chemical Transport Model (US EPA, 2017). EPA generated hourly, one-way nested boundary conditions (i.e., global-scale to regional-scale) from a 2011 2.0 degree x 2.5 degree GEOS-Chem simulation. Following the convention of the U.S. EPA regional haze modeling, LADCO used year 2011 GEOS-Chem boundary conditions for modeling 2028 air quality with CAMx.
>
> Photolysis Rates: LADCO prepared the photolysis rate inputs as well as albedo/haze/ozone/snow inputs for CAMx. Day-specific O_3 column data were based on the Total Ozone Mapping Spectrometer (TOMS) data measured using the satellite-based Ozone Monitoring Instrument (OMI). Albedo were based on land use data. For CAMx there is an ancillary snow cover input that will override the land use-based albedo input. LADCO used the TUV photolysis rate processor to prepare clear-sky photolysis rates for CAMx. If there were periods of more than a couple of days where daily TOMS data were unavailable in 2011, the TOMS measurements were interpolated between the days with valid data; in the case where large periods of TOMS data were missing, monthly average TOMS data were used. CAMx was also configured to use the in-line TUV to adjust for cloud cover and account for the effects that modeled aerosol loadings have on photolysis rates; this latter effect on photolysis may be especially important in adjusting the photolysis rates due to the occurrence of particulate matter (PM) concentrations associated with emissions from fires.
>
> Landuse: LADCO used landuse/landcover data from the U.S. EPA WRF simulation.

Spin-Up Initialization: LADCO used a minimum of ten days of model spin up (e.g., December 21-31, 2010) for the 12 km modeling domain. LADCO ran monthly CAMx simulations, initializing each month with a 10-day spin-up period.

LADCO used CAMx to simulate the entire year for 2011 and 2028. LADCO selected a CAMx configuration that was consistent with previous regional haze modeling applications performed by LADCO and U.S. EPA. U.S. EPA (2017) provides complete details of their 2011 CAMx simulation, including a performance evaluation.

Table 3-1. LADCO 2011 and 2016 CAMx modeling platform configurations

Science Options	CAMx 2011 Configuration	CAMx 2016 Configuration
Model Codes	CAMx v6.40	CAMx v7.0
Simulation Period	December 21, 2010 – December 31, 2011	December 21, 2015 – December 31, 2016
Horizontal Grid Mesh	12 km, 396 col x 246 rows	12 km, 396 col x 246 rows
Vertical Grid Mesh	25 CAMx layers collapsed from 35 WRF layers	35 WRF layers (no collapsing)
Grid Interaction	None	None
Initial Conditions	10 day spin-up on 12 km grid	10 day spin-up on 12 km grid
Boundary Conditions	12km from GEOS-Chem	12km from hemispheric CMAQ
Emissions		
Baseline Emissions Processing	Sparse Matrix Operator Kernel Emissions (SMOKE), EPA's MOtor Vehicle Emission Simulator (MOVES) and Biogenic Emission Inventory System (BEIS)	
Emissions Modeling Platform	U.S. EPA 2011 "EN" with ERTAC 2.7 EGU Point and hourly CEMs	U.S. EPA 2016 "FH" Platform with ERTAC 16.1 EGU Point and hourly CEMs
Chemistry		
Gas Phase Chemistry	CB6r4	CB6r4
Aerosol Chemistry	CF + SOAP	CF + SOAP
Meteorology		
Model Codes	WRF v3.4	WRF v3.8
Meteorological Processor	WRFCAMx v4.3	WRFCAMx v4.6
Horizontal Diffusion	Spatially varying	Spatially varying
Vertical Diffusion	CMAQ-like in WRF2CAMx	CMAQ-like in WRF2CAMx
Diffusivity Lower Limit	Kz_min = 0.1 to 1.0 m^2/s or 2.0 m^2/s	Kz_min = 0.1 to 1.0 m^2/s or 2.0 m^2/s
Dry Deposition	Zhang dry deposition scheme (CAMx)	Zhang dry deposition scheme (CAMx)
Wet Deposition	CAMx-specific formulation	CAMx-specific formulation
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) -- Fast Solver	Euler Backward Iterative (EBI) -- Fast Solver

Science Options	CAMx 2011 Configuration	CAMx 2016 Configuration
Vertical Advection Scheme	Implicit scheme w/ vertical velocity update (CAMx)	Implicit scheme w/ vertical velocity update (CAMx)
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme	Piecewise Parabolic Method (PPM) scheme
Integration Time Step	Wind speed dependent	Wind speed dependent
Source Apportionment	PSAT with 26 state and region tags	

Figure 3-3. CAMx 12-km modeling domain (12US2)

3.3.2 2011 and 2028 Emissions Data

LADCO based the 2011 and 2028 emissions data for this study on the U.S. EPA 2011v6.3 (“EN”) emissions modeling platform (US EPA, 2017b). U.S. EPA generated this platform for their assessment of interstate transport for the 2015 O_3 NAAQS (U.S. EPA, 2016a), and used these data for their preliminary regional haze modeling for Round 2 of the RHR (U.S. EPA, 2017a). LADCO also used these data in support of our member states’ interstate transport SIPs for the 2015 ozone NAAQS (LADCO, 2018). While the U.S. EPA made several changes to the forecasted 2028 emissions in the “EN” platform relative to the earlier “EL” platform, the changes to the base year (2011) model between the two platforms were minor (US EPA, 2017b).

LADCO replaced the EGU emissions in the U.S. EPA EN platform with 2028 EGU forecasts estimated with the ERTAC EGU Tool version 2.7 (MARAMA, 2012), as described in Section 3.2. Since there are differences in the way that EGUs are classified in ERTAC and U.S. EPA's IPM, LADCO used ERTAC's 2028 non-EGU point inventory to replace the same sector in U.S. EPA's 2011 EN modeling platform. We used the U.S. EPA EN platform emissions estimates for all other inventory sectors. Table 3-2 shows the 2011 and 2028 inventory components used by LADCO to forecast regional haze.

Table 3-2. LADCO 2011 emissions modeling platform inventory components

Sector	Abbreviation	Base Year Data Source	Future Year Data Source
Agriculture	ag	U.S. EPA 2011ek	U.S. EPA 2028el
Area and Fugitive Dust	afdust	U.S. EPA 2011ek	U.S. EPA 2028el
Biogenic	beis	U.S. EPA 2011en	U.S. EPA 2011en
C1/C2 Commercial Marine	cmv_c1c2	U.S. EPA 2011en	U.S. EPA 2028en
C3 Commercial Marine	cmv_c2	U.S. EPA 2011en	U.S. EPA 2028en
Nonpoint	nonpt	U.S. EPA 2011en	U.S. EPA 2028en
Offroad Mobile	nonroad	U.S. EPA 2011en	U.S. EPA 2028en
Nonpoint Oil & Gas	np_oilgas	U.S. EPA 2011ek	U.S. EPA 2028en
Onroad Mobile	onroad	U.S. EPA 2011el	U.S. EPA 2028en
Point Oil & Gas	pt_oilgas	U.S. EPA 2011ek	U.S. EPA 2028en
Electricity Generation	ptegu	U.S. EPA 2011el	ERTAC EGU 2.7
Industrial Point	ptnonipm	U.S. EPA 2011en	MARAMA 2011v2[15]
Rail	rail	U.S. EPA 2011ek	U.S. EPA 2028el
Residential Wood Combustion	rwc	U.S. EPA 2011ek	U.S. EPA 2028el
Agricultural Fires	ptagfire	U.S. EPA 2011ek	U.S. EPA 2011ek
Wild and Prescribed Fires	ptfire	U.S. EPA 2011ek	U.S. EPA 2011ek
Mexico Anthropogenic	Multiple	U.S. EPA 2011ek	U.S. EPA 2011ek
Canada Anthropogenic	Multiple	U.S. EPA 2011en	U.S. EPA 2011en

3.4 2016 Modeling Platform

3.4.1 Air Quality Model Configuration

LADCO based our CAMx air quality modeling platform for this application on the configuration that the U.S. EPA used for their updated regional haze modeling (US EPA, 2019b). LADCO used CAMx 7.0 (Ramboll, 2020) as the photochemical grid model for this application. Similar to the 2011 modeling

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[15] MARAMA developed a non-EGU point inventory for use with the ERTAC EGU2.7 emissions from the 2011NEIv2

platform, LADCO was able to leverage data and software elements that U.S. EPA distributed for regulatory rulemaking.

The LADCO 2016 CAMx modeling used a similar configuration as the 2011 modeling platform. The horizontal domains are the same between the two simulations (12US2 modeling domain). The 2016 CAMx simulation used all 35 of the WRF vertical layers with no layer collapsing.

Table 3-1 summarizes the CAMx science configurations and options LADCO used for the 2016 and 2028 CAMx modeling for this application. We used the Piecewise Parabolic Method (PPM) advection solver for horizontal transport along with the spatially varying (Smagorinsky) horizontal diffusion approach. We used K-theory for vertical diffusion using the CMAQ-like vertical diffusivities from WRFCAMx. The CB6r4 gas-phase chemical mechanism was selected because it includes the latest chemical kinetic rates and represents improvements over the other alternative CB05 and SAPRC chemical mechanisms as well as active methane chemistry. Additional CAMx inputs were as follows:

> Meteorological Inputs: LADCO used the U.S. EPA 2016 WRF data for this study (US EPA, 2019c). The U.S. EPA used version 3.8 of the WRF model, initialized with the 12-km North American Model (NAM) from the National Climatic Data Center (NCDC) to simulate 2016 meteorology. Complete details of the WRF simulation, including the input data, physics options, and four-dimensional data assimilation (FDDA) configuration are detailed in the Meteorology Model Performance for Annual 2016 Simulation WRFv3.8 report (US EPA, 2019c). LADCO prepared the WRF data for input to CAMx with version 4.6 of the WRFCAMx software.
>
> Initial/Boundary Conditions: LADCO used 2016 initial and boundary conditions for CAMx generated by the U.S. EPA from a northern hemisphere simulation of the Community Multiscale Air Quality (CMAQ) model (US EPA, 2019d). EPA generated hourly, one-way nested boundary conditions (i.e., hemispheric-scale to regional-scale) from a 2016 108-km x 108-km polar stereographic CMAQ simulation of the northern hemisphere. Following the convention of the U.S. EPA 2016 regional haze modeling (U.S. EPA, 2019b), LADCO used year 2016 CMAQ boundary conditions for modeling 2016 and 2028 air quality with CAMx.
>
> Photolysis Rates: LADCO prepared the photolysis rate inputs in the same manner as for the 2011 modeling platform described above.

Landuse: LADCO used landuse/landcover data from the U.S. EPA WRF 2016 simulation.

Spin-Up Initialization: A minimum of ten days of model spin up (e.g., December 21-31, 2015) was used for the 12 km modeling domain. LADCO ran quarterly CAMx simulations, initializing each quarter with a 10-day spin-up period.

LADCO used CAMx to simulate the entire year for 2016 and 2028. LADCO selected a CAMx configuration that was consistent with previous regional haze modeling applications performed by U.S. EPA. U.S. EPA (2019b) provides complete details of their 2016 CAMx simulation, including a performance evaluation.

3.4.2 2016 and 2028 Emissions Data

LADCO collected 2016 and 2028 emissions data for this study primarily from the U.S. EPA 2016 v1 ("2016fh_16") emissions modeling platform (U.S. EPA, 2020). U.S. EPA and the 2016 Emissions Inventory Collaborative[16] generated this platform for use in O_3 NAAQS and Regional Haze SIPs.

In addition to a base year emissions estimate for use in a model performance evaluation, LADCO developed a typical-year emissions estimate for comparison with the 2028 forecast (see Section 4.2.3). The typical emissions included three taconite facility industrial point sources. All three sources temporarily shut down in 2016 and restarted operations in 2017, and are included in the 2028 inventory. LADCO also removed an emissions record from the 2016 inventory for the Wisconsin Rapids wastewater treatment facility that incorrectly added 5,000 tons/year of NOx to the inventory for this source. Table 3-3 shows the sources in Minnesota that LADCO included in the typical year emissions that are not included in the 2016 actual base year emissions.

Table 3-3. LADCO typical year inventory sources

Facility	State	NOx Emissions (tons/year)	SO_2 Emissions (tons/year)
US Steel Keetac	MN	5,009	533
Northshore Mining Silver Bay	MN	785	151
United Taconite Fairlane	MN	374	275

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[16] http://views.cira.colostate.edu/wiki/wiki/10202

LADCO replaced the 2028 EGU emissions in the U.S. EPA "2016fh" emissions modeling platform with 2028 EGU forecasts estimated with the ERTAC EGU Tool version 16.1 (MARAMA, 2012), as discussed above. LADCO also used the ERTAC non-EGU point inventory in our 2016 modeling platform to ensure consistency with the EGU sector.

Figure 3-4 through Figure 3-9 show 2016 daily total EGU NOx emissions by fuel type for each of the LADCO states. These figures show that in 2016 the NOx emissions from power generation in the LADCO region were primarily emitted by sources that burn coal, that there is significant day to day variation in power plant emissions, and that the summer and winter seasons are the peak periods of EGU NOx emissions.

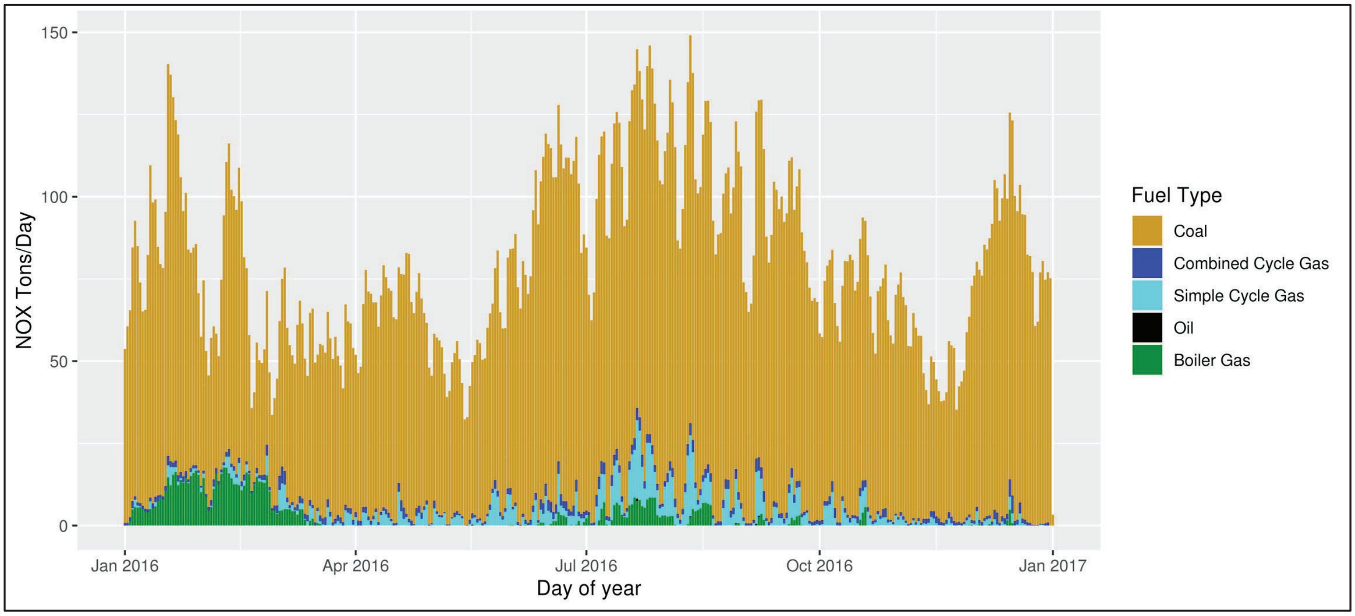

Figure 3-4. Illinois power generation 2016 daily NOx emissions by fuel type

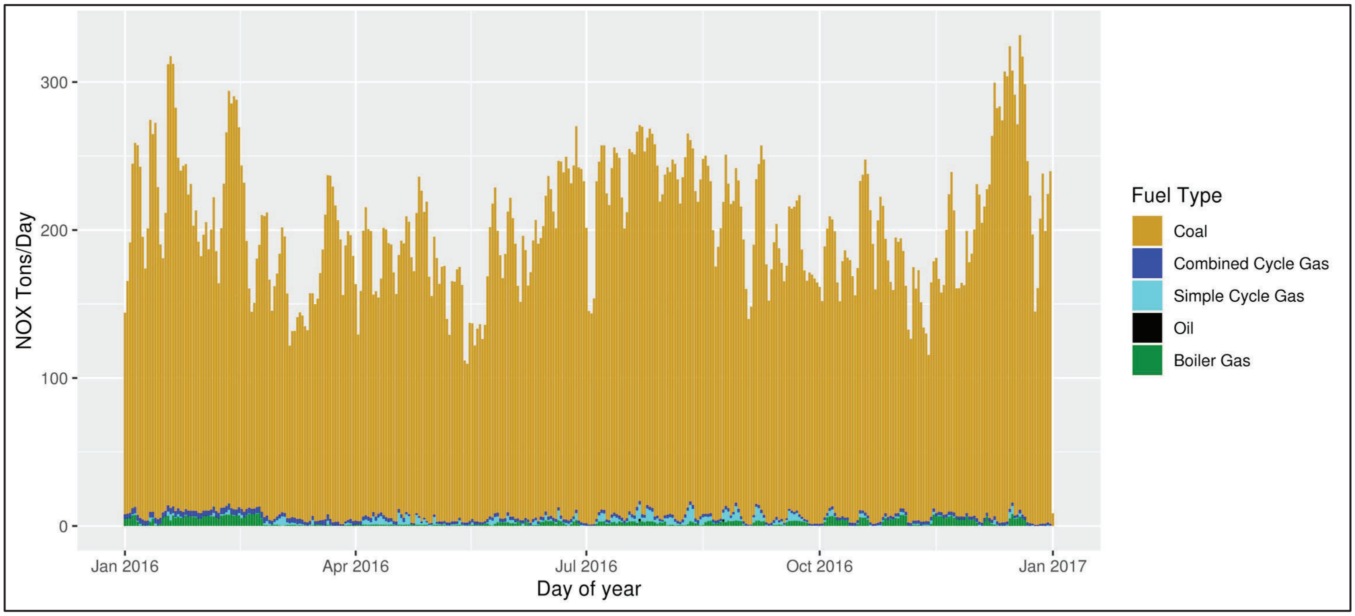

Figure 3-5. Indiana power generation 2016 daily NOx emissions by fuel type

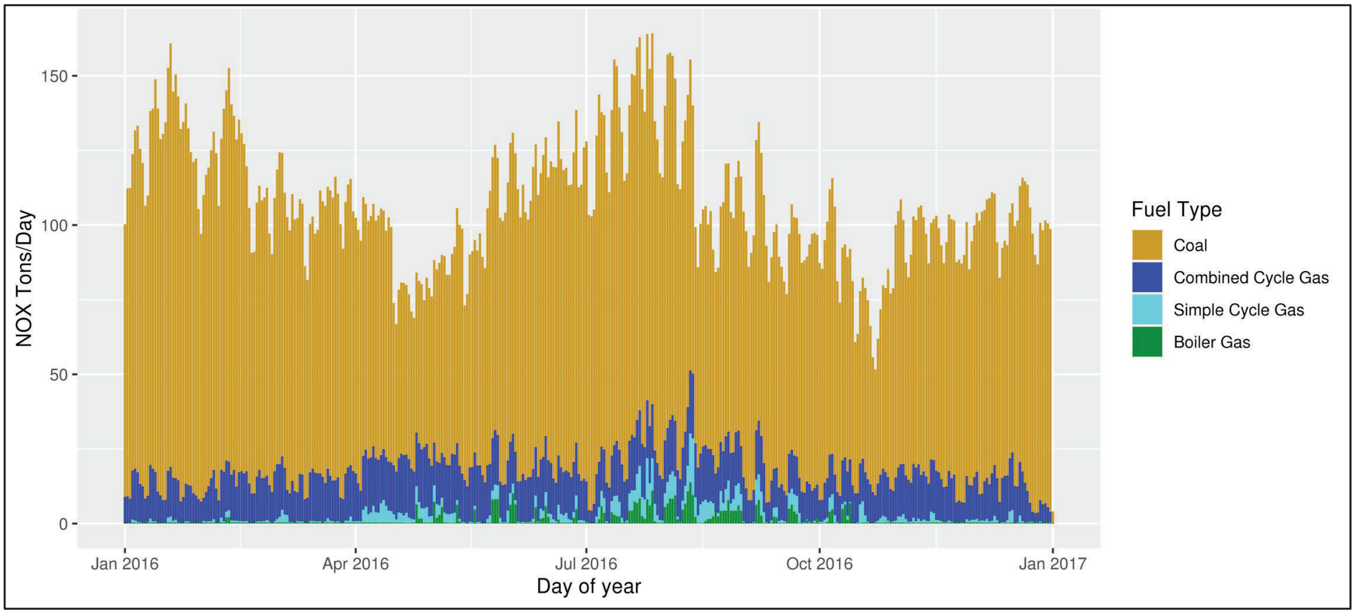

Figure 3-6. Michigan power generation 2016 daily NOx emissions by fuel type

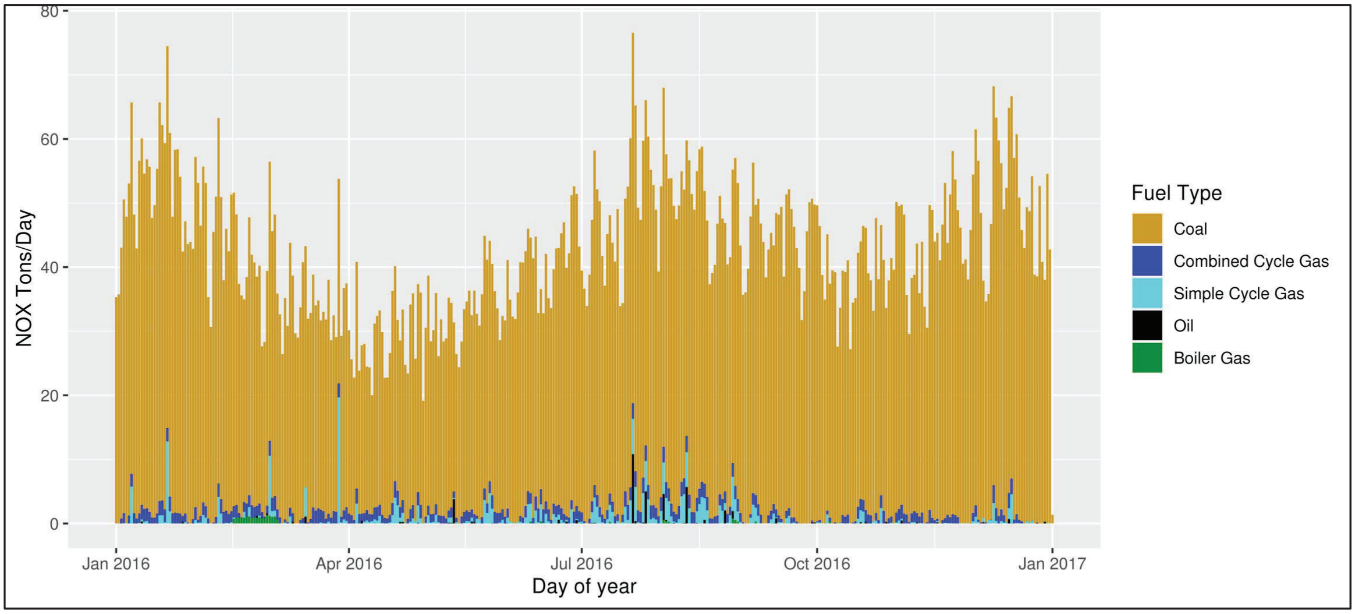

Figure 3-7. Minnesota power generation 2016 daily NOx emissions by fuel type

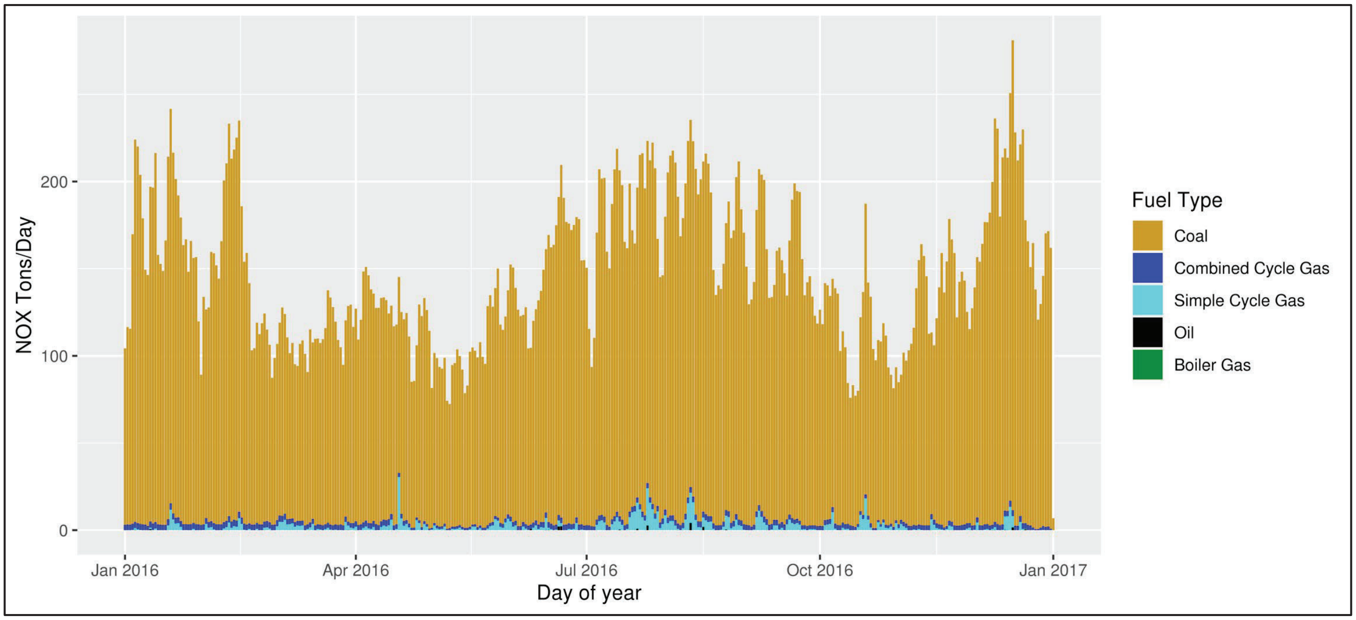

Figure 3-8. Ohio power generation 2016 daily NOx emissions by fuel type

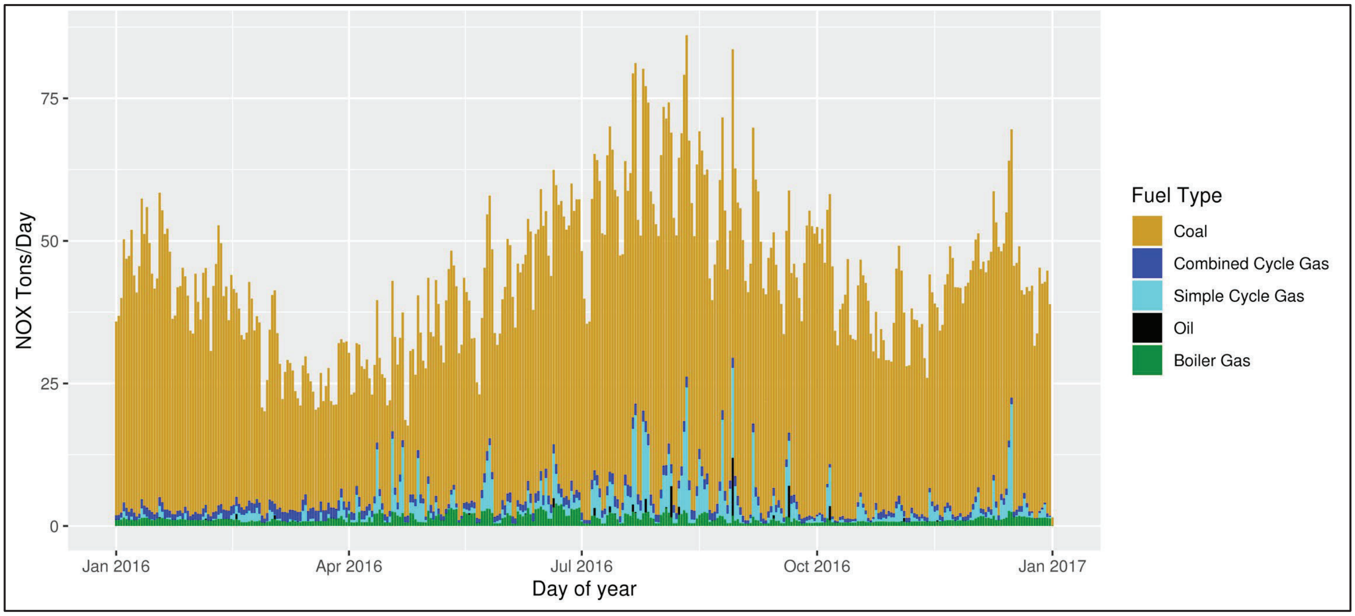

Figure 3-9. Wisconsin power generation 2016 daily NOx emissions by fuel type

LADCO modified the ERTAC EGU 16.1 inventory forecasts for 2028 for the 2016 base year modeling to exclude the emissions from 62 EGU units that announced shutdowns that will occur before 2028. These announcements came after the ERTAC EGU 16.1 emissions were developed. LADCO zeroed out the 2028 emissions from these units in our 2016-based modeling forecasts for 2028. Supplemental materials Section S3 lists the additional units that LADCO removed from our 2016-based 2028 modeling.

Figure 3-10 compares 2016 and 2028 daily total SO_2 emissions from all EGUs in the LADCO region. The two lines in the figure illustrate the daily temporal variability in SO_2 emissions from electricity generating point sources across the LADCO region.

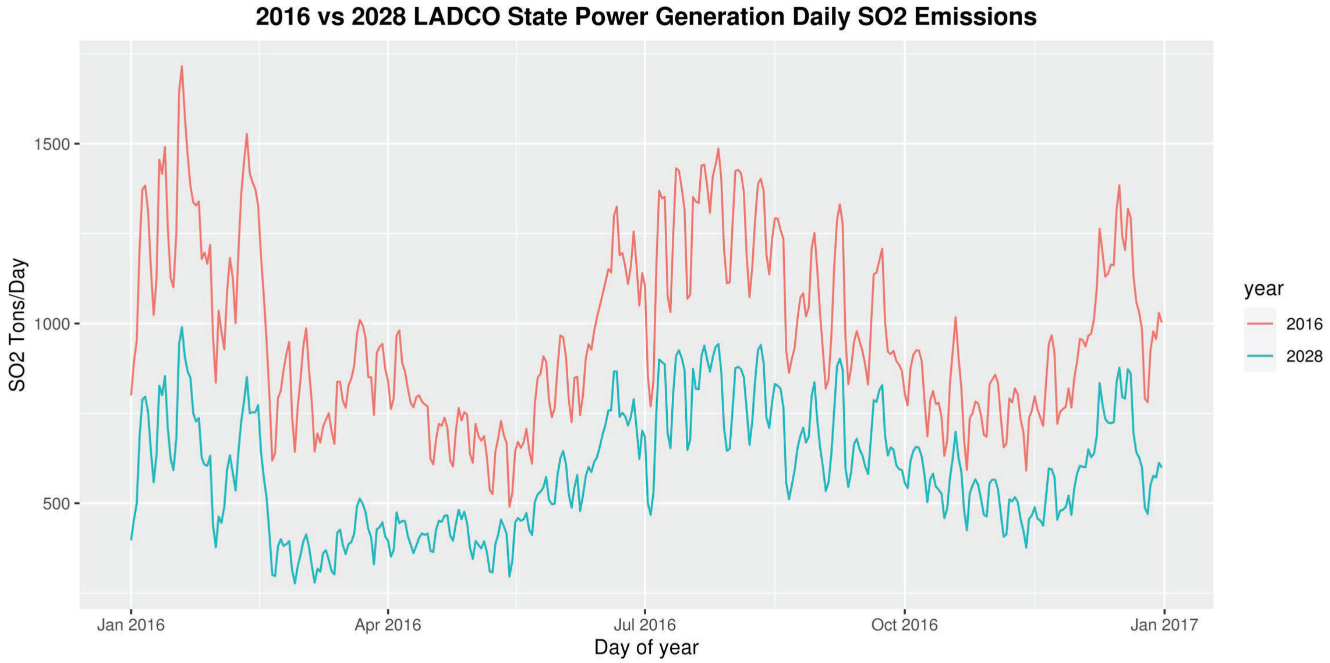

Figure 3-10. Daily total LADCO region SO_2 emissions from EGUs in 2016 and 2028

The Electronic Docket to this TSD includes a spreadsheet with point source facility (EGU and non-EGU) annual emissions totals for 2016 and 2028.

Table 3-4 lists the 2016 base year and 2028 future year inventory components that LADCO used to simulate 2016 and 2028 air quality for this application.

Table 3-4. LADCO 2016 emissions modeling platform inventory components

Sector	Abbreviation	Base Year Data Source	Future Year Data Source
Agriculture	ag	U.S. EPA 2016fh	U.S. EPA 2028fh
Fugitive Dust	afdust	U.S. EPA 2016fh	U.S. EPA 2028fh
Airports	airports	U.S. EPA 2016fi	LADCO 2028v1b
Biogenic	beis	U.S. EPA 2016fh	U.S. EPA 2016fh
C1/C2 Commercial Marine	cmv_c1c2	U.S. EPA 2016fh	U.S. EPA 2028fh
C3 Commercial Marine	cmv_c2	U.S. EPA 2016fh	U.S. EPA 2028fh
Nonpoint	nonpt	U.S. EPA 2016fh	U.S. EPA 2028fh
Offroad Mobile	nonroad	U.S. EPA 2016fh	U.S. EPA 2028fh
Nonpoint Oil & Gas	np_oilgas	U.S. EPA 2016fh	U.S. EPA 2028fh
Onroad Mobile	onroad	U.S. EPA 2016fh	U.S. EPA 2028fh
Point Oil & Gas	pt_oilgas	U.S. EPA 2016fh	U.S. EPA 2028fh
Electricity Generation	ptertac	ERTAC 16.1	ERTAC 16.1
Industrial Point	ptnonertac	U.S. EPA 2016fh	MARAMA 16.1 2028
Minnesota Taconite	ptmntaconite	Provided by MPCA	Provided by MPCA
Rail	rail	U.S. EPA 2016fh	U.S. EPA 2028fh
Residential Wood Combustion	rwc	U.S. EPA 2016fh	U.S. EPA 2028fh
Agricultural Fires	ptagfire	U.S. EPA 2016fh	U.S. EPA 2016fh
Wild and Prescribed Fires	ptfire	U.S. EPA 2016fh	U.S. EPA 2016fh
Mexico Anthropogenic	othar/othpt/	U.S. EPA 2016fh	U.S. EPA 2028fh
Canada Anthropogenic	othar/othpt	U.S. EPA 2016fh	U.S. EPA 2028fh

3.5 Source Apportionment Modeling

LADCO used the CAMx Particulate Matter Source Apportionment Tool (PSAT) to calculate emissions tracers for identifying upwind sources of haze at downwind monitoring sites.

3.5.1 2011 Source Apportionment Configuration

LADCO configured CAMx to use the point source override option in PSAT for tagging states, regions, and inventory sectors for the 2011-based 2028 simulation. LADCO applied state and region tags in the emissions processing sequence rather than using a geographic spatial mask of the emissions data. This approach ensures that the emissions for each source area are accurately apportioned to the state in which they are located. LADCO modified the U.S. EPA 2023en U.S. Source Apportionment (USSA) emissions modeling platform, and applied it to the "EN" 2028 modeling platform to prepare emissions for this simulation. Table 3-5 lists the 26 tags used in the simulation.

For this simulation, LADCO used PSAT to trace the PM and haze impacts from primary and secondary nitrate and sulfate precursors, primary and secondary organic aerosols, and soil dust.

Table 3-5. LADCO CAMx 2028_{2011} PSAT tags

Tag	Description	Tag	Description
1	Biogenic	14	KS
2	IL	15	NE
3	WI	16	ND
4	IN	17	SD
5	OH	18	WV
6	MI	19	KY
7	MN	20	ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, DC
8	IA	21	VA, NC, SC, TN, GA, AL, MI, FL
9	MO	22	NM, AZ, CO, UT, WY, MT, ID, WA, OR, CA, NV
10	AR	23	Canada/Mexico
11	LA	24	Fire
12	TX	25	Offshore
13	OK	26	Tribes

3.5.2 2016 Source Apportionment Configuration

For the 2016-based 2028 PSAT simulation LADCO used a combination of a geographic spatial mask to tag states and regions, and the CAMx point source override option to tag individual point sources and inventory source groups. Table 3-6 lists the PSAT tags used for the 2016-based 2028 CAMx simulation. PSAT tags 2 through 15 used a geographic spatial mask of the 12-km modeling grid to apportion emissions to the states and regions. Emissions in grid cells with fractional coverage across multiple states were assigned to the state with the dominant coverage in the grid cell. PSAT tags 16 through 25 were used to tag emissions from specific point sources and source groups, including commercial marine, fires, and industrial point sources in Indiana (tags 18-25). Appendix C lists the NAICS and SCC codes associated with each of the PSAT tags for the Indiana point sources.

For this simulation, LADCO used PSAT to trace the PM and haze from primary and secondary nitrate and sulfate precursors, primary carbonaceous aerosols, and soil dust. LADCO used two source groups to distinguish anthropogenic and biogenic sources within each of the tags. LADCO did not use the CAMx PSAT organic aerosol tracer for this simulation.

Table 3-6. LADCO CAMx 2028_{2016} PSAT tags

Tag	Description	Tag	Description
1	Other	14	NM, AZ, CO, UT, WY, MT, ID, WA, OR, CA, NV, ND, SD
2	IL	15	Canada/Mexico
3	WI	16	Commercial Marine (C1/C2/C3)
4	IN	17	Fires
5	OH	18	Rockport EGU (IN)
6	MI	19	Gibson EGU (IN)
7	MN	20	All other IN EGUs
8	IA	21	IN Cement Manufacturing
9	MO	22	IN Iron and Steel
10	TX	23	IN Plastics and Resin
11	LA, OK, KS, NE, AR	24	IN Aluminum Production
12	ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, DC	25	All other IN point sources
13	WV, KY, VA, NC, SC, TN, GA, AL, MI, FL		

3.6 CAMx Model Performance Evaluation Approach

This section describes the approaches LADCO took to evaluate CAMx model performance. Section 6 describes the results of this evaluation. The CAMx model performance evaluation (MPE) presented here focuses on PM and haze species at surface monitors in and near the LADCO region. As this TSD is focused on regional haze, particular attention is paid to model performance at monitors in the Class I areas. LADCO used the Atmospheric Model Evaluation Tool (AMET) version 1.3 to pair the model results and surface observations in space and time, generate bi-variate statistics of model performance, and to produce MPE plots.

LADCO evaluated the CAMx 2011 and 2016 modeled PM concentrations and reconstructed visibility against concurrent measured surface ambient concentrations using graphical displays of model performance and statistical model performance measures. LADCO compared the statistical measures against established model performance goals and criteria following the procedures recommended in EPA's photochemical modeling guidance documents (e.g., EPA, 2018).

3.6.1 Available Ambient Monitoring Data for the Model Evaluation

LADCO used the following routine air quality measurement data networks operating in in 2011 and 2016 to assess CAMx model performance:

EPA AQS Surface Air Quality Data: Data files containing hourly-averaged concentration measurements at a wide variety of state and EPA monitoring networks are available in the Air Quality System (AQS) database throughout the U.S. The AQS consists of many sites that tend to be mainly located in and near major cities. The standard hourly AQS AIRS monitoring stations typically measure hourly ozone, NO_2, NOx and CO concentration and there are thousands of sites across the U.S. The Federal Reference Method (FRM) network measures 24-hour total $PM_{2.5}$ mass concentrations using a 1:3 day sampling frequency, with some sites operating on an everyday frequency. The Chemical Speciation Network (CSN) measures speciated $PM_{2.5}$ concentrations including sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), elemental carbon (EC), organic carbon (OC), and elements at 24-hour averaging time period using a 1:3 or 1:6 day sampling frequency

IMPROVE Monitoring Network: The Interagency Monitoring of Protected Visual Environments (IMPROVE) network collects 24-hour average $PM_{2.5}$ and PM_{10} mass and speciated $PM_{2.5}$ concentrations (with the exception of ammonium) using a 1:3 day sampling frequency. IMPROVE monitoring sites are mainly located at more rural Class I area sites that correspond to specific National Parks, Wilderness Areas and Fish and Wildlife Refuges across the U.S., with a large number of sites located in the western U.S. There are also some IMPROVE protocol sites in urban areas.

3.6.2 Model Performance Statistics, Goals and Criteria

EPA's modeling guidance (2018) notes that PM models might not be able to achieve the same level of model performance as ozone models. Indeed, $PM_{2.5}$ species are defined by the measurement technology used to measure them and different measurement technologies can produce quite different $PM_{2.5}$ concentrations. To account for the variability in PM measurements, researchers developed PM model performance goals and criteria that are less stringent than ozone model performance goals (Boylan, 2004; Boylan and Russell, 2006; Simon et al., 2012). More recently Emery et al. (2017) conducted a metaanalysis of 38 peer-reviewed articles reporting air quality model performance for PM species. Table 3-7 lists the recommendations of the authors for performance goals and criteria for different PM model species. The MPE metrics recommended by the authors are shown in Table 3-8.

Table 3-7. PM model performance goals and criteria (Emery et al., 2017)

Species	NMB*		NME*		r*	
	Goal	Criteria	Goal	Criteria	Goal	Criteria
24-hr $PM_{2.5}$, SO_4, NH_4	≤±10%	≤30%	≤±35%	≤50%	>0.70	>0.40
24-hr NO_3	≤±15%	≤65%	≤±65%	≤115%	None	None
24-hr OC	≤±15%	≤50%	≤±45%	≤65%	None	None
24-hr EC	≤±20%	≤40%	≤±50%	≤75%	None	None

* NMB = normalized mean bias; NME = normalized mean error; r = correlation coefficient.

These model performance goals are not used to assign passing or failing grades to model performance, but rather to help interpret the model performance and intercompare across locations, species, time periods and model applications. The model inputs to CAMx vary hourly, but tend to represent average conditions that do not account for unusual or extreme conditions. For example, an accident or large event could cause significant increases in congestion and motor vehicle emissions that are not accounted for in the average emissions inputs used in the model.

Emery et al. (2017) compiled and interpreted the PM model performance from 38 air quality modeling studies in the peer-reviewed literature and developed the following recommendations on what should be reported in a model performance evaluation:

- Photochemical modeling studies should report model performance as Normalized Mean Bias (NMB) and Error (NME), and correlation coefficient (*r*). The confidence interval of *r* should be included with the results (Table 3-8).
- Concentration cutoffs should not be used for PM species because of the lower background concentrations of PM
- Temporal scales for 24-hr total and speciated PM should not exceed 3 months (or 1 season); spatial scales should range from urban to ≤1000 km.

- It is important to report processing steps in the model evaluation and how the predicted and observed data were paired and whether data are spatially/temporally averaged before the statistics are calculated.
- Predicted values should be taken from the grid cell that contains the monitoring site, although bilinear interpolation to the monitoring site point can be used for higher resolution modeling (< 12 km).
- Spatial displays should be used in the model evaluation to evaluate model predictions away from the monitoring sites. Time series of predicted and observed concentrations at a monitoring site should also be used.
- Graphical plots are useful for evaluating models in conjunction with statistics. Specifically, time series (either as individual sites, or as means and variability over multiple sites), scatter diagrams (time-paired regression or time-unpaired rank-ordered comparisons), and cumulative distribution plots are particularly useful for understanding model performance and model behavior over entire ranges of concentrations.
- For regulatory applications, extend the general MPE to focus bias and error calculations on the number of modeled days used in developing the relative reduction factors (RRFs) for each PM species.

LADCO incorporated these and the recommendations of U.S. EPA (2018) into the LADCO CAMx model performance evaluation for the 2011 and 2016 modeling platforms used for this TSD. The LADCO evaluation products include qualitative and quantitative evaluation metrics for total $PM_{2.5}$ and PM species.

Table 3-8. Definition of model performance evaluation statistical measures used to evaluate the CTMs.

Statistical Measure	Mathematical Expression	Notes
Correlation Coefficient (r)	$\frac{\sum_{i=1}^{N}[(P_i - \bar{P})x(O_i - \bar{O})]}{\sqrt{\sum_{i=1}^{N}(P_i - \bar{P})^2 x \sum_{i=1}^{N}(O_i - \bar{O})^2}}$	Range: 0,1 r = 1 is perfect correlation r = 0 is totally uncorrelated P = Predicted O = Observed
Normalized Mean Error (NME)	$\frac{\sum_{i=1}^{N}\lvert P_i - O_i \rvert}{\sum_{i=1}^{N} O_i}$	Range: 0%, +∞ Reported as % P = Predicted O = Observed
Normalized Mean Bias (NMB)	$\frac{\sum_{i=1}^{N}(P_i - O_i)}{\sum_{i=1}^{N} O_i}$	Range: -100%, +∞ Reported as % P = Predicted O = Observed

4 Emissions Summaries

In this section we summarize the base and future year emissions modeling results used to forecast haze conditions in 2028. The emissions projections from the base years to 2028 are the foundation of the air quality model forecasts of future year PM concentrations and haze conditions. The emissions plots and tables in this section illustrate and quantify how the U.S. emissions modeling community, including LADCO, U.S. EPA, and state air quality planning agencies forecasted air pollution emissions at the time of the second regional haze implementation period.

4.1 2011 Modeling Platform

As described in Section 3.3.2, LADCO based the 2011 and 2028 emissions data for this study on the U.S. EPA 2011v6.3 (“EN”) emissions modeling platform (US EPA, 2017b). LADCO replaced the EGU emissions in the U.S. EPA EN platform with 2028 EGU forecasts estimated with the ERTAC EGU Tool version 2.7 (MARAMA, 2012). ERTAC EGU 2.7 integrated state-reported information on EGU operations and forecasts as of May 2017. Table 3-2 shows the 2011 and 2028 inventory components used by LADCO to forecast regional haze.

The following sections summarize the 2011 and 2028 emissions used by LADCO for simulating regional haze conditions during these years.

4.1.1 2011 Emissions Summary

LADCO state total emissions for the 2011 modeling platform are shown in Table 4-1. These emissions totals do not include biogenic sources. In Figure 4-1 and Figure 4-2 we show tile plots of daily total 2011 NOx and SO_2 emissions, respectively, gridded to the 12US2 modeling domain. Table 4-2 shows the 2011 emissions for each LADCO state by emissions inventory sector.

Table 4-1. 2011 annual total emissions by state for all anthropogenic sectors (tons/year)

State	NH_3	NOx	$PM_{2.5}$	SO_2	VOC
Illinois	11,490	542,488	55,566	287,832	812,683
Indiana	7,061	464,561	53,483	425,201	570,781
Michigan	10,939	458,442	73,816	273,598	1,027,207
Minnesota	20,332	342,334	139,857	70,655	990,775
Ohio	13,520	565,513	98,549	680,042	732,132
Wisconsin	7,610	283,971	60,426	147,113	768,382

Onroad and nonroad mobile sources are the primary sources of NOx emissions in the LADCO region. The point sector, which include EGUs, is the primary source of SO_2 emissions. Biogenic emissions are the primary source of volatile organic compounds (VOCs) at a regional and annual total level.

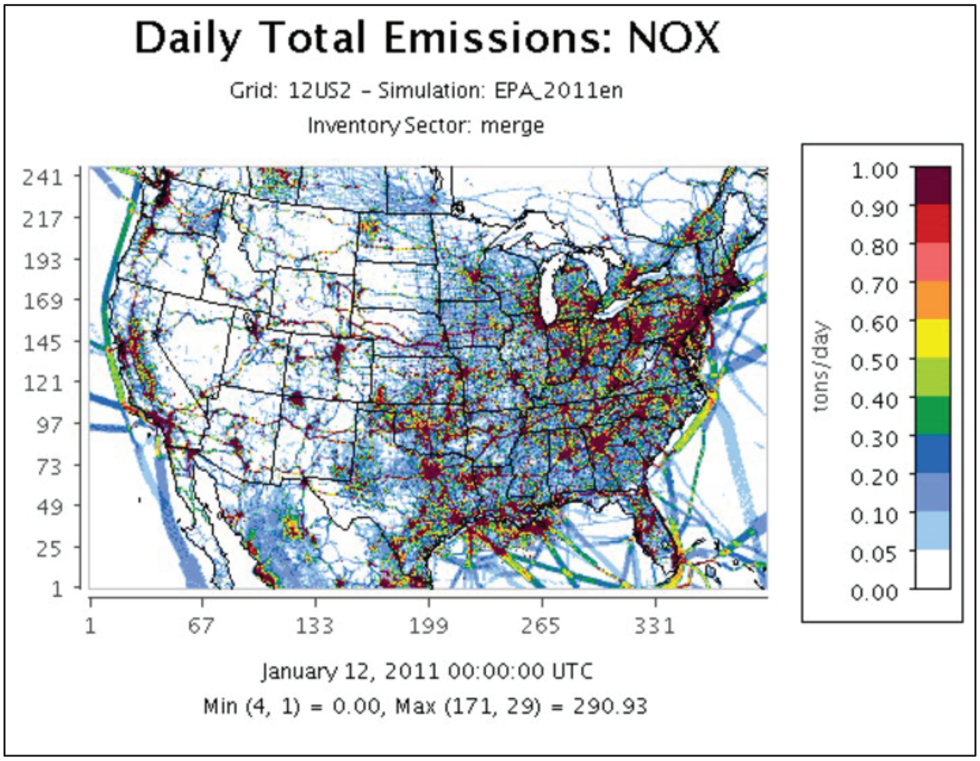

Figure 4-1. Daily total gridded 2011 NOx emissions for an example weekday (tons/day)

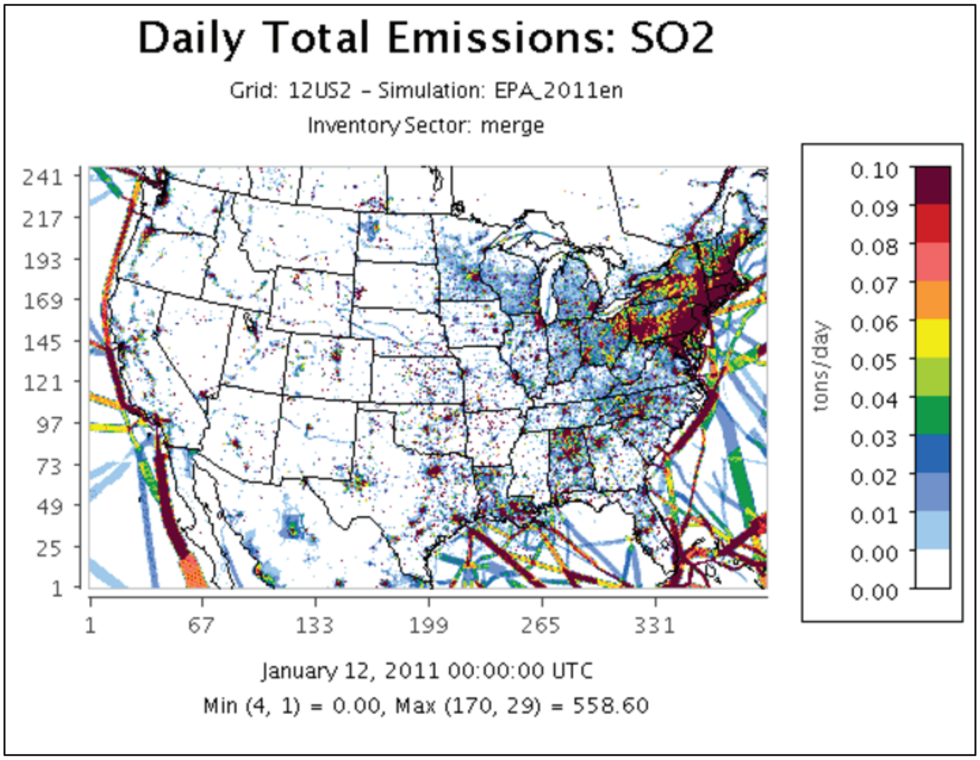

Figure 4-2. Daily total gridded 2011 SO_2 emissions for an example weekday (tons/day)

Table 4-2. 2011 annual emissions totals

State	Group	2011 Emissions (tons/year)				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		35,836			440,546
	Fires	1,041	1,004	5,561	519	14,966
	NonPoint	5,185	43,506	15,770	5,102	145,085
	Nonroad	128	135,410	9,068	1,393	71,976
	Onroad	3,420	176,709	6,174	1,073	67,386
	Point	1,716	150,024	18,992	279,745	72,724
Indiana	Biogenics		21,016			286,402
	Fires	423	445	2,306	225	6,107
	NonPoint	2,087	17,275	18,723	2,453	104,253
	Nonroad	66	67,906	4,707	352	42,212
	Onroad	3,334	171,438	5,403	817	83,362
	Point	1,151	186,481	22,344	421,354	48,445
Michigan	Biogenics		14,351			576,931
	Fires	511	442	2,695	239	7,342
	NonPoint	5,190	32,713	48,181	3,804	157,047
	Nonroad	93	67,127	6,382	2,593	123,697
	Onroad	4,101	194,625	6,186	953	106,140
	Point	1,044	149,184	10,374	266,007	56,050
Minnesota	Biogenics		26,137			516,225
	Fires	13,111	10,924	70,357	6,177	190,325
	NonPoint	3,240	25,065	41,491	5,895	118,203
	Nonroad	76	73,758	5,866	644	76,960
	Onroad	2,445	123,520	4,375	587	68,356
	Point	1,461	82,931	17,768	57,352	20,705
Ohio	Biogenics		17,952			340,817
	Fires	163	165	876	84	2,343
	NonPoint	4,335	38,660	34,226	4,809	147,055
	Nonroad	96	95,195	6,685	912	70,411
	Onroad	4,790	250,433	8,050	1,085	129,619
	Point	4,136	163,108	48,712	673,152	41,886
Wisconsin	Biogenics		15,078			480,085
	Fires	596	566	3,179	294	8,571
	NonPoint	2,930	23,065	39,299	2,987	113,317
	Nonroad	64	53,101	4,559	544	84,430
	Onroad	2,342	127,174	4,585	587	60,066
	Point	1,677	64,987	8,803	142,700	21,911
Grand Total		70,953	2,657,309	481,697	1,884,441	4,901,958

4.1.2 2028_{2011} Emissions Summary

LADCO state total 2028_{2011} emissions[17] projections for the LADCO 2011 modeling platform are shown in Table 4-3. These emissions totals do not include biogenic sources. Figure 4-3 and Figure 4-5 are tile plots of daily total 2028 NOx and SO_2 emissions, respectively, gridded to the 12US2 modeling domain. Figure 4-4 and Figure 4-6 show differences in daily total NOx and SO_2 emissions between 2011 and 2028, respectively. Table 4-4 shows the 2028_{2011} emissions for each LADCO state by emissions inventory sector.

Table 4-3. 2028_{2011} annual total emissions by state for all anthropogenic sectors (tons/year)

State	NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	10,936	292,583	42,154	168,040	705,028
Indiana	5,906	246,805	43,526	196,016	468,536
Michigan	9,663	210,960	62,158	89,274	841,588
Minnesota	20,010	188,083	131,497	42,452	893,958
Ohio	11,503	254,645	70,536	195,434	584,024
Wisconsin	6,234	146,140	52,115	50,233	673,886

As shown in Table 4-5 the U.S. EPA 2011 EN emissions used by LADCO project that in 2028 there will be significant reductions in NOx emissions in the LADCO member states from nonroad mobile (> 50% reductions), onroad mobile (> 70%), and industrial point sources (> 25%) relative to the 2011 base year. Additionally, the shutdowns of large EGUs will result in more than a 40% reduction in total SO_2 emissions. LADCO estimates that the combination of gasoline and diesel onroad vehicles will account for significant decreases in $PM_{2.5}$ (60% reductions) and VOC (70% reductions) emissions across the region.

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[17] The subscript with the future year (i.e., 2028_{2011}) indicates the base year from which the future year emissions are projected. We use this convention to distinguish between the two 2028 simulations presented in this TSD.

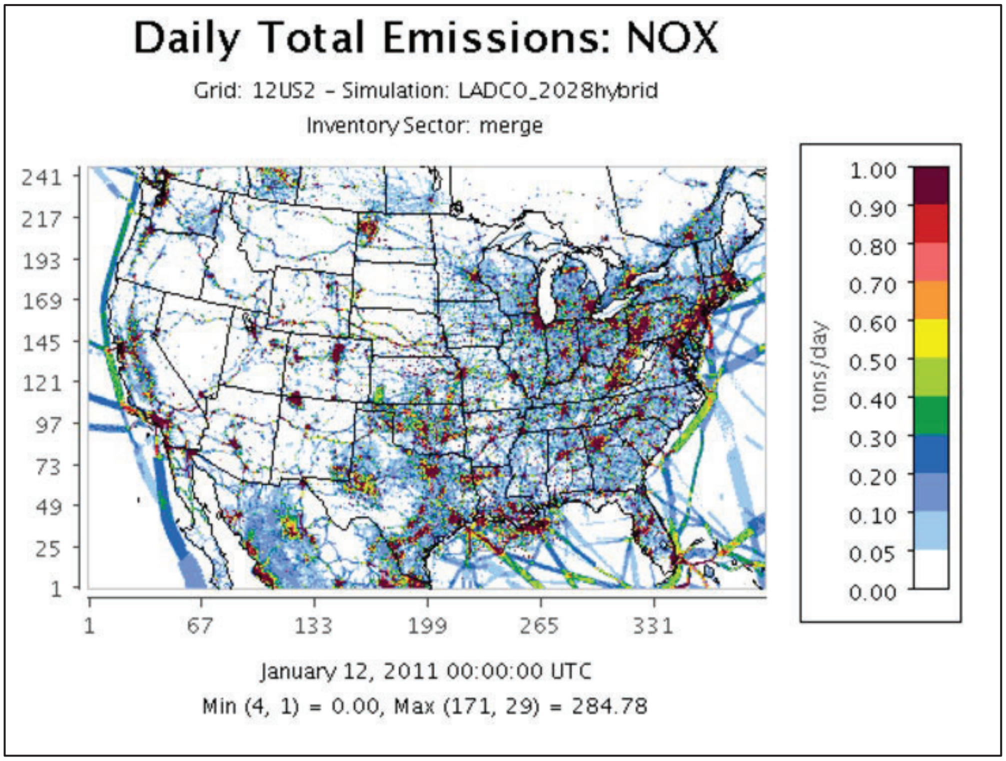

Figure 4-3. Daily total gridded 2028$_{2011}$ NOx emissions for an example weekday (tons/day)

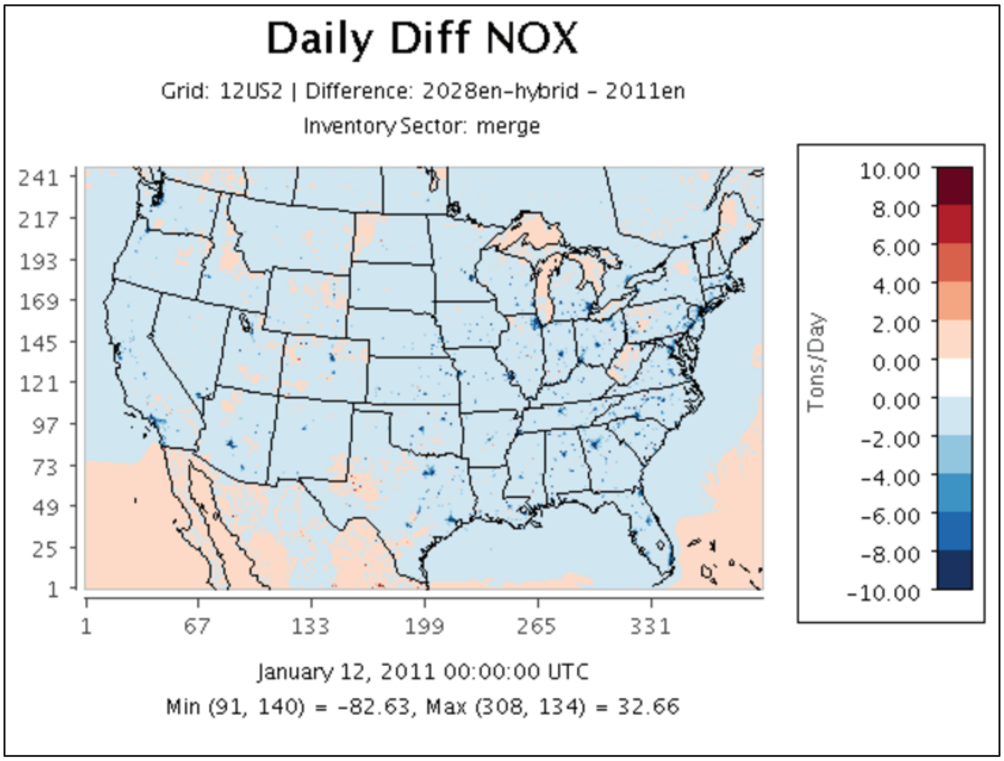

Figure 4-4. Difference (2028-2011) in daily total gridded NOx emissions for an example weekday (tons/day)

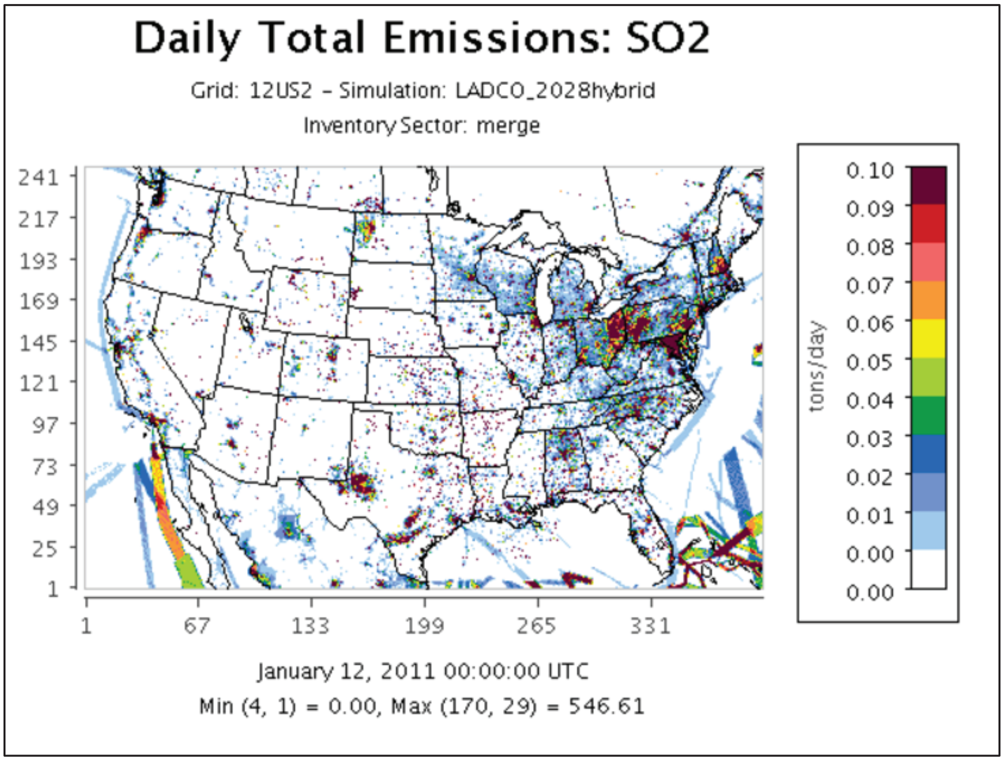

Figure 4-5. Daily total gridded 2028_{2011} SO_2 emissions for an example weekday (tons/day)

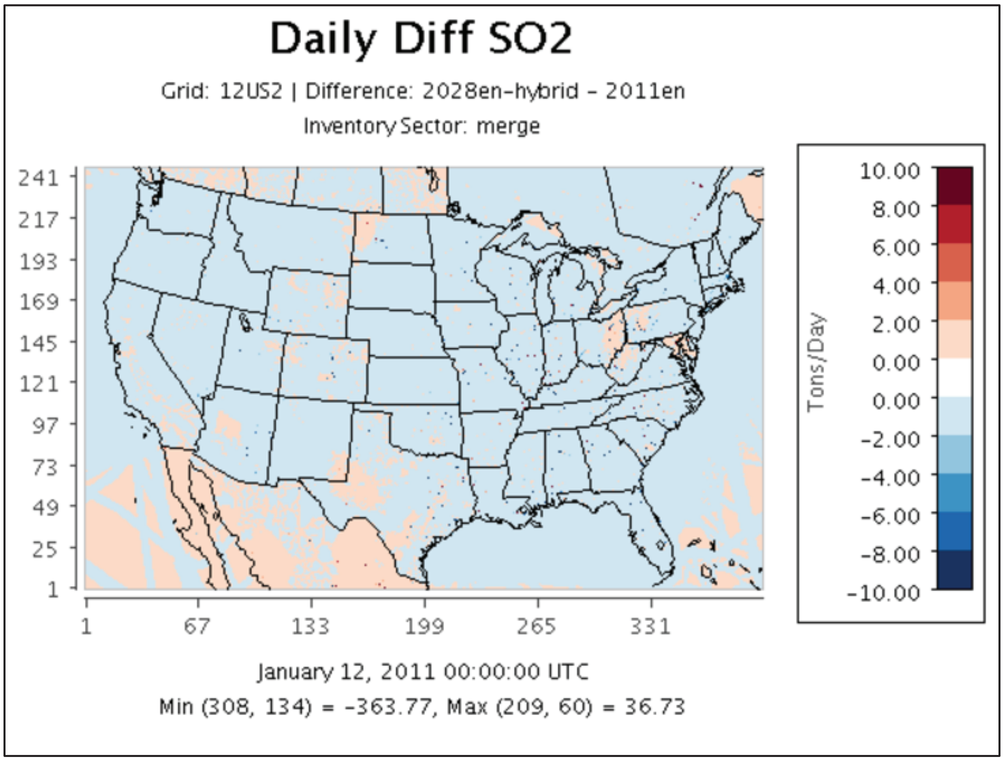

Figure 4-6. Difference (2028-2011) in daily total gridded SO_2 emissions for an example weekday (tons/day)

Table 4-4. 2028_{2011} annual emissions totals

State	Group	2028 Emissions (tons/year)				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		35,836			440,546
	Fires	1,041	1,004	5,561	519	14,966
	NonPoint	5,119	45,490	14,169	3,298	138,366
	Nonroad	163	63,084	3,543	206	43,917
	Onroad	2,830	56,628	2,493	451	23,773
	Point	1,783	90,542	16,388	163,566	43,460
Indiana	Biogenics		21,016			286,402
	Fires	423	445	2,306	225	6,107
	NonPoint	1,959	17,369	16,877	2,313	94,942
	Nonroad	85	31,734	1,858	88	24,757
	Onroad	2,175	38,877	1,812	324	20,251
	Point	1,263	137,364	20,674	193,066	36,077
Michigan	Biogenics		14,351			576,931
	Fires	511	442	2,695	239	7,342
	NonPoint	4,991	33,902	45,334	2,374	139,194
	Nonroad	116	36,261	2,915	209	67,993
	Onroad	2,478	42,030	1,840	316	27,716
	Point	1,567	83,975	9,374	86,135	22,412
Minnesota	Biogenics		26,137			516,225
	Fires	13,111	10,924	70,357	6,177	190,325
	NonPoint	3,205	24,489	41,397	3,083	110,379
	Nonroad	92	34,984	2,162	108	38,569
	Onroad	1,614	27,406	1,420	238	18,409
	Point	1,988	64,143	16,160	32,847	20,053
Ohio	Biogenics		17,952			340,817
	Fires	163	165	876	84	2,343
	NonPoint	4,198	41,237	32,166	4,357	139,121
	Nonroad	116	44,708	3,019	130	42,407
	Onroad	2,844	49,229	2,322	418	29,479
	Point	4,181	101,354	32,153	190,445	29,857
Wisconsin	Biogenics		15,078			480,085
	Fires	596	566	3,179	294	8,571
	NonPoint	2,796	22,581	37,050	2,478	106,033
	Nonroad	77	26,907	1,835	87	38,878
	Onroad	1,659	33,157	1,416	246	18,531
	Point	1,106	47,852	8,634	47,128	21,787
Grand Total		64,250	1,339,217	401,986	741,448	4,167,021

Table 4-5. Base and future year annual emissions percent change (2028-2011)

State	Group	Percent Change 2011 to 2028				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-1.3%	4.6%	-10.2%	-35.4%	-4.6%
	Nonroad	27.1%	-53.4%	-60.9%	-85.2%	-39.0%
	Onroad	-17.2%	-68.0%	-59.6%	-58.0%	-64.7%
	Point	3.9%	-39.6%	-13.7%	-41.5%	-40.2%
Indiana	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-6.1%	0.5%	-9.9%	-5.7%	-8.9%
	Nonroad	28.3%	-53.3%	-60.5%	-75.0%	-41.4%
	Onroad	-34.8%	-77.3%	-66.5%	-60.4%	-75.7%
	Point	9.8%	-26.3%	-7.5%	-54.2%	-25.5%
Michigan	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-3.8%	3.6%	-5.9%	-37.6%	-11.4%
	Nonroad	25.5%	-46.0%	-54.3%	-91.9%	-45.0%
	Onroad	-39.6%	-78.4%	-70.3%	-66.8%	-73.9%
	Point	50.0%	-43.7%	-9.6%	-67.6%	-60.0%
Minnesota	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-1.1%	-2.3%	-0.2%	-47.7%	-6.6%
	Nonroad	20.6%	-52.6%	-63.1%	-83.3%	-49.9%
	Onroad	-34.0%	-77.8%	-67.6%	-59.5%	-73.1%
	Point	36.1%	-22.7%	-9.0%	-42.7%	-3.2%
Ohio	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-3.2%	6.7%	-6.0%	-9.4%	-5.4%
	Nonroad	21.2%	-53.0%	-54.8%	-85.7%	-39.8%
	Onroad	-40.6%	-80.3%	-71.2%	-61.5%	-77.3%
	Point	1.1%	-37.9%	-34.0%	-71.7%	-28.7%
Wisconsin	Biogenics		0.0%			0.0%
	Fires	0.0%	0.0%	0.0%	0.0%	0.0%
	NonPoint	-4.6%	-2.1%	-5.7%	-17.0%	-6.4%
	Nonroad	19.9%	-49.3%	-59.7%	-84.0%	-54.0%
	Onroad	-29.2%	-73.9%	-69.1%	-58.1%	-69.1%
	Point	-34.1%	-26.4%	-1.9%	-67.0%	-0.6%
Grand Total		-9.4%	-49.6%	-16.5%	-60.7%	-15.0%

4.2 2016 Modeling Platform

As described in Section 3.4.2, LADCO based the 2016 and 2028 emissions data for this study on the U.S. EPA 2016fh_16 (“FH”) emissions modeling platform (US EPA, 2020). LADCO replaced the EGU emissions in the U.S. EPA FH platform with 2028 EGU forecasts estimated with a modified version of the ERTAC EGU Tool version 16.1 (MARAMA, 2012). Table 3-4 lists the 2016 base year and 2028 future year inventory components that LADCO used to simulate 2016 and 2028 air quality for this application.

The following sections summarize the 2016 and 2028 emissions used by LADCO for simulating regional haze conditions during these years.

4.2.1 2016 Emissions Summary

The tables and figures in this section summarize the emissions used in the LADCO 2016 CAMx simulation. Table 4-6 shows the LADCO state annual 2016 total emissions for all sectors, and Figure 4-7 and Figure 4-8 are tile plots of the 12-km gridded, daily total NOx and SO_2 emissions, respectively, for a winter weekday (Friday, January 15). The NOx plot illustrates that the highest emissions occur in proximity to urban areas and roadways. The SO_2 plot shows that coal EGU point sources and urban areas are the dominant emissions sources for this pollutant. Table 4-7 shows the 2016 annual emissions totals by LADCO member state and major inventory group.

Table 4-6. 2016 annual total emissions by state for all sectors (tons/year)

State	NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	102,364	387,877	109,474	107,987	800,485
Indiana	86,725	327,142	83,341	129,328	528,217
Michigan	53,366	304,362	66,074	107,265	920,538
Minnesota	208,325	248,879	127,312	35,447	825,120
Ohio	86,354	352,630	106,689	148,912	706,730
Wisconsin	63,286	194,841	68,269	36,468	677,145

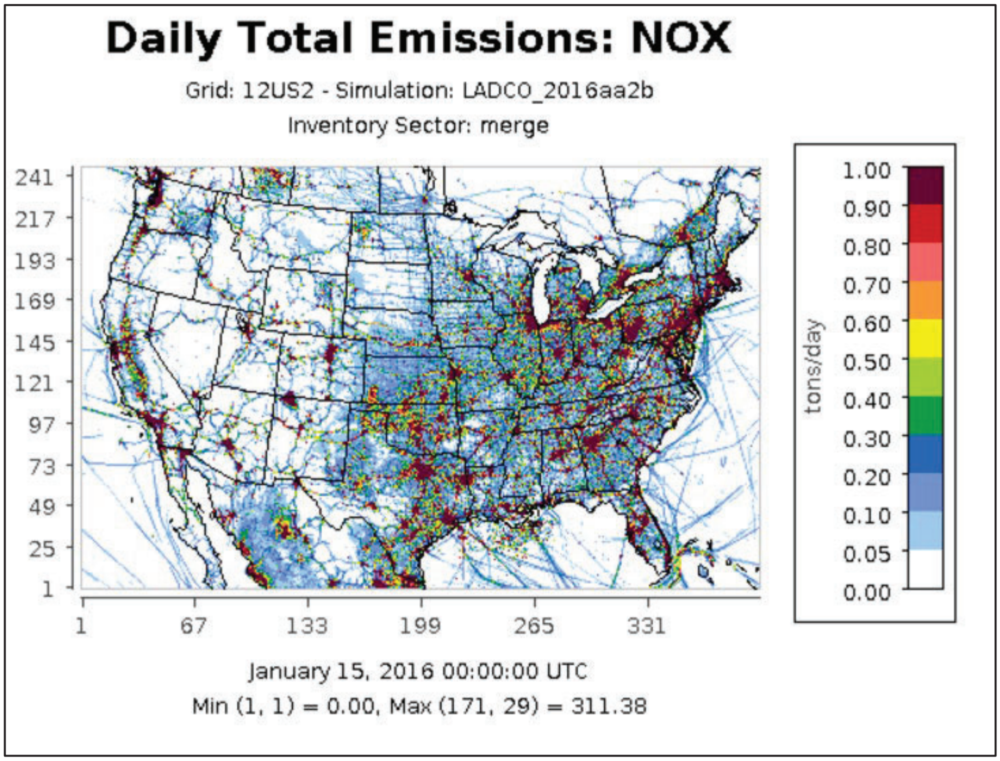

Figure 4-7. Daily total gridded 2016 NOx emissions for an example weekday (tons/day)

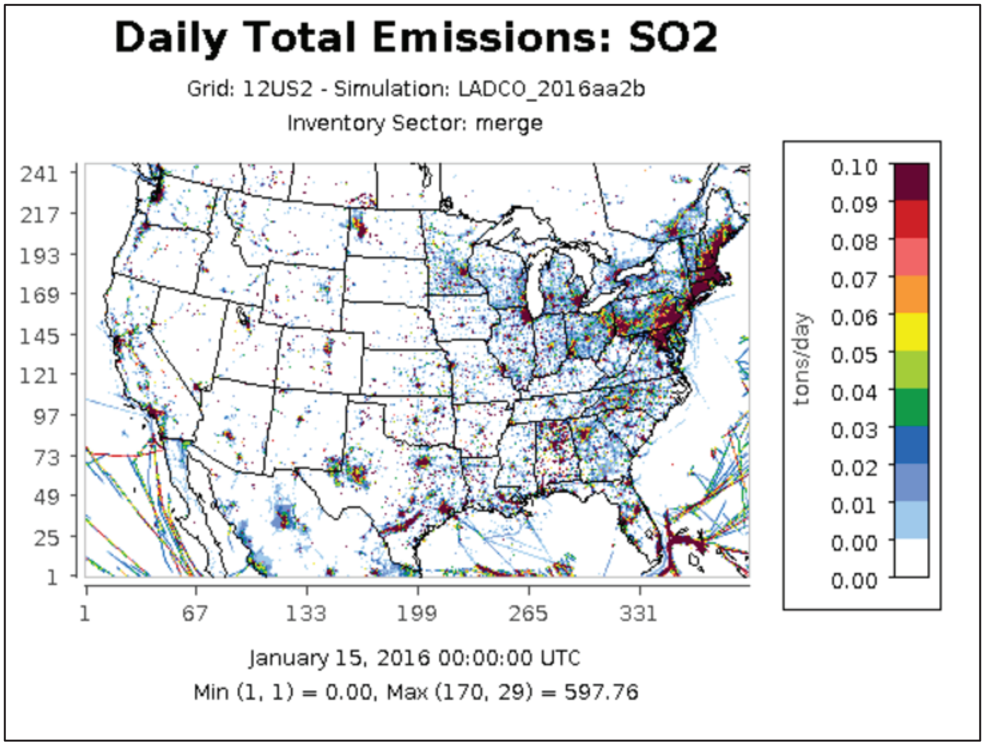

Figure 4-8. Daily total gridded 2016 SO_2 emissions for an example weekday (tons/day)

Table 4-7. 2016 annual emissions totals

State	Group	2016 Emissions (tons/year)				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		38,921			422,736
	Fires	1,434	1,390	7,662	716	20,607
	NonPoint	96,053	102,399	80,406	5,946	211,921
	Nonroad	79	49,234	4,515	94	38,539
	Onroad	3,300	117,837	4,217	705	65,574
	Point	1,498	78,096	12,674	100,526	41,108
Indiana	Biogenics		21,381			279,976
	Fires	720	697	3,849	359	10,356
	NonPoint	81,708	34,816	46,889	1,142	129,207
	Nonroad	56	36,791	3,208	66	20,407
	Onroad	2,737	103,694	3,385	616	55,049
	Point	1,504	129,763	26,010	127,145	33,222
Michigan	Biogenics		14,572			593,916
	Fires	605	435	3,133	256	8,699
	NonPoint	48,254	66,217	47,856	7,480	174,178
	Nonroad	53	25,644	2,919	67	54,091
	Onroad	3,073	97,879	3,053	695	63,809
	Point	1,381	99,615	9,113	98,767	25,845
Minnesota	Biogenics		28,031			510,385
	Fires	4,931	2,606	24,907	1,807	70,882
	NonPoint	200,203	41,001	83,986	4,404	129,706
	Nonroad	73	43,042	4,192	86	52,838
	Onroad	1,915	66,467	2,195	395	41,382
	Point	1,203	67,732	12,032	28,755	19,927
Ohio	Biogenics		18,120			360,156
	Fires	465	459	2,492	235	6,689
	NonPoint	78,786	64,951	71,145	4,061	192,544
	Nonroad	68	40,429	3,692	82	38,405
	Onroad	3,736	122,966	3,931	852	76,612
	Point	3,299	105,705	25,429	143,682	32,324
Wisconsin	Biogenics		16,095			484,780
	Fires	793	709	4,200	378	11,404
	NonPoint	59,119	33,655	53,366	2,075	81,793
	Nonroad	44	23,906	2,431	54	41,548
	Onroad	1,861	80,086	2,845	413	34,837
	Point	1,469	40,390	5,427	33,548	22,783
Grand Total		**600,422**	**1,815,731**	**561,157**	**565,407**	**4,458,233**

4.2.2 2028_{2016} Emissions Summary

The tables and figures in this section summarize the emissions used in the LADCO 2016-based 2028 CAMx simulation. Table 4-8 shows LADCO state total annual emissions, Figure 4-9 and Figure 4-11 show gridded daily total 2016 NOx and SO_2 emissions for a winter weekday (Friday, January 15). The spatial patterns seen in these figures match with the patterns in the 2016 emissions figures shown previously. Figure 4-10 and Figure 4-12 show the locations where emissions are projected to change in 2028 relative to 2016. The emissions differences indicate widespread changes across the region, with larger emissions changes at locations where there are projected to be EGU shutdowns and new controls applied at specific plants. The largest NOx emissions reductions will occur along roadways and in urban areas; emissions increases are projected in oil and gas development regions, in Mexico, and in Canadian offshore sources in the Great Lakes. SO_2 emissions reductions are projected to occur in urban areas and where power plants are located.

Table 4-8. 2028_{2016} annual total emissions by state for all sectors (tons/year)

State	NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	110,871	229,820	103,309	52,788	334,078
Indiana	94,931	175,508	76,884	84,814	214,407
Michigan	55,886	190,164	62,566	53,976	269,661
Minnesota	220,374	146,231	121,290	29,319	274,186
Ohio	94,278	211,025	96,585	109,883	298,719
Wisconsin	65,446	128,962	64,876	26,948	158,065

Table 4-9 shows the LADCO state total 2028_{2016} annual emissions tons for the haze species. Table 4-10 compares 2028 and 2016 annual haze emissions by inventory group for each LADCO state. Negative numbers in these tables indicate percent emissions reductions in 2028 relative to 2016. Comparisons of the EGU and industrial point source emissions changes between 2016 and 2028 is confounded by the different methods used by the U.S EPA and ERTAC EGU projection models for distinguishing EGU from non-EGU industrial point sources. ERTAC only models sources with CEM data while EPA does economic projections of all units that sell power to the grid including facilities with co-generation units like paper mills and aluminum foundries. For the LADCO modeling that used ERTAC to project power plant emissions, we used the EPA 2028 inventory projections for those sources that generate power but do not have CEMs.

LADCO projects that overall both the NOX and SO_2 emissions will decrease in 2028 relative to 2016 in all of the LADCO states. The NOx reductions for the anthropogenic sectors (i.e., excluding biogenics and wildfires) range from 28 to 42%, driven primarily by reductions in onroad and offroad mobile source emissions. We project that the SO_2 emissions reductions will be significant, at around 18 to 51% in each of the LADCO states. These reductions are the result of changes to the power sector, primarily coal-fired EGU shutdowns.

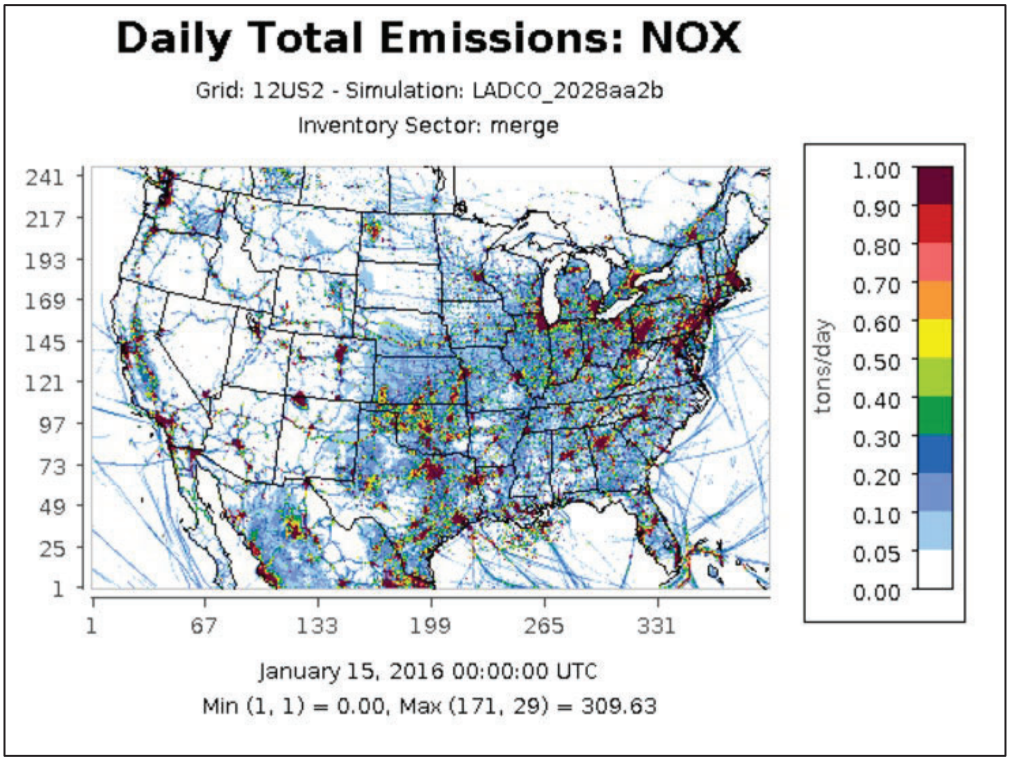

Figure 4-9. Daily total gridded 2028_{2016} NOx emissions for an example weekday (tons/day)

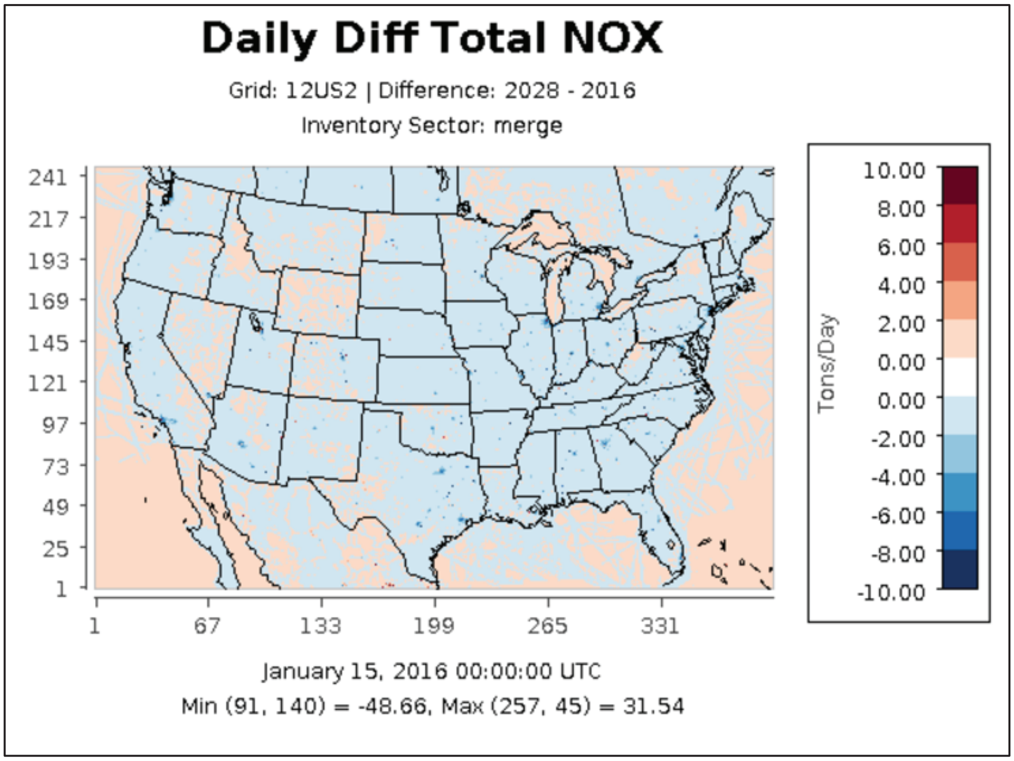

Figure 4-10. Difference (2028-2016) in daily total gridded NOx emissions for an example weekday (tons/day)

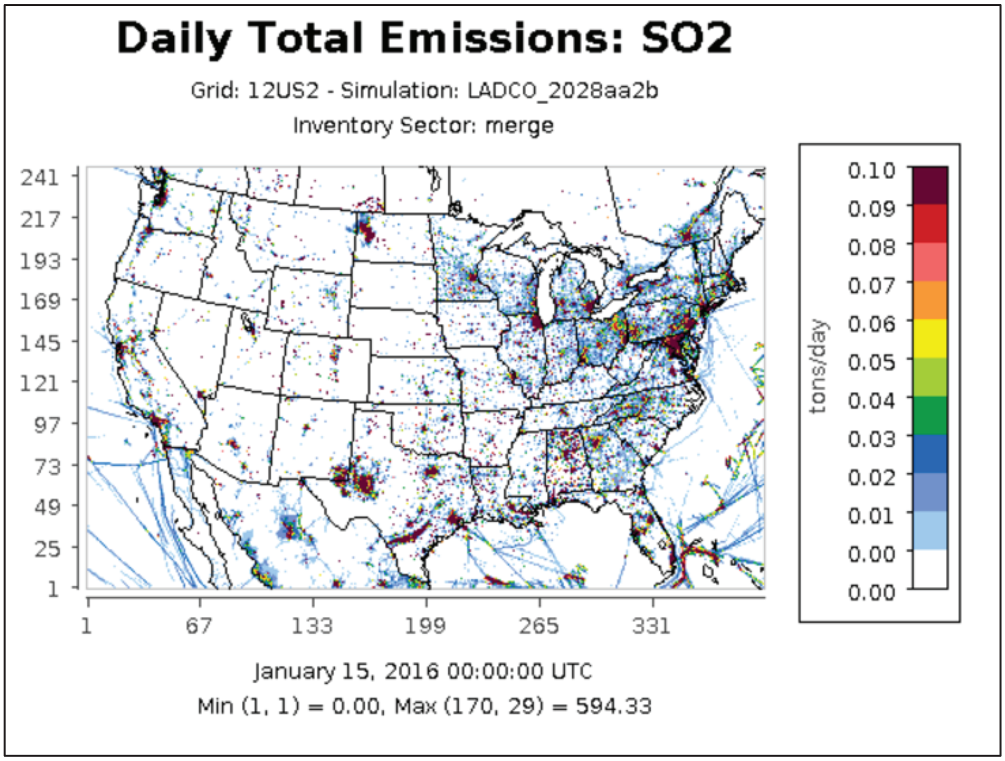

Figure 4-11. Daily total gridded 2028_{2016} SO_2 emissions for an example weekday (tons/day)

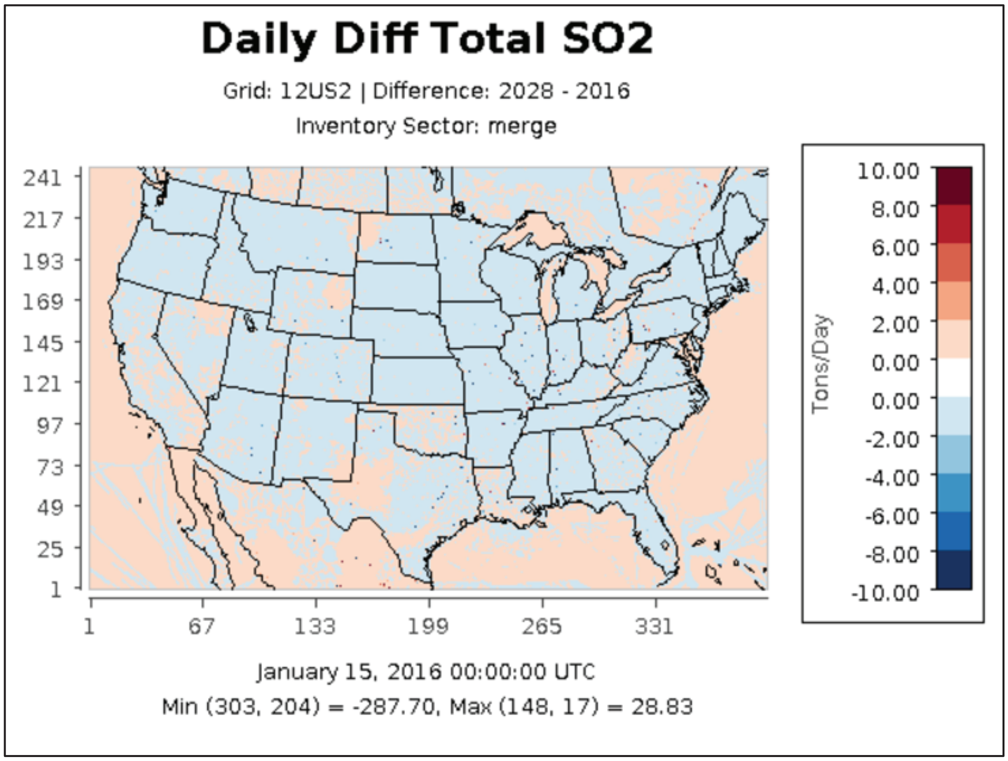

Figure 4-12. Difference (2028-2016) in daily total gridded SO_2 emissions for an example weekday (tons/day)

Table 4-9. 2028_{2016} annual emissions totals

State	Group	2028 Emissions (tons/year)				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		38,921			422,736
	fires	1,434	1,390	7,662	716	20,607
	nonpoint	104,358	88,663	78,804	6,002	212,101
	nonroad	87	25,289	2,281	68	28,404
	onroad	2,845	41,417	1,987	402	29,271
	point	2,147	73,061	12,575	45,600	43,695
Indiana	Biogenics		21,381			279,976
	fires	720	697	3,849	359	10,356
	nonpoint	89,324	30,049	46,254	1,097	130,268
	nonroad	65	18,170	1,518	54	15,928
	onroad	2,292	36,034	1,588	321	23,806
	point	2,530	90,558	23,675	82,983	34,049
Michigan	Biogenics		14,572			593,916
	fires	605	435	3,133	256	8,699
	nonpoint	50,722	60,755	47,159	7,098	171,926
	nonroad	57	16,675	1,667	41	34,236
	onroad	2,606	31,924	1,544	295	28,268
	point	1,896	80,375	9,063	46,286	26,532
Minnesota	Biogenics		28,031			510,385
	fires	4,931	2,606	24,907	1,807	70,882
	nonpoint	212,377	36,904	81,747	4,208	130,097
	nonroad	79	23,742	2,055	60	33,624
	onroad	1,629	22,024	984	192	19,091
	point	1,358	60,955	11,597	23,052	20,492
Ohio	Biogenics		18,120			360,156
	fires	465	459	2,492	235	6,689
	nonpoint	85,161	57,923	70,496	4,361	197,290
	nonroad	77	22,287	1,940	60	27,314
	onroad	3,155	40,015	1,948	378	34,097
	point	5,420	90,341	19,709	104,849	33,329
Wisconsin	Biogenics		16,095			484,780
	fires	793	709	4,200	378	11,404
	nonpoint	60,146	30,053	53,158	2,046	82,126
	nonroad	49	13,894	1,250	36	25,025
	onroad	1,687	25,272	1,025	229	16,538
	point	2,771	59,034	5,243	24,259	22,972
Grand Total		**641,787**	**1,218,830**	**525,512**	**357,727**	**4,201,065**

Table 4-109. 2016 modeling platform annual emissions percent change (2016-2028)

State	Group	Percent Change 2016 to 2028				
		NH_3	NOX	$PM_{2.5}$	SO_2	VOC
Illinois	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	8.65%	-13.41%	-1.99%	0.93%	0.08%
	Nonroad	9.53%	-48.64%	-49.47%	-27.73%	-26.30%
	Onroad	-13.78%	-64.85%	-52.88%	-43.07%	-55.36%
	Point	43.35%	-6.45%	-0.78%	-54.64%	6.29%
Indiana	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	9.32%	-13.69%	-1.36%	-3.94%	0.82%
	Nonroad	15.23%	-50.61%	-52.68%	-18.34%	-21.95%
	Onroad	-16.26%	-65.25%	-53.08%	-47.88%	-56.75%
	Point	68.25%	-30.21%	-8.98%	-34.73%	2.49%
Michigan	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	5.12%	-8.25%	-1.46%	-5.11%	-1.29%
	Nonroad	7.83%	-34.97%	-42.89%	-38.35%	-36.71%
	Onroad	-15.19%	-67.38%	-49.43%	-57.51%	-55.70%
	Point	37.25%	-19.31%	-0.55%	-53.14%	2.66%
Minnesota	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	6.08%	-9.99%	-2.67%	-4.45%	0.30%
	Nonroad	8.30%	-44.84%	-50.98%	-30.31%	-36.36%
	Onroad	-14.94%	-66.86%	-55.16%	-51.31%	-53.86%
	Point	12.85%	-10.00%	-3.61%	-19.83%	2.83%
Ohio	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	8.09%	-10.82%	-0.91%	7.40%	2.46%
	Nonroad	13.21%	-44.87%	-47.45%	-27.56%	-28.88%
	Onroad	-15.55%	-67.46%	-50.43%	-55.60%	-55.49%
	Point	64.29%	-14.53%	-22.49%	-27.03%	3.11%
Wisconsin	Biogenics		0.00%			0.00%
	Fires	0.00%	0.00%	0.00%	0.00%	0.00%
	NonPoint	1.74%	-10.70%	-0.39%	-1.38%	0.41%
	Nonroad	10.22%	-41.88%	-48.58%	-33.78%	-39.77%
	Onroad	-9.38%	-68.44%	-63.97%	-44.56%	-52.53%
	Point	88.67%	46.16%	-3.38%	-27.69%	0.83%
Average		**6.89%**	**-32.87%**	**-6.35%**	**-36.73%**	**-5.77%**

4.2.3 Typical Year Emissions Platform

Emissions estimates used in modeling can provide a faithful match to real-world base year activity, called an “actual” inventory. Actual inventories are used for model validation to confirm that the model can reproduce the initial pollutant concentrations. In LADCO’s point source actual inventories, which are based on hourly CEM data, we modeled extended point source facility shutdowns in the base year for some large facilities. These shutdowns may have occurred for maintenance or due to malfunctions at the facility.

We also build “typical” inventories to be used as the basis for a future year projection. For some point source facilities in Minnesota that did not operate in 2016, we included zero emissions in the actual emissions scenarios. If the plants operated in subsequent contemporary years, we reviewed the historical record for those plants and found that for three sources in Minnesota the 2017 emissions were representative of typical emissions activity.

LADCO worked with staff from the state of Minnesota to include hourly data and alternate base and future year estimates for some facilities that were not operating in 2016 because of maintenance or other operational issues. For these facilities, we used 2017 emissions numbers in the 2016 typical year modeling inventory and projected 2028 emissions from these numbers. We did this because the alternative approach of using actual (zero) 2016 emissions and a 2028 projected inventory in which the plants were operating at expected levels would simulate increases in future year emissions that were not representative of the base period. These unrepresentative increases would incorrectly impact the relative reduction factors used to project future haze conditions in the region.

LADCO used actual 2016 emissions inventories for a model performance evaluation run and typical inventories as the basis for future year projections. All the emissions summary tables in this TSD use typical emissions from the impacted facilities. Emissions for most inventory sectors were identical between the two types of emissions platforms. The facilities that had significant emissions differences between the actual and typical inventories are shown in Table 3-3.

4.3 Comparison of 2011 and 2016 Emissions Platforms

LADCO's 2016 modeling platform differs from the 2011 platform in several important ways. For EGU sources we used the ERTAC model. The ERTAC model is designed to use base year CEM data to define emissions patterns. These patterns define both base and future year regional and plant level behaviors. Our projections to 2028 used the corresponding base year CEM data for both 2011 and 2016. Since the 2011-based projections to 2028 were developed in 2017, we did not include any new EGU shutdowns or controls announced between 2017 and mid-2020 in the simulation.

The ERTAC EGU runs in 2017 that were used for our 2011-based modeling had 54 unit shutdowns between 2017 and 2028. The ERTAC 16.1 runs done in late 2020, which we used for our 2016-based modeling, included 46 additional shutdowns above the ones included in the 2011 simulation. Further, LADCO included an additional 62 unit shutdowns in our 2028_{2016} simulation based on information from our member states on new shutdowns as of September 2020. The final LADCO 2028_{2016} CAMx simulation excluded emissions from a total of 162 units because of announced shutdowns.

LADCO staff worked with the Coordinating Research Council (CRC) to build national emissions modeling inputs that became the county-specific national defaults for several onroad mobile inputs and resulted in improved emissions in the 2016 modeling platform. This work included CRC project A-115, which decoded all the vehicle identification numbers (VIN) in the country to produce updated vehicle fleet age distributions. CRC, LADCO, and a group of states evaluated the methods and data used to set default age distributions and found that older vehicles were being over-counted in the national default data because they were not being removed from the vehicle count database when they left the in-use fleet of vehicles. Figure 4-13 shows the impact on vehicle counts in one state when these older vehicles are removed from the data. We were able to show that because these vehicles are the oldest and highest emitting vehicles in the fleet, a small difference in their population had a significant impact on emissions. Telemetry data for vehicle speed and a second Telemetry project for data on time of hour/weekday/month activity were also included in new national defaults in the 2016 modeling platform.

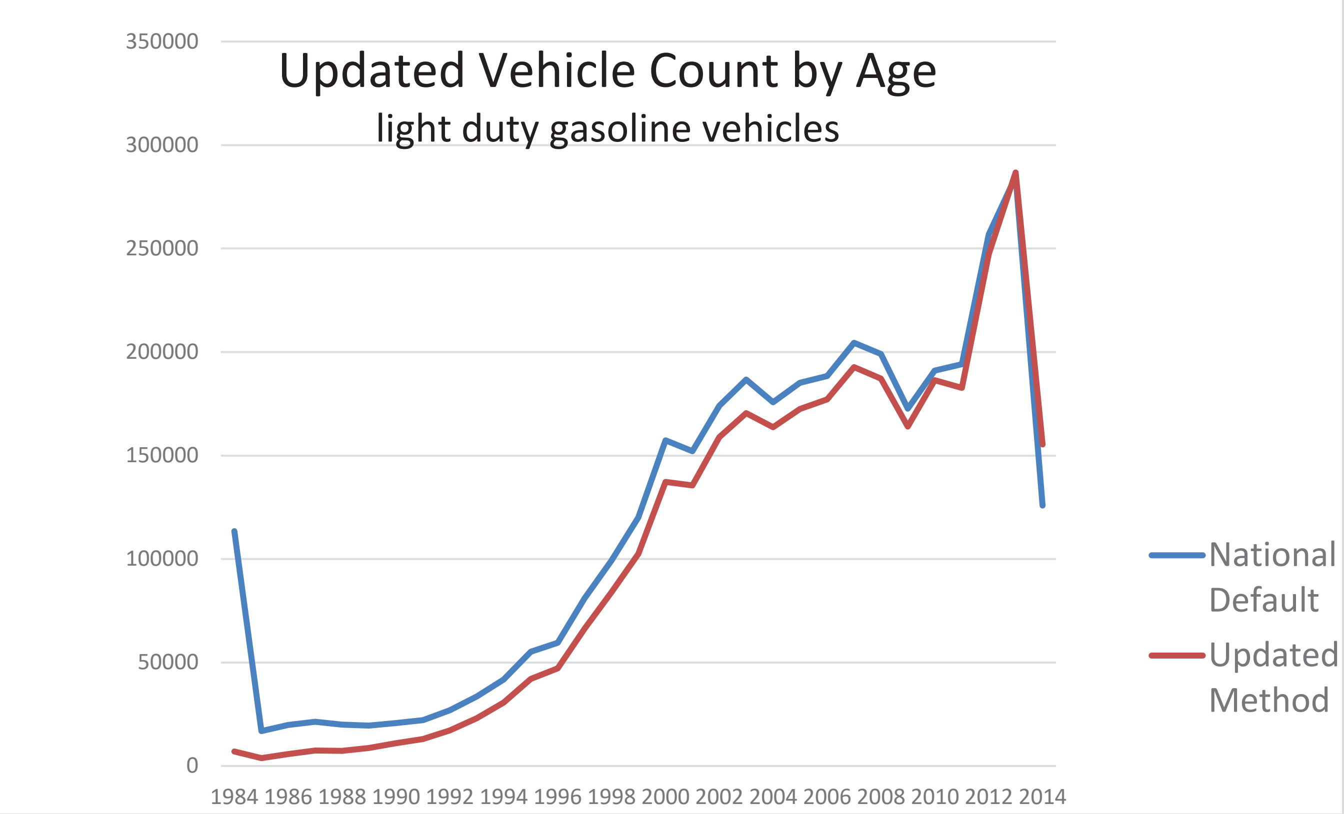

Figure 4-13 Change in vehicle age counts based on updated methodologies to decode VINs.

Several emissions sectors use day-specific temperature and activity data as the basis of their emissions estimates. As the different base years have different meteorology and activity data, the base and future year emissions are changed with the different base year conditions. These sectors include biogenics, wind-blown dust, wildfire, prescribed fire, and onroad motor vehicles.

In the 2011 emissions inventory there were limited emissions estimates from livestock and fertilizer operations. In the 2016 emissions inventory, EPA included agricultural ammonia emissions as a dedicated emissions sector. In most of the LADCO states this change resulted in an order of magnitude increase in estimated NH_3 emissions.

The marine vessels inventory also improved between the 2011 and 2016, when EPA included national 4-minute interval location data of individual ships to define speed, power, and location. This improvement led to hourly vessel-specific estimates of fuel use and emissions.

Oil and gas inventories were also improved as fracking became more prevalent and emissions increased in parts of the country where new fuel reserves were developed, including in Ohio. EPA and states built new national databases of site-specific oil and gas emissions as well as nonpoint inventories at the county level for smaller operations. For Ohio, the 2011 annual NOx emissions were 319 tons, while the 2016 emissions were 13,114 tons. These changes were partially improvements in inventory methods and partially due to increases in oil field development and operation.

5 Class I Area Q/d Analysis

This section describes the data and methods used by LADCO to aid our members in screening emissions source impacts on Class I areas for the second regional haze implementation period. The surrogate analysis of tons/year emissions (Q) divided by distance in kilometers (d) from the Class I areas, known as Q/d, is used to screen emissions source impacts at downwind receptors in lieu of air quality modeling results. LADCO created Q/d results for industrial point sources using preliminary 2016 emissions inventory data. LADCO completed the Q/d calculations in January 2019 using the best available inventories at that time

LADCO did not make any decisions about how the data that we generated would be applied by our member states in their four factor analysis process. We provided stationary sources emissions data and Q/d information at different Q/d threshold for different combinations of haze precursors to aid our member states in decision making for their four factor analyses. This section describes the data that LADCO collected and generated to support these decisions.

5.1 Inventory Sources

Starting in March 2018, LADCO produced a series of Q/d analyses for use by the LADCO member states for regional haze planning. The LADCO Regional Haze workgroup and Project Team provided guidance to LADCO on which sources to include in the Q/d analysis. These groups decided early in the second Regional Haze implementation period to focus the Q/d analysis on point sources of NOx and SO_2. LADCO followed this guidance to produce Q/d results for different inventory years.

The first Q/d versions used 2011-based emissions inventories and included 2011, 2018, and 2028 data. LADCO also computed Q/d values for point sources from different versions of inventories for Canada and Mexico. As LADCO and the LADCO member states learned of new EGU shutdown announcements that were made since the release of the 2011 inventories, the LADCO members requested that the Q/d analyses be redone with newer data.

In January 2019, state and federal participants in the LADCO Regional Haze Technical Workgroup agreed to use the latest available 2016 inventory for a new Q/d analysis by LADCO. The National Emissions Inventory Collaborative 2016 alpha inventory represented the best estimate of 2016 point emissions at the time[18]. Table 5-1 shows the point source components of the 2016 alpha inventory that LADCO used for the Q/d analysis.

Table 5-1. Point source inventory components used for the 2016 alpha Q/d analysis

Sector	Filename	Description
Electricity Generating Unit (EGU) point	ptegu_2016NEIv2_composite.csv	2016 emissions from the National Emissions Inventory (NEI) integrated with CEM (continuous emissions monitoring) hourly data.
Non-EGU industrial point	ptnonipm_2016alpha_POINT_ 03apr2018_nf_v3.csv	2016 emissions of non-EGU industrial point sources.
Point oil and gas	2028el_marama_pt_oilgas_2011neiv2_ point_20140913_02dec2016_v1.csv	2028 emissions for oil and gas sources. In April of 2018 no 2016 oil and gas inventory was available. We chose to use MARAMA's 2011-based projected 2028 oil and gas inventory that included many new oil and gas fields and sites.
Non-US point	canada_mexico.ff10.csv	2013 and 2025 point inventories from Environment and Climate Change Canada were interpolated to year 2016. 2008 inventories for Mexico were projected to the years 2014 and 2018, and then those emissions were interpolated to the year 2016.

5.2 Q/d Analysis Spreadsheets

LADCO developed a utility in R (QD_2028_V2.1.R) to extract the inventory data, calculate Q/d for each facility, and format the data for Microsoft Excel. Because a four factor analysis requires a list of sources at the process (Source Classification Code) level, LADCO developed the Q/d utility to generate a list of all facilities that contribute to 80% of the cumulative Q/d values for each Class 1 area. From those top 80% facilities, the utility further filters out those processes with emissions less than 1 ton/year.

LADCO originally used a cumulative Q/d threshold of 80% to select sources to be consistent with U.S. EPA's 2016 proposed regional haze rule guidance (U.S. EPA, 2016d). Although U.S. EPA ultimately did not

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[18] https://www.epa.gov/air-emissions-modeling/2016v71-alpha-platform

recommend any specific threshold in their 2019 regional haze guidance (U.S. EPA, 2019a), the LADCO Regional Haze Workgroup explored the impacts of using different thresholds for selecting sources. LADCO used an 80% threshold for our final Q/d analyses. The workgroup felt that this threshold produced a sufficient list of sources for the LADCO member states to consider for further analysis, including for the four- factor analysis.

Table 5-2 presents Q/d threshold groups for sources in the LADCO region. This table shows the cumulative Q/d and emissions contributions from point sources in the LADCO region for different Q/d values. For example, an analysis that uses a Q/d of 4 would include 95 facilities across the LADCO region that are associated with 75.4% of the regional total Q/d, and emit 79.6% and 60.2% of the regional total point source NOx and SO_2, respectively.

Table 5-2. Q/D threshold groups for sources in the LADCO region

	Q/D threshold Group		
Description	**Q/d=1**	**Q/d=4**	**Q/d=10**
Total facilities In Group	175	95	47
Sum of Q/d	3,898	3,263	2,421
% of Q/d	90.1%	75.4%	57.1%
Sum of emissions (SO_2, NOx, $PM_{2.5}$, NH_3; tons/yr)	892,320	713,332	496,748
% of total emissions captured	86.4%	69.1%	48.1%
Sum of SO_2 emissions (tons/yr)	488,799	414,771	302,882
% of SO_2 emissions	93.9%	79.6%	58.2%
Sum of NOx emissions (tons/yr)	363,188	270,729	176,513
% of NOx emissions	80.7%	60.2%	39.2%

LADCO created an Excel spreadsheet for our member states to use in their Q/d analyses. We tagged the facility processes with four-factor analysis group codes, which are based on NAICS codes. We worked with the LADCO member states and stakeholders to generate a list of facilities that belong to seven NAICS-code categories. These categories include the sources across the LADCO region in specific NAICS code groups with Q/d values greater than 1.0. We calculated this Q/d threshold using the sum of NOX, SO_2, $PM_{2.5}$, NH_3, and VOC emissions at each facility (Q)[19] and for the Class 1 area closest to the facility (d).

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[19] The Q/d support data developed by LADCO and shown here used the National Emissions Collaborative 2016v1 inventory.

Table 5-3 shows the NAICS codes and the four factor groups for sources in the LADCO region with Q/d values greater than 1. We provided this list of facilities organized by four factor analysis groups to the LADCO member states to refine based on alternative selection criteria, such as different Q/d thresholds. The sources included in the seven groups in Table 5-3 represent 94.7% of the total Q/d in the region[20].

Table 5-3. Four factor groups used for the LADCO Q/d analysis (Q/d > 1)

4-factor group ID	NAICS	NAICS name	# of Facilities	# of Units	Facility Total Q/d	% of Total Q/d
1	221112	Fossil Fuel Electric Power Generation	81	210	2690	69.0
2	212210	Iron Ore Mining	9	58	374	9.6
3	322121	Paper (except Newsprint) Mills	16	36	182	4.7
3	311221	Wet Corn Milling	5	13	45	1.2
3	311313	Beet Sugar Manufacturing	3	6	14	0.4
3	322110	Pulp Mills	2	4	9	0.2
3	322130	Paperboard Mills	3	3	7	0.2
4	327310	Cement Manufacturing	10	28	104	2.7
4	327410	Lime Manufacturing	8	13	45	1.2
5	331110	Iron and Steel Mills and Ferroalloy Manufacturing	9	33	77	2.0
6	486210	Pipeline Transportation of Natural Gas	16	40	77	2.0
6	221210	Natural Gas Distribution	2	2	4	0.1
7	324199	All Other Petroleum and Coal Products Manufacturing	6	12	47	1.2
7	324110	Petroleum Refineries	5	6	9	0.2

LADCO developed the spreadsheet QoverD_V5.7_2016_scc.xlsx (see the Electronic Docket) to investigate how different inventory years base years, future years, and source inventories impact the Q/d calculation results. We developed this spreadsheet as a tool for our member states to evaluate different Q/d calculation methods and values. In addition to sources in all states, Canada, and Mexico, the spreadsheet includes all facilities with emissions greater than 1 ton/year of any pollutant, and the distances from each facility to every class 1 area in the country.

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[20] The LADCO regional haze workgroup concurred on a process to exclude very small sources or sources that had negligible Q/d values from this analysis. The Total Q/d number for the region only includes those sources with non-negligible Q/d impacts.

The spreadsheets and emissions data files used by the LADCO states for the Q/d analysis during the second regional haze implementation period are available in the electronic docket to this TSD.

6 CAMx Model Performance Evaluation Results

This section summarizes the operational evaluation of the LADCO CAMx simulations for the two modeling platforms used for the second regional haze implementation period. As described in Section 3.6, LADCO compared particulate matter (PM) surface layer concentrations from 2011 and 2016 annual base year CAMx simulations to ambient surface monitoring data to evaluate the skill of the model at reproducing the observations. The LADCO model performance evaluation (MPE) results for each of the modeling years are compared to model performance benchmarks and to MPE results from U.S. EPA modeling of similar data. Additional MPE results and discussion for the LADCO 2011 and 2016 CAMx simulations are in the Supplemental Materials Section S5.

We emphasize the nitrate and sulfate model performance during the winter (January, February, and December) and spring (March, April, and May) months as these are species and periods that experience the most anthropogenic impairment to visibility at the Class I areas in the LADCO region. Figure 6-1 shows the distribution of most impaired days in each month across all of the LADCO region Class I areas during the period 2014-2018. The winter and spring months account for over 70% of the most impaired days in the Great Lakes region. The PM species contribution plot for Voyageurs National Park in Figure 6-2 shows that nitrate and sulfate aerosol contributed 79% of the light extinction on the most impaired days during the period 2014-2018. The PM species contributions for the other LADCO region Class I areas are similar to Voyageurs[21].

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[21] Source: Federal Land Manager Environmental Database; http://views.cira.colostate.edu/fed/

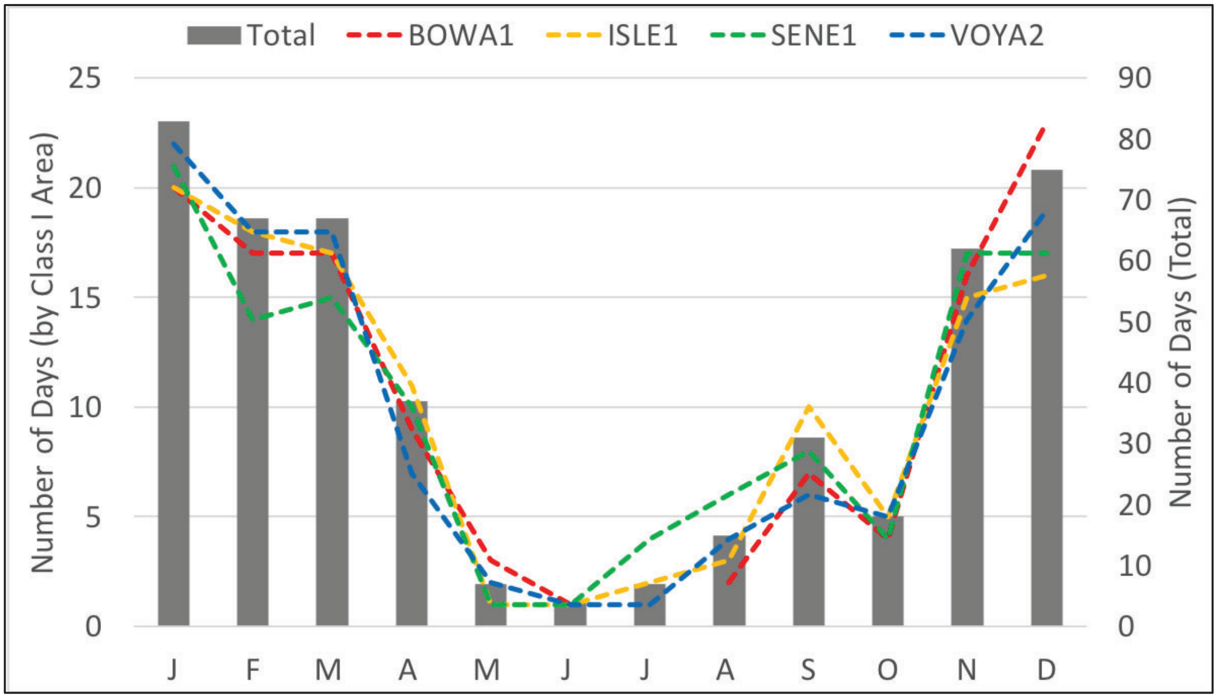

Figure 6-1. Monthly distribution of most impaired days for the LADCO region Class I areas during the period 2014-2018.

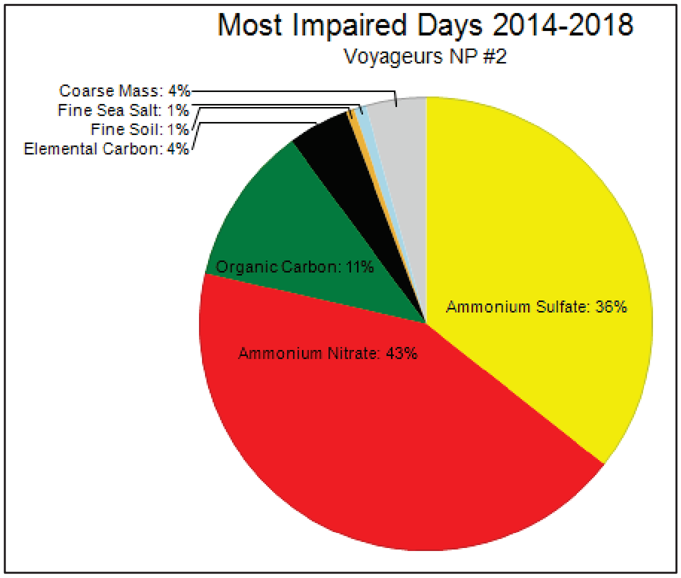

Figure 6-2. Average PM species composition at Voyageurs National Park, MN on the most impaired days during the period 2014-2018.

6.1 2011 CAMx Model Performance Evaluation Results

A summary of the CAMx MPE results for 2011 are presented in this section. The summary first presents annual and regional average MPE statistics for all CSN and IMPROVE monitoring locations in the LADCO region to provide an overview of the CAMx model's skill at simulating $PM_{2.5}$. Supplemental Materials Section S5 includes seasonal and regional MPE metrics to identify how well the model can estimate PM concentrations during different times of the year. Section S5 includes model performance information for different $PM_{2.5}$ components (total $PM_{2.5}$, sulfate, nitrate, and total carbonaceous aerosols[22]) to quantify how well the model can simulate the key light scattering species that most contribute to visibility impairment.

6.1.1 Annual PM Model Performance

Table 6-1 presents annual and regional average model performance statistics for the CSN and IMPROVE monitors in the LADCO region. Relative to the performance goals (which are more stringent) and criteria (which are less stringent) in Table 3-7, the LADCO 2011 CAMx simulation had acceptable performance for annual average total $PM_{2.5}$, sulfate, and nitrate for both the CSN and IMPROVE networks. The model performance statistics for all three of these species were near or within the more restrictive performance goals for NMB, NME, and correlation. While Emery et al. (2017) did not provide performance benchmarks for total carbonaceous (TC = organic aerosol + elemental carbon) $PM_{2.5}$, the goals and criteria for EC and OC are close to each other and can be used to evaluate the modeled TC concentrations. The 2011 CAMx estimates of TC at the IMPROVE locations in the LADCO region were within the performance benchmarks. The notable LADCO 2011 CAMx simulation performance issue on an annual and regional basis is with TC at the CSN monitors. The CAMx simulation overestimates of the observed TC concentrations (NMB = +68.5%) are outside of the performance criteria (40-50%) for carbonaceous aerosols.

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[22] Ammonium ion (NH_4^+) evaluation is not reported here because the ammonium ion species reported by the monitoring networks is not a true measurement and thus is not readily comparable to the CAMx modeled species. Soil and sea salt are not included in this evaluation because they are a small component of the measured visibility at the LADCO class I areas on the most impaired days;

Annual average statistics for all of the 2011 simulation $PM_{2.5}$ species at the IMPROVE monitors in the LADCO region are within the NMB performance goals and the NME performance criteria. The LADCO 2011 CAMx simulation performance meets the performance criteria for nitrate at the IMPROVE monitors for both NMB and NME.

Table 6-1. LADCO 2011 CAMx annual average PM modeling performance summary

Species	Obs (μg/m³)	CAMx (μg/m³)	NMB (%)	NME (%)	r
CSN $PM_{2.5}$	10.89	11.63	9.95	35.83	0.76
IMPROVE $PM_{2.5}$	6.63	6.89	7.41	40.52	0.75
CSN SO_4	2.20	1.86	-12.96	36.29	0.76
IMPROVE SO_4	1.83	1.53	-7.58	38.20	0.76
CSN NO_3	1.83	1.83	2.47	51.01	0.73
IMPROVE NO_3	0.93	1.13	25.93	70.66	0.72
CSN TC	2.92	4.63	68.46	80.93	0.70
IMPROVE TC	2.38	2.69	19.20	53.21	0.68
Key:	Met MPE Goal		Met MPE Criteria		

6.1.2 Seasonal PM Model Performance

Supplemental Materials Section S5.1.5 includes 2011 seasonal CAMx model performance statistics tables for the CSN and IMPROVE monitors in each LADCO state. The seasonal and site average statistics in these tables include observed and modeled concentrations, NMB, NME, and correlation

The skill of the LADCO 2011 CAMx simulation at simulating observed $PM_{2.5}$ species at CSN and IMPROVE monitors in the region was mixed. The LADCO CAMx 2011 modeling results are comparable to the U.S. EPA 2011 modeling platform used for preliminary regional haze modeling (U.S. EPA, 2017a), as expected since the two modeling platforms were nearly identical. Intercomparing the LADCO and U.S. EPA 2011 CAMx simulations is complicated by the use of different regions to calculate performance statistics. The six-state LADCO region used here for calculating performance statistics overlaps with but is not completely inclusive of the states in the Ohio Valley and Upper Midwest regions used by U.S. EPA.

While the LADCO 2011 CAMx simulation of total $PM_{2.5}$ had an overprediction bias through most of the year, it achieved the MPE benchmarks for the spring and winter months at most of the CSN and IMPROVE monitors in the LADCO region. The LADCO 2011 CAMx simulation had regional average spring and winter NMBs for total $PM_{2.5}$ at the IMPROVE monitors of +8.6% and +29%, respectively.

Figure 6-3 summarizes the winter and spring 2011 CAMx model performance at the IMPROVE monitors in the LADCO region. These plots compare the observed (left stacked bar) and CAMx simulated (right stacked bar) $PM_{2.5}$ species averaged across all IMPROVE monitors in the LADCO region for each season. The spring season CAMx overprediction bias across the region is driven by excess nitrate and organic aerosol in the model. The $PM_{2.5}$ species “Other” in this plot represents fine crustal and seasalt particles, and it is also overpredicted by CAMx. The winter season CAMx overprediction bias is driven primarily by excess organic aerosol in the model, and to a lesser extent excess Other PM.

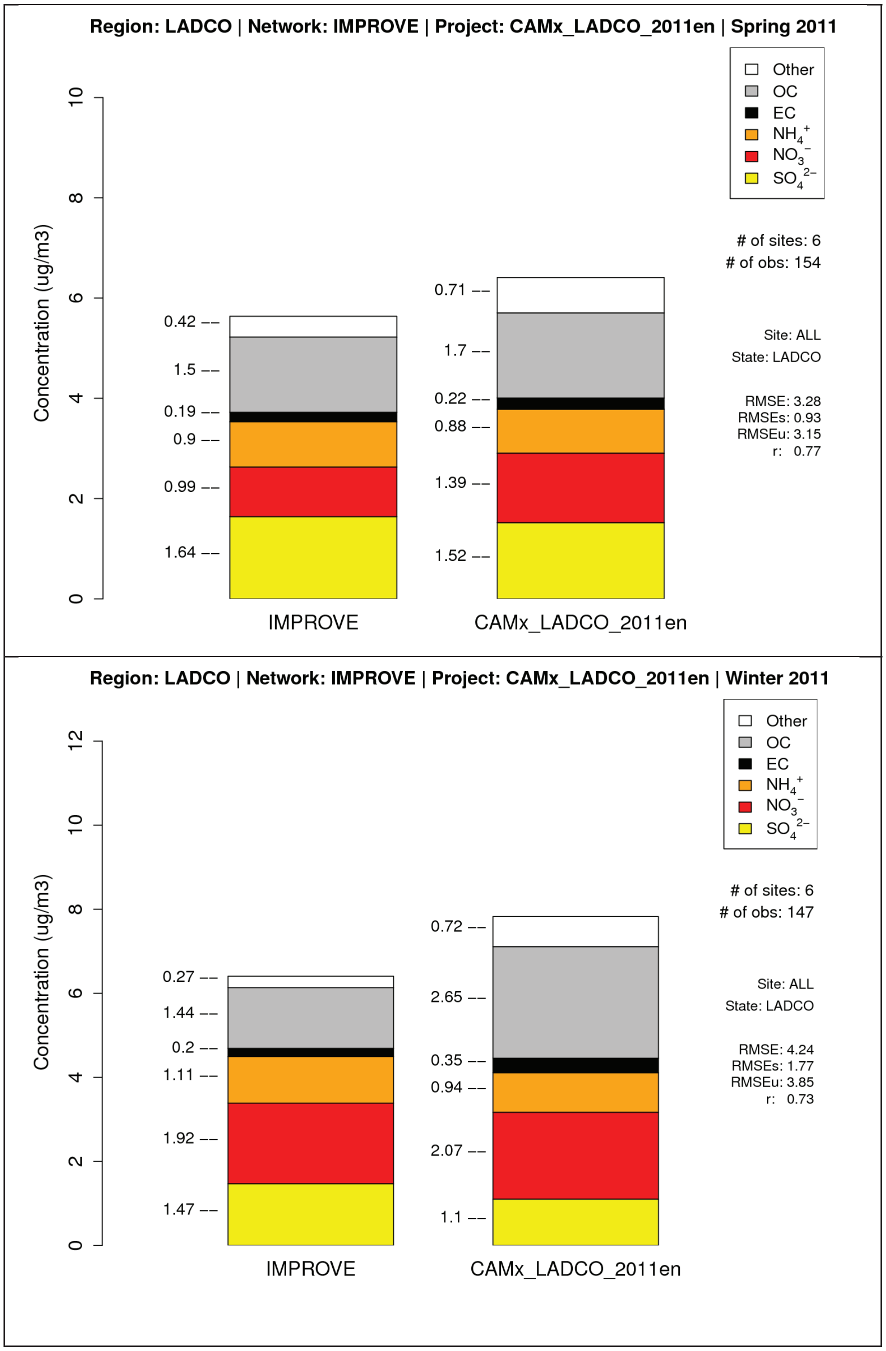

Figure 6-3. Stacked bar plot of spring (top) and winter (bottom) season $PM_{2.5}$ species averaged across all IMPROVE monitors in the LADCO region.

6.1.3 Comparison of LADCO and U.S. EPA 2011 PM Model Performance

The U.S. EPA 2011 CAMx simulation had regional average NMBs (average of the Ohio Valley and Upper Midwest regions) at the IMPROVE monitors in the spring and winter of +13.7%, and +19%, respectively.

The significant wintertime overprediction bias for total $PM_{2.5}$ at the Minnesota IMPROVE sites (NMB > +52%) noted in Supplemental Materials Section S5.1.1 is also present in the U.S. EPA results (Figure 26 in U.S. EPA, 2017a).

Both the LADCO and U.S. EPA CAMx 2011 simulations of spring season sulfate show the stark spatial gradient from overprediction to underprediction (i.e., positive to negative NMBs) along the southern part of the LADCO region. Both simulations also underpredicted wintertime sulfate throughout most of the LADCO region, and produced lower biases (i.e., good simulations) for the northern Class I area IMPROVE monitors.

The U.S. EPA CAMx 2011 simulation overpredicted nitrate in the spring and underpredicted nitrate in the winter, similar to the LADCO simulation. The two simulations both generally captured the monthly variability in observed nitrate concentrations at both the IMPROVE and CSN monitors with concentrations peaking in the winter months (e.g., Figure S 5-11). As with the LADCO CAMx simulation, the U.S. EPA simulation also had a large wintertime nitrate overprediction bias at the northern Class I area IMPROVE monitors (NMB > +40%).

The U.S. EPA (2017a) reported MPE results for elemental and organic carbon aerosols. While LADCO reports total carbonaceous aerosols here, the winter and spring season overpredictions are evident in the results from both simulations.

6.2 2016 CAMx Model Performance Evaluation Results

A summary of the CAMx MPE results for 2016 are presented in this section. The summary presents annual average MPE statistics for all CSN and IMPROVE monitoring locations in the LADCO region to provide an overview of the CAMx model's skill in simulating $PM_{2.5}$. Supplemental Materials Section S5 includes seasonal and regional MPE metrics that are used to identify how well the model can estimate PM concentrations during different times of the year. As with the 2011 simulation, Section S5 also includes model performance information for different $PM_{2.5}$ components (total $PM_{2.5}$, sulfate, nitrate, and total carbonaceous aerosols) to quantify how well the model can simulate the key light scattering species that most contribute to visibility impairment.

6.2.1 Annual PM Model Performance

Table 6-2 presents annual and regional average model performance statistics for the CSN and IMPROVE monitors in the LADCO region. Relative to the performance goals and criteria in Table 3-7, CAMx shows marginally acceptable performance for average total $PM_{2.5}$, sulfate, and nitrate. CAMx meets the more restrictive NMB performance goal only for nitrate at the IMPROVE sites. CAMx achieved the NMB model performance criteria for total $PM_{2.5}$ and sulfate at both networks, and CSN nitrate. The CAMx 2016 simulation had a severe overprediction bias for the carbonaceous aerosols.

Table 6-2. LADCO 2016 CAMx PM modeling performance summary

Species	**Obs ($\mu g/m^3$)**	**CAMx ($\mu g/m^3$)**	**NMB (%)**	**NME (%)**	**r**
CSN $PM_{2.5}$	8.19	10.37	30.47	44.68	0.71
IMPROVE $PM_{2.5}$	4.75	5.63	22.82	42.61	0.66
CSN SO_4	1.13	1.42	33.68	48.60	0.70
IMPROVE SO_4	0.99	1.07	16.50	39.53	0.71
CSN NO_3	1.26	1.42	40.19	78.38	0.52
IMPROVE NO_3	0.72	0.64	11.89	75.46	0.50
CSN TC	2.18	4.46	116.93	121.80	0.66
IMPROVE TC	1.89	2.72	56.44	69.95	0.64
Key:	Met MPE Goal		Met MPE Criteria		

6.2.2 Seasonal PM Model Performance

Supplemental Materials Section S5.2.6 includes seasonal CAMx model performance tables for the CSN and IMPROVE monitors in each LADCO state. The seasonal and site average statistics in these tables include observed and modeled concentrations, NMB, NME, and correlation

The LADCO 2016 CAMx simulation performance in simulating observed $PM_{2.5}$ species at CSN and IMPROVE monitors in the region was mixed. As with the 2011 CAMx modeling platform, the LADCO 2016 CAMx simulation exhibited better skill with the inorganic aerosol species than with the carbonaceous aerosols. The CAMx 2016 simulation had particularly poor performance in estimating organic aerosols.

Figure 6-4 summarizes the winter and spring CAMx model performance at the IMPROVE monitors in the LADCO region. These plots compare the observed (left stacked bar) and CAMx simulated (right stacked bar) $PM_{2.5}$ species averaged across all IMPROVE monitors in the LADCO region for each season. The spring season CAMx overprediction bias across the region is driven by excess organic aerosol and $PM_{2.5}$ "Other", which includes fine crustal and seasalt particles. On a seasonal, regionwide basis the LADCO 2016 CAMx simulation compares well to the springtime IMPROVE observations for sulfate, nitrate, ammonium, and elemental carbon. The winter season CAMx overprediction bias at the LADCO IMPROVE sites is also driven primarily by excess organic aerosol in the model, and to a lesser extent excess $PM_{2.5}$ Other. The total $PM_{2.5}$ overprediction is attenuated by underpredictions of wintertime nitrate and ammonium.

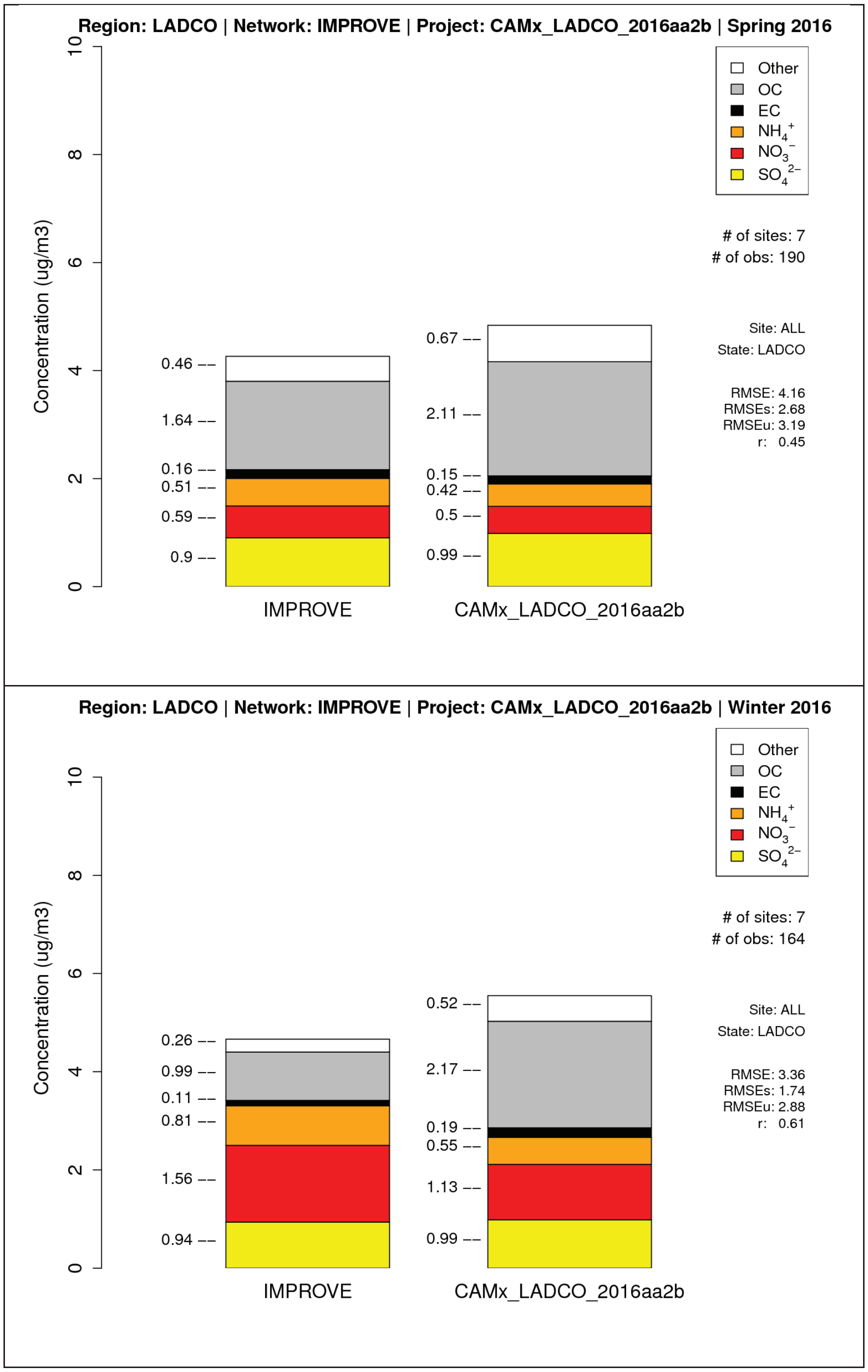

Figure 6-4. Stacked bar plot of 2016 spring (top) and winter (bottom) season $PM_{2.5}$ species averaged across all IMPROVE monitors in the LADCO region.

6.2.3 Comparison of LADCO and U.S. EPA 2016 PM Model Performance

The LADCO CAMx 2016 modeling results are comparable to the U.S. EPA 2016 modeling platform used for their preliminary regional haze modeling (U.S. EPA, 2019b), as expected since the two modeling platforms were nearly identical. As with the 2011 modeling platform, intercomparing the LADCO and U.S. EPA 2016 CAMx simulations is complicated by the use of different regions to calculate performance statistics.

While the LADCO 2016 CAMx simulation of total $PM_{2.5}$ had an overprediction bias through most of the year, it achieved the model performance benchmarks for the spring and winter months at most of the CSN and IMPROVE monitors in the LADCO region. The LADCO 2016 CAMx simulation had regional average spring and winter NMBs for total $PM_{2.5}$ at the IMPROVE monitors of +15.5% and +29.2%, respectively. The U.S. EPA 2016 CAMx simulation of total $PM_{2.5}$ had regional average NMBs (average of the Ohio Valley and Upper Midwest regions) at the IMPROVE monitors in the spring and winter of +16.3% and +31%, respectively. The LADCO 2016 CAMx simulation had regional average spring and winter NMBs for total $PM_{2.5}$ at the CSN monitors of +23.3% and +34%, respectively. In comparison, the U.S. EPA 2016 CAMx simulation had regional average NMBs at the CSN monitors in the spring and winter of +12% and +17%, respectively.

Both the LADCO and U.S. EPA CAMx 2016 simulations overpredicted sulfate throughout the year in most of the LADCO region. Both simulations better predicted (i.e., lower NMBs) sulfate in the winter months than in the spring. The LADCO 2016 CAMx simulation had regional average spring and winter NMBs for sulfate at the IMPROVE monitors of +7.2% and +9.4%, respectively. The U.S. EPA 2016 CAMx simulation had regional average NMBs at the IMPROVE monitors in the spring and winter of +11% and +7.2%, respectively.

The U.S. EPA 2016 CAMx simulation overpredicted nitrate in the spring and underpredicted nitrate in the winter, similar to the LADCO 2016 simulation. The two simulations both generally captured the monthly variability in observed nitrate concentrations at both the IMPROVE and CSN monitors with concentrations peaking in the winter months. As with the LADCO CAMx simulation, the U.S. EPA 2016 simulation also produced a large underprediction bias at the northern Class I area IMPROVE monitors in the winter (NMB > +40%).

The U.S. EPA (2019b) reported MPE results for elemental and organic carbon aerosols. While LADCO reports total carbonaceous aerosols here, the severe winter and spring season overpredictions are evident in the results from both simulations.

6.3 Model Performance Discussion

In the preceding sections and in Supplemental Materials Section S5 we present MPE results for the PM species components of regional haze estimated by the LADCO 2011 and 2016 CAMx simulations. To narrow the scope of the evaluation for this TSD, we focused on the CAMx performance in simulating spring and winter season nitrate and sulfate. We chose to focus our evaluation on these periods and species because they are associated with the most anthropogenically impaired conditions at the Class I areas in the LADCO region.

Table 6-3 compares the LADCO 2011 CAMx and 2016 CAMx simulation model performance for the spring and winter seasons by monitoring network and PM species. The table shows the average CAMx NMB and NME values across the CSN and IMPROVE monitor locations in the six-state LADCO region for the spring and winter seasons. This table presents a more comprehensive view of the model species than in the preceding sections because it includes the carbonaceous aerosol species and ammonium ion in addition to sulfate and nitrate. Dark green shading indicates if the simulation achieved the performance goal for the model species; light green shading indicates that the model achieved the less stringent performance criteria (Emery et al., 2017).

Looking across all of the MPE benchmarks in Table 6-3, both of the LADCO CAMx simulations achieved either the model performance goals or criteria for most of the species in the two seasons. The LADCO 2011 CAMx simulation of spring season PM species at the IMPROVE sites had the best model performance with most of the species achieving the more stringent MPE goals for both NMB and NME. While not as strong as the 2011 simulation, the spring season 2016 CAMx simulation of PM at the IMPROVE monitors achieved at least the NMB and NME criteria for most of the species. In both years, the CAMx simulations generally better estimated PM at the more rural IMPROVE sites compared to the CSN sites (i.e., lower NMB and NME at IMPROVE vs CSN).

A comparison of the CAMx model performance across the two base years shows fairly comparable results. CAMx did not simulate well the carbonaceous aerosols, and organic aerosol in particular, in either of the base years. The model overestimated these species in both the spring and winter seasons and at both of the networks shown in Table 6-3. The CAMx 2011 simulation of nitrate at the CSN monitor locations is slightly better than the 2016 simulation, but both simulation years achieved the MPE goals for winter season nitrate. Where the 2011 simulation overpredicted nitrate at the IMPROVE monitors in both seasons, the 2016 simulation underpredicted nitrate and had slightly lower absolute NMB and NME values. The 2011 and 2016 simulations of sulfate at the IMPROVE monitors were comparable. Where the 2011 simulation unpredicted sulfate on average across the IMPROVE sites, the 2016 simulation overpredicted spring and winter season sulfate. Notable deficiencies in the LADCO CAMx simulation performance are winter 2011 (NMB = -38%) and spring 2016 (NMB = +31%) sulfate at the CSN monitors, and organic aerosols in both years at the CSN monitors.

The LADCO CAMx simulations performed relatively well in estimating spring and winter season nitrate and sulfate at the IMPROVE monitors in both years. This result is significant because these two species are the biggest contributors to haze in the LADCO region Class I areas on the most impaired days. The PM model performance for both the 2011 and 2016 LADCO simulations are very similar to the models used by U.S. EPA for their recent regional haze assessments (U.S. EPA, 2017a; U.S. EPA, 2019b). We cannot infer the impacts of the CAMx biases and errors on how the model responds to emissions changes with the information that we have here. Namely, we cannot quantify the impacts of the CAMx biases on the relative response factors (RRFs) and derived future year PM design values and derived haze projections because we don't know how much each of the model processes (e.g., emissions, chemistry, deposition) contribute to the total bias and error in the model.

Table 6-3. NMB (%) and NME (%) summary statistics for LADCO 2011 and 2016 CAMx simulations[23]

Species	2011				2016			
	Spring		Winter		Spring		Winter	
Statistic	**NMB**	**NME**	**NMB**	**NME**	**NMB**	**NME**	**NMB**	**NME**
CSN								
EC	42.80	64.11	88.27	97.86	-4.86	43.05	45.92	63.25
NH_4	17.77	39.36	-16.40	39.21	120.26	130.69	31.46	63.74
NO_3	30.79	63.58	-11.49	35.06	20.08	67.29	-10.27	48.21
OA	56.91	66.65	111.73	117.23	61.15	71.74	129.51	132.40
$PM_{2.5}$	19.60	37.73	8.43	30.43	18.81	37.85	25.82	41.74
SO_4	1.49	37.18	-38.15	46.23	31.17	45.60	10.05	38.68
TC	53.84	64.50	107.62	113.43	35.08	54.74	105.17	108.63
IMPROVE								
EC	16.46	47.23	82.02	83.93	0.41	43.60	90.36	94.67
NH_4	-8.12	35.64	-6.05	40.57	-14.65	37.01	-32.62	42.88
NO_3	18.50	61.85	29.65	61.57	-8.40	59.04	-25.11	61.56
OA	12.19	44.58	88.07	89.42	41.97	69.76	126.35	126.85
$PM_{2.5}$	11.48	35.26	36.81	49.06	21.18	47.91	30.78	54.23
SO_4	-0.69	32.37	-17.72	49.80	17.08	36.72	11.78	39.36
TC	12.53	43.78	87.39	88.53	38.52	66.78	122.76	123.28
Key:	Met MPE Goal		Met MPE Criteria					

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[23] Dark green shading indicates if the simulation achieved the performance goal for the model species; light green shading indicates that the model achieved the less stringent performance criteria (Emery et al., 2017).

7 Future Year Haze Projections

The air quality modeling that LADCO completed to support regional haze SIPs for the second implementation period culminated in estimating 2028 regional haze conditions in U.S. Class I areas. The future year haze projections described in this section will be available to the LADCO member states to use as weight of evidence to support their demonstration of progress towards natural visibility conditions in 2064. This section presents the methods that LADCO used to forecast 2028 haze conditions, examples of the analysis products from our work, and instructions for how to access our forecasted visibility data for all of the nation's Class I areas.

7.1 Methods

LADCO followed the U.S. EPA Modeling Guidance for Demonstrating Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze (US EPA, 2018) for estimating the 2028 future year visibility condition. Hereafter, the EPA's modeling guidance is referred to as "the SIP Modeling Guidance". The SIP Modeling Guidance describes the recommended modeling analyses to track RHR reasonable progress goals (RPGs). The RPGs reflect the states' long-term strategy for meeting the requirements of the RHR. LADCO completed two set of CAMx modeling runs for forecasting haze in 2028, one is based on 2011 base year and another one is based on 2016 base year. Using these modeling outputs and IMPROVE visibility data, LADCO estimated 2028 visibility conditions.

As required by the RHR, a state's RPGs must produce an improvement in visibility for the 20 percent most anthropogenically impaired days and ensure no degradation in visibility for the 20 percent clearest days, relative to baseline visibility conditions. The baseline for each Class I area is the average visibility (in deciviews) for the years 2000 through 2004. The visibility conditions in these years are the benchmarks for the requirements to improve or not degrade visibility on different types of days. In addition, states are required to determine the rate of improvement in visibility needed to reach natural conditions by 2064 for the 20 percent most anthropogenically impaired days.

The LADCO visibility projections followed the procedures in Section 5 of the SIP Modeling Guidance. Future year modeled visibility is forecast relative to a 5-year period centered around the base modeling year. LADCO estimated the 2028 visibility from the 2011 and 2016 base years using ambient IMPROVE data for the 2009-2012 and the 2014-2018 periods, respectively. LADCO estimated base and future year visibility with the "revised" IMPROVE equation (Pitchford, 2007). The revised IMPROVE equation "reconstructs light extinction" from modeled and measured PM species concentrations and relative humidity data. The IMPROVE equation calculates visibility impairment or beta extinction (b_{ext}) in units of inverse megameters (Mm^{-1}) as follows:

$$b_{ext} = 2.2 \times fs(RH) \times [\text{Small Sulfate}] + 4.8 \times fL(RH) \times [\text{Large Sulfate}]$$

$$+ 2.4 \times fs(RH) \times [\text{Small Nitrate}] + 5.1 \times fL(RH) \times [\text{Large Nitrate}]$$

$$+ 2.8 \times \{\text{Small Organic Mass}] + 6.1 \times [\text{Large Organic Mass}]$$

The total sulfate, nitrate, and organic mass concentrations are each split into two fractions, representing small and large size distributions of those components. Site-specific Rayleigh scattering is calculated based on the elevation and annual average temperature of each IMPROVE monitoring site.

LADCO used the U.S. EPA Software for Model Attainment Test- Community Edition (SMAT-CE) Version 1.6 (SMAT-CE)[24] tool to calculate 2028 deciview (dv) values on the 20% most anthropogenically impaired and 20% clearest days at each of the IMPROVE monitors in Class I Areas. We used SMAT-CE to estimate the 2028 future year visibility on the 20% most anthropogenically impaired days and 20% clearest days at each Class I area using the observed IMPROVE data (2009-2013 and 2014-2018) and the relative percent change in modeled PM species between 2016 and 2028; and between 2011 and 2028. The SMAT-CE tool outputs individual year and 5-year average base year and future year dv values on the 20% most impaired days and 20% clearest days. Additional SMAT-CE output variables include the results of intermediate calculations, such as PM species light extinction values (both base and future year) and species-specific RRFs (on the 20% most impaired and clearest days).

The process for calculating future year visibility conditions with SMAT-CE is described in the following six steps (see the SIP Modeling Guidance for a more detailed description and examples). LADCO applied this process to data from each Class I area (i.e., each IMPROVE monitoring site).

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[24] https://www.epa.gov/scram/photochemical-modeling-tools

1. Estimate anthropogenic impairment (in Mm^{-1}) on each day using observed speciated $PM_{2.5}$ and PM_{10} data for each of the 5 years comprising the base period and rank the days based on impairment. This ranking is used to determine the 20 percent most anthropogenically impaired days. For each Class I area, also rank observed visibility (in dv) on each day using the same speciated data. This ranking will determine the 20 % clearest days.
2. Calculate the mean dv for the 20 percent most anthropogenically impaired days and 20 percent clearest days for each of the 5 years comprising the base period and the 5-year mean dv for the most impaired and clearest days.
3. Use the CAMx model to simulate air quality with base (2011 and 2016) and future year (2028) emissions. We applied SMAT-CE to the model results to develop site-specific relative response factors (RRFs) for each component of PM identified in the "revised" IMPROVE equation. The RRFs are an average percent change in species concentrations based on the measured 20% most impaired and 20% clearest days from 2011 or 2016.
4. Multiply the species-specific RRFs by the measured daily species concentration data during the 2009-2013 and 2014-2018 base periods for each day in the measured 20% most impaired day set and each day in the 20% clearest day set. This results in daily future year 2028 PM species concentration data.
5. Using the results in Step 4 and the IMPROVE algorithm, calculate the future daily extinction coefficients for the previously identified 20% most impaired days and 20% clearest days in each of the five base years.
6. Calculate daily dv values (from total daily extinction) and then compute the future year (2028) average mean dv values for the 20% most impaired days and 20% clearest days for each year. Average the five years together to get the final future mean dv values for the 20% most impaired days and 20% clearest days.

Table 7-1 details the settings used by LADCO for the SMAT-CE runs to estimate the 2028 future year dv value.

Table 7-1. SMAT-CE software configuration settings for 2028 visibility calculations

SMAT Option	Settings/file used for the 2011-based 2028 visibility calculation	Settings/file used for the 2016-based 2028 visibility calculation
IMPROVE algorithm	Use new version	Use new version
Grid cells at monitor or Class I area centroid?	Use grid cells at monitor	Use grid cells at monitor
IMPROVE data file	ClassIareas_NEWIMPROVEALG_2000to2018_2020_may5_IMPAIRMENT.csv[25]	ClassIareas_NEWIMPROVEALG_2000to2018_2020_may5_IMPAIRMENT.csv
Start monitor year	2009	2014
End monitor year	2013	2018
Temporal adjustment at monitor	3x3	3x3
Minimum years required for a valid monitor	1	1
Baseline model file	mats.PM.12US2.bulk.LADCO_2011en.csv	mats.PM.12US2.bulk.2016_ladco_v1b.cb6r4.csv
Forecast model file	mats.PM.12US2.bulk.LADCO_2028HAZE.csv	mats.PM.12US2.bulk.2028_ladco_v1b.cb6r4.csv

7.2 LADCO 2028 Haze Projections

The base and future year dv values on the 20% clearest and most impaired days at Class I areas within LADCO states for the 2011 and 2016 base model periods and 2028 future year are shown in Table 7-2 and Table 7-3, respectively. The last column of each table shows the predicted dv change at each Class I area on the 20% most impaired days. The visibility conditions at the Class I areas in the LADCO region

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[25] The IMPROVE ambient data file has the 20% most impaired days identified as "group 90" days and 20% clearest days identified as "group 10" days. The definition of the most impaired days uses the EPA recommended methodology from Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program. Technical Guidance on Tracking Visibility Progress for the Second Implementation Period of the Regional Haze Program | Visibility and Regional Haze | US EPA. The IMPROVE data file used for this analysis included patched and/or substituted data.

were predicted to improve on average by about 2 dv by 2028 as compared to the 2011 base year, and to have about a 0.8 dv improvement relative to the 2016 base year.

Table 7-2. Base and future year deciview values on the 20% clearest and 20% most impaired days at Class I area within LADCO region for the base model period (2009-2013) and future year (2028)

	20% Clearest Days (dv)			20% Most Impaired Days (dv)		
IMPROVE Site ID	Base Period	Future Year	Change (2028-2011)	Base Period	Future Year	Change (2028 -2011)
BOWA1	4.83	4.79	-0.04	16.42	14.43	-1.99
ISLE1	5.40	5.29	-0.11	17.63	15.48	-2.15
SENE1	5.50	5.35	-0.15	19.92	17.34	-2.58
VOYA2	5.68	5.60	-0.08	17.12	15.08	-2.04

Table 7-3. Base and future year deciview values on the 20% clearest and 20% most impaired days at Class I area within LADCO region for the base model period (2014-2018) and future year (2028)

	20% Clearest Days (dv)			20% Most Impaired Days (dv)		
IMPROVE Site ID	Base Period	Future Year	Change (2028 -2016)	Base Period	Future Year	Change (2028 -2016)
BOWA1	4.48	4.30	-0.07	13.96	13.17	-0.79
ISLE1	5.30	5.23	-0.07	15.54	14.83	-0.71
SENE1	5.27	5.17	-0.10	17.57	16.67	-0.90
VOYA2	5.31	5.25	-0.06	14.18	13.36	-0.82

Figure 7-1 shows the visibility glidepath at the Boundary Waters Canoe Area (BOWA) in Minnesota for the 20% most impaired days based on the 2011- and 2016-based 2028 CAMx simulations. The glidepath represents a linear rate of progress and shows the amount of visibility improvement needed in each implementation period to achieve natural visibility conditions in the Class I area by 2064. The figure compares the glidepath with the observed visibility conditions (yellow dots) for 2000-2018[26], baseline visibility condition (observed condition in 2000-2004 period)[27], base year visibility condition (green dot at 2011 or 2016), as well as the predicted 2028 visibility condition (red dot at 2028), and the 2064 target

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[26] Dataset was obtained from EPA in June 2020; Filename: ClassIareas_NEWIMPROVEALG_2000to2018_2020_may5_IMPAIRMENT.csv

[27] Guidance on Regional Haze State Implementation Plans for the Second Implementation Period (8/2019) https://www.epa.gov/visibility/guidance-regional-haze-state-implementation-plans-second-implementation-period; Natural and Baseline Visibility Condition Values from https://www.epa.gov/sites/production/files/2020-06/documents/memo_data_for_regional_haze_technical_addendum.pdf

of natural conditions[27] for a particular Class I area. In addition, a dashed blue line drawn between the visibility condition in baseline period (2000-2004) and natural condition in 2064 shows a uniform rate of progress (URP) and/or called "glidepath" line between these two points. The glidepath represents a linear or uniform rate of progress and is the amount of visibility improvement needed in each implementation period to achieve natural visibility conditions in the Class I area by 2064.

The RHR allows states to optionally propose adjustments at the end point of the glidepath (URP) to exclude uncontrollable haze contributions, such as contributions from international anthropogenic emissions and certain prescribed fires. The proposed adjustments for each Class I area must be developed using scientifically valid data and methods. U.S. EPA demonstrated in their preliminary (U.S. EPA, 2017a) and updated (U.S. EPA, 2019b) regional haze modeling efforts how the glidepath endpoints could be adjusted. LADCO used the same approaches demonstrated by U.S. EPA to adjust the glidepath endpoints for our 2011 and 2016-based visibility projections.

The figures below also show the adjusted glidepath. The adjusted glidepath for the 2011-based 2028 visibility prediction accounts for contributions from Mexico and Canada anthropogenic emissions. In addition to the Canadian and Mexico sources inside the modeling domain, the adjustment to the glidepath for the 2016-based 2028 visibility predictions also considered international anthropogenic sources outside of the modeling domain, including non-U.S. Class 3 commercial marine emissions (U.S. EPA, 2019b). The glidepath adjustments for the 2011-based modeling are smaller than the 2016-based modeling because they are calculated using fewer haze precursor sources.

Figure 7-1 through Figure 7-4 show the 2011-based and 2016-based LADCO 2028 visibility predictions relative to the URP glidepath for the Boundary Waters Canoe Area (BOWA), Isle Royale National Park (ISLE), Seney National Wildlife Refuge (SENE), and Voyageurs National Park (VOYA) Class I areas, respectively.

LADCO's CAMx visibility forecasts for Class I areas outside of the LADCO region are available in an electronic docket to this TSD in the following spreadsheets:

LADCO 2011-based 2028 Class I Area Visibility Forecasts (6.6 Mb XLSX file)

LADCO 2016-based 2028 Class I Area Visibility Forecasts (6.4 Mb XLSX file)

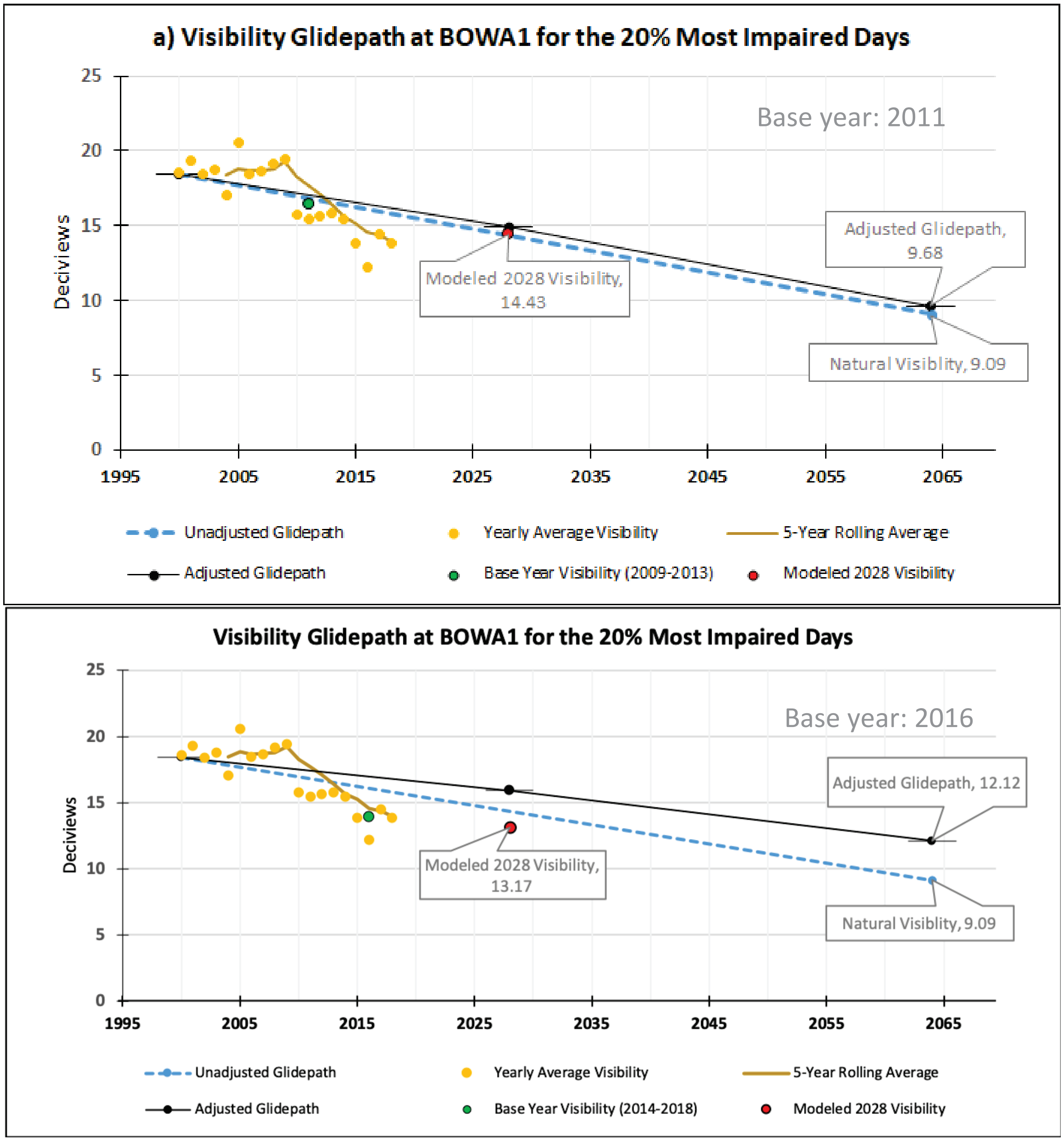

Figure 7-1. Visibility glidepath at BOWA1 IMPROVE site for the 20% most impaired days based on the (a) 2011 based 2028 prediction and (b) the 2016 based 2028 prediction[28].

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[28] Note that the adjusted glidepath for the 2011 based prediction is accounted only the contribution from Mexico & Canada anthropogenic emissions, while the adjusted glidepath for 2016 based prediction was accounted for contributions from Mexico & Canada anthropogenic, Non-US C3 commercial marine, international boundary condition and wildland prescribed fire emissions.

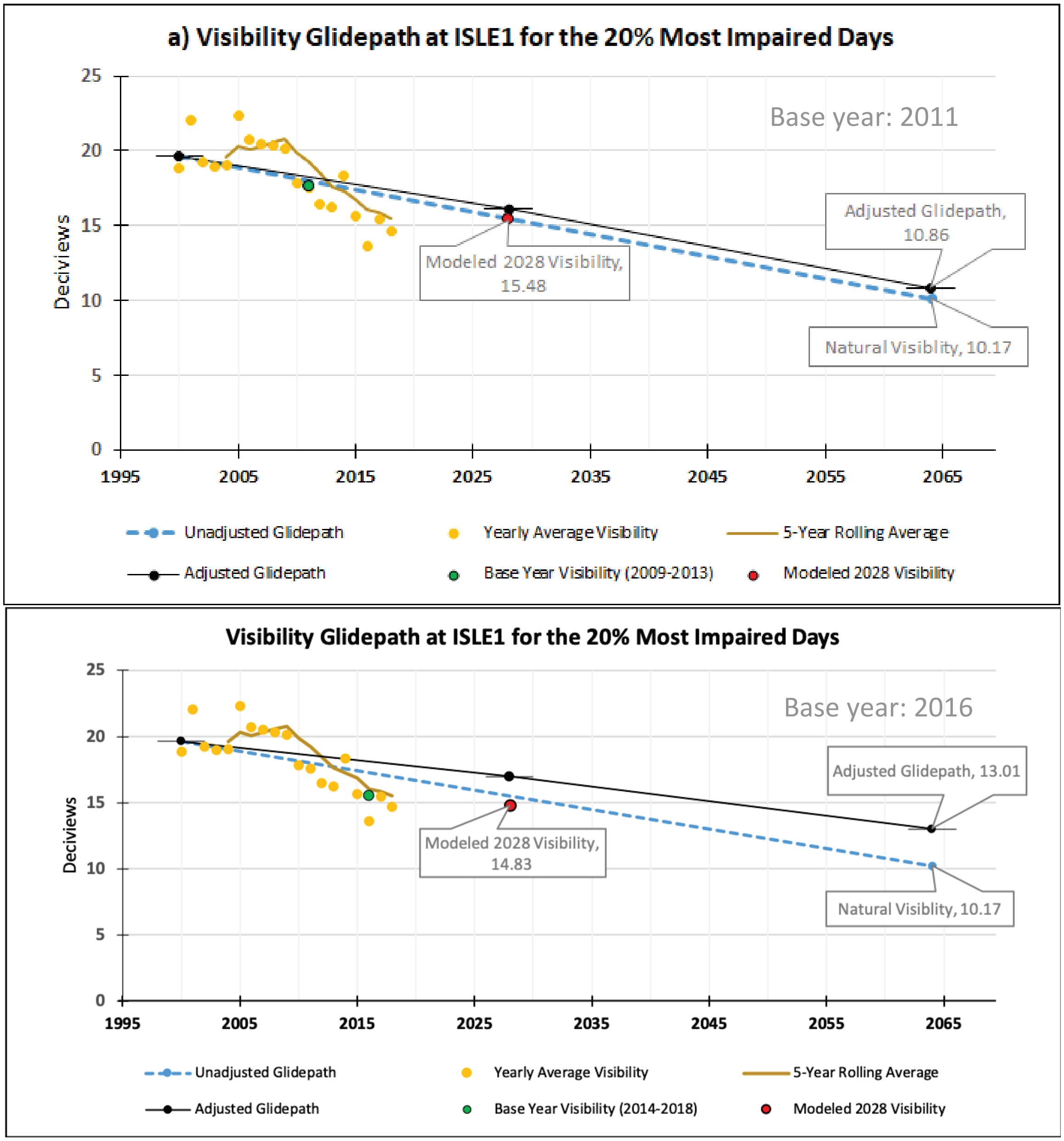

Figure 7-2. Visibility glidepath at ISLE1 IMPROVE site for the 20% most impaired days based on the (a) 2011 based 2028 prediction and (b) the 2016 based 2028 prediction.

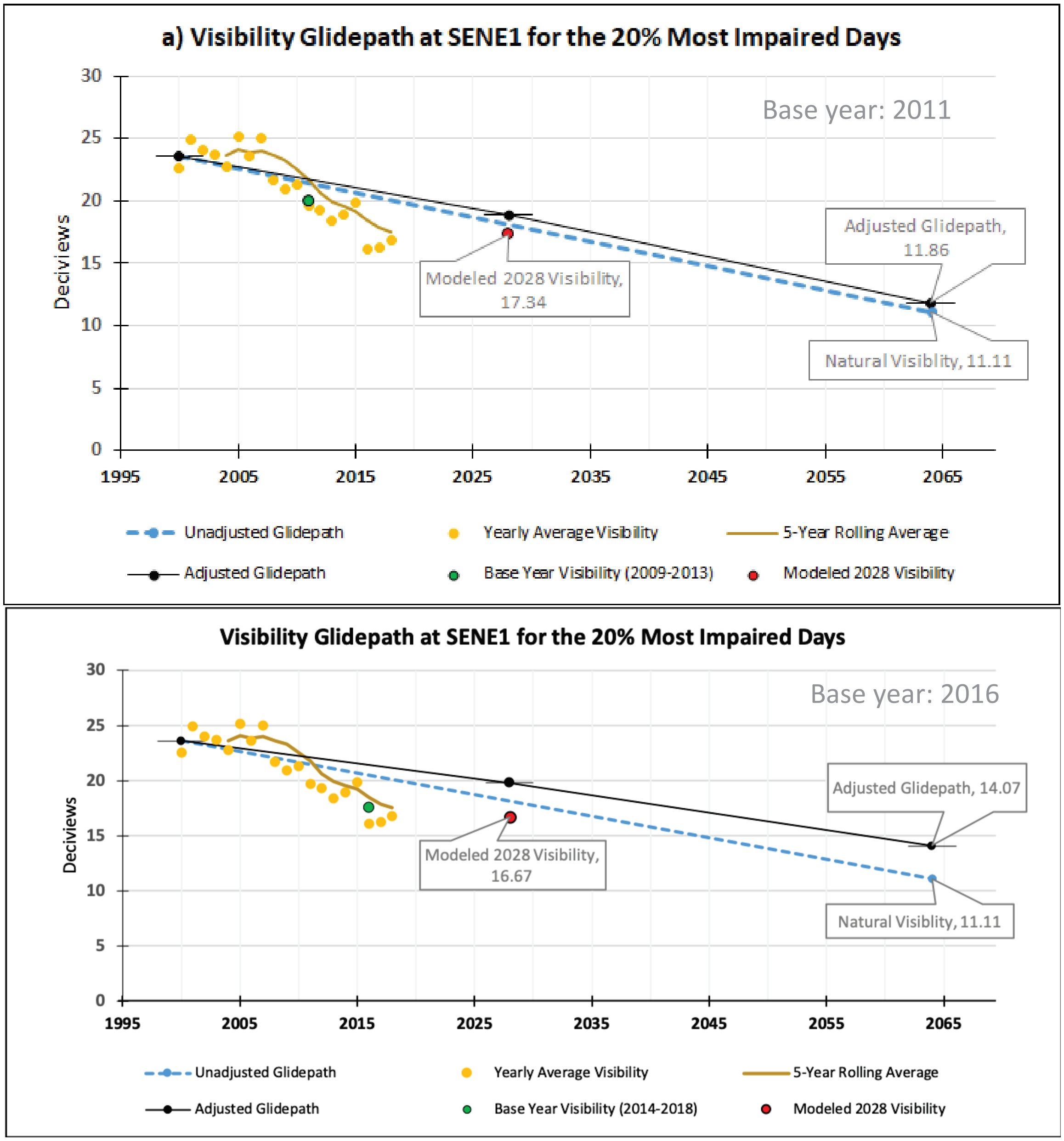

Figure 7-3. Visibility glidepath at SENE1 IMPROVE site for the 20% most impaired days based on the (a) 2011 based 2028 prediction and (b) the 2016 based 2028 prediction.

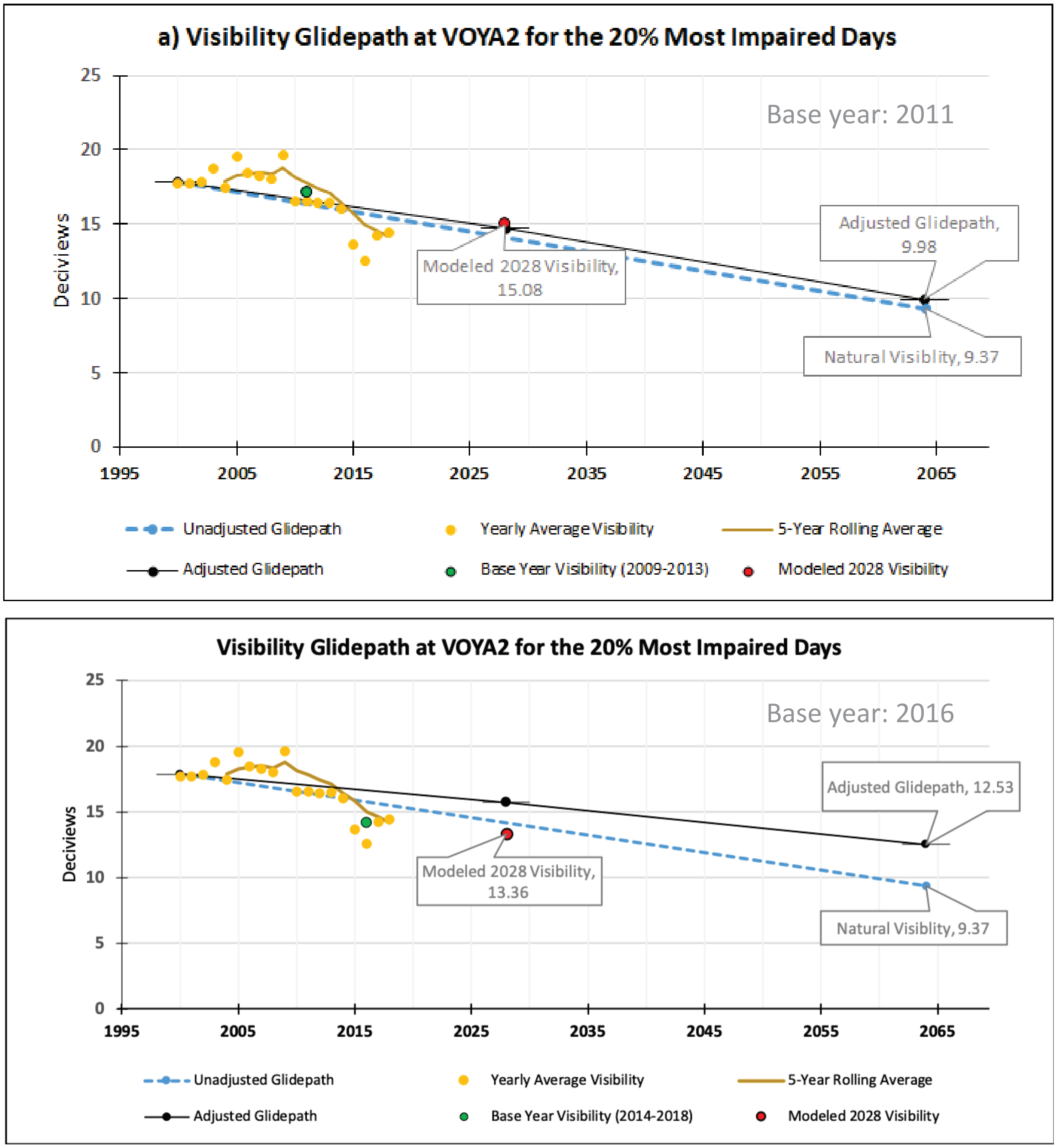

Figure 7-4. Visibility glidepath at VOYA2 IMPROVE site for the 20% most impaired days based on the (a) 2011 based 2028 prediction and (b) the 2016 based 2028 prediction.

The information in these figures is tabulated in Table 7-4 and Table 7-6. The glidepath plots show that the yearly average dv values at the IMPROVE monitors in the LADCO region are decreasing from year to year. One notable trend in these plots is the reduction in the base year visibility (green dot) in the 2016 base year relative to 2011. The 2016 base year visibility conditions are all well below the glidepath. Predicted 2028 visibility conditions based on the 2016 modeling platform shows that the visibility in the

Class I areas in Minnesota and Michigan is about 1.4 dv below the unadjusted glidepath line (i.e., URP). Accounting for the adjustment due to the international contribution, LADCO estimated 2028 visibility on the 20% most impaired days to be about 2.6 dv below the URP line. Table 7-5 and Table 7-7 show the baseline and predicted visibility on the 20% clearest days for the 2011 and 2016-based LADCO modeling.

Table 7-4. Comparison of observed and projected visibility on the 20% most impaired days at Class I areas within LADCO region (2011 base year)

IMPROVE Site ID	Visibility on 20% Most Impaired Days for the 2011 base year (dv)					Impact of Glidepath Adjustment (2028) (B-A)
	Observed Baseline (2000-2004)	Observed Base Years (2009-2013)	Projected Year (2028) (A)	Unadjusted Glidepath Value (2028) (B)	Natural Conditions (2064)	
BOWA1	18.43	16.42	14.43	14.69	9.09	-0.26
VOYA2	17.88	17.12	15.08	14.48	9.37	0.60
ISLE1	19.63	17.63	15.48	15.85	10.17	-0.37
SENE1	23.58	19.92	17.34	18.59	11.11	-1.25

Table 7-5. Comparison of observed and projected visibility on the 20% clearest days at Class I areas within LADCO region (2011 base year)

IMPROVE Site ID	Visibility on 20% Clearest Days for the 2011 base year (dv)			
	Observed Baseline (2000-2004)	Observed Base Years (2009-2013)	Projected Year (2028)	Natural Conditions (2064)
BOWA1	6.50	4.83	4.79	3.48
VOYA2	7.15	5.68	5.60	4.27
ISLE1	6.77	5.40	5.29	3.72
SENE1	7.14	5.50	5.35	3.74

Table 7-6. Comparison of observed and projected visibility on the 20% most impaired days at Class I areas within LADCO region (2016 base year)

IMPROVE Site ID	Visibility on 20% Most Impaired Days for the 2016 base year (dv)					Impact of Glidepath Adjustment (2028) (B-A)
	Observed Baseline (2000-2004)	Observed Base Years (2014-2018)	Projected Year (2028) (A)	Unadjusted Glidepath Value (2028) (B)	Natural Conditions (2064)	
BOWA1	18.43	13.96	13.17	14.69	9.09	-1.52
VOYA2	17.88	14.18	13.36	14.48	9.37	-1.12
ISLE1	19.63	15.54	14.83	15.85	10.17	-1.02
SENE1	23.58	17.57	16.67	18.59	11.11	-1.92

Table 7-7. Comparison of observed and projected visibility on the 20% clearest days at Class I areas within LADCO region (2016 base year)

IMPROVE Site ID	Visibility on 20% Clearest Days for the 2016 base year (dv)			
	Observed Baseline (2000-2004)	Observed Base Years (2014-2018)	Projected Year (2028)	Natural Conditions (2064)
BOWA1	6.50	4.48	4.41	3.48
VOYA2	7.15	5.31	5.25	4.27
ISLE1	6.77	5.30	5.23	3.72
SENE1	7.14	5.27	5.17	3.74

8 PSAT Source Apportionment Results

LADCO conducted source apportionment modeling with CAMx to quantify source-receptor relationships for PM and haze in 2028. The PSAT results show the extent to which emission from different source regions impair visibility in downwind Class I areas. In particular, the techniques used by LADCO to process the PSAT results provide information on the sources that contribute to haze on both the most impaired and clearest days at Class I areas.

In Section 3.5, we discussed the Particulate Matter Source Apportionment Technique (PSAT) configurations for the LADCO 2011-based and 2016-based CAMx simulation. The configuration descriptions included the PSAT emission source or sector tags for quantifying the contributions of upwind states, regions, and inventory sectors at downwind Class I areas. For the 2011-based 2028 PSAT run, LADCO tagged the 2028 emissions by individual LADCO states and neighboring regions (Table 8-1).

CAMx PSAT uses multiple tracer families to track the fate of both primary and secondary PM species, including sulfate (PSO4), particulate nitrate (PNO3), ammonium (PNH4), primary elemental carbon (PEC), primary organic aerosol (POA), secondary organic aerosol (SOA), and primary fine and coarse particles. In addition, PSAT can track contributions from the initial and boundary conditions to the model.

For the 2011-based simulation, LADCO used all of the PSAT tracer families to quantify the haze contributions at Class I areas. Based on those results, we refined the PSAT configuration for the 2016-based simulation to exclude the SOA tracer because it is both computationally expensive to simulate and anthropogenic sources are small contributors to SOA in the LADCO-region Class I areas.

Table 8-1. Source Tag Descriptions for CAMx PSAT runs for 2028_{2011} and 2028_{2016} simulations

Tag #	2028_{2011} Tag Description	2028_{2016} Tag Description
1	Biogenic	Other
2	IL	IL
3	WI	WI
4	IN	IN
5	OH	OH
6	MI	MI
7	MN	MN
8	IA	IA
9	MO	MO
10	AR	TX
11	LA	LA, OK, KS, NE, AR
12	TX	ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, DC
13	OK	WV, KY, VA, NC, SC, TN, GA, AL, MI, FL
14	KS	NM, AZ, CO, UT, WY, MT, ID, WA, OR, CA, NV, ND, SD
15	NE	Canada/Mexico
16	ND	Commercial Marine (C1/C2/C3)
17	SD	Fires
18	WV	Rockport EGU (IN)
19	KY	Gibson EGU (IN)
20	ME, NH, VT, MA, RI, CT, NY, NJ, PA, DE, MD, DC	All other IN EGUs
21	VA, NC, SC, TN, GA, AL, MI, FL	IN Cement Manufacturing
22	NM, AZ, CO, UT, WY, MT, ID, WA, OR, CA, NV	IN Iron and Steel
23	Canada/Mexico	IN Plastics and Resin
24	Fire	IN Aluminum Production
25	Offshore	All other IN point sources
26	Tribes	IC
27	IC	BC
28	BC	

8.1 PSAT Post-processing for Source Contribution Estimates

LADCO post-processed the CAMx PSAT tagged species model outputs to create SMAT-CE input files. This process involved operations on both the 2028 "bulk outputs" and the source sector specific (or "tagged") source apportionment outputs. The "bulk outputs" are the total PM species concentrations (e.g. sulfate, nitrate, etc.) that are identical to the total species concentrations from the non-source apportionment model run for 2028. However, the source apportionment tracking of PM species uses slightly different variables names for the tagged outputs. The SMAT-CE input variable names and matching CAMx species names for the 2028 bulk and 2028 tagged outputs are tabulated in Table 8-2.

Table 8-2. SMAT input variables and their matching species names for CAMx "bulk" and "PSAT" source output files

SMAT-CE species	SMAT-CE species name	"Combine file" output species	CAMx species in "bulk output"	CAMx species in "tag output"
SO4	Sulfate	PM25_SO4	PSO4	PS4
NO3	Nitrate	PM25_NO3	PNO3	PN3
NH4[29]	Ammonium	PM25_NH4	PNH4	PN4
EC	Elemental carbon	PM25_EC	PEC	PEC
OC[30]	Organic carbon	PM25_OM	POA+SOA1+SOA2+SOPA+SOA3+SOA4+SOPB	POA+PO1+PO2+PPPA+O3+PO4+PPB
CRUSTAL[31]	Crustal	PM25_CRUSTRAL	FPRM+FCRS	PFN+PFC
CM	Coarse PM	PMC_TOT	CCRS+CPRM	PCS+PCC
PM25[32]	Total $PM_{2.5}$	PM25_TOT	PSO4+PNO3+PNH4+PEC+NA+PCL+FPRM+FCRS+SOA1+SOA2+SOPA+SOA3+SOA4+SOPB+POA	PS4+PN3+PN4+POA+PEC+PO1+PO2+PO3+PO4+PPA+PPB+PFN+ PFC

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[29] Modeled ammonium concentrations are not used in the post-processing of the 2028 visibility values because the IMPROVE network does not measure ammonium. The IMPROVE equation assumes that sulfate and nitrate is fully neutralized by ammonia.

[30] LADCO's 2028_{2016} CAMx PSAT simulation did not include the organic carbon tracers

[31] LADCO's 2028_{2011} CAMx PSAT simulation was run without writing individual crustal fine particles, thus, the crustal amount was estimated by the sum of fine crustal particles (FCRS) and other fine particles (FPRM).

[32] Total PM2.5 concentration data is needed as a SMAT input variable, however, it is not used in the visibility calculations for regional haze. Visibility calculations only use the species specific model outputs.

The model attainment test software SMAT-CE processes daily total and speciated PM concentrations from the base and future year model (bulk and PSAT) runs from a 3 grid cell x 3 grid cell matrix surrounding each IMPROVE monitor location in the CAMx modeling domain. LADCO used the following steps to prepare the SMAT-CE input files and to run the software to calculate future year visibility at the Class I areas:

1. Combine hourly CAMx “bulk output” into hourly total and speciated PM concentrations (File A) using the species shown in Table 8-2.
2. Generate hourly pseudo total and speciated PM concentration outputs (File X’) for each source tag by subtracting the tagged source apportionment output (File X) from File A.
3. Generate daily average total (File $\bar{A}$) and speciated PM (File $\overline{X}'$) concentration files from File A and File X’, respectively
4. Extract the results in File $\bar{A}$ and File $\overline{X}'$ from 3x3 grid cells surrounding each IMPROVE monitor location in the modeling domain. LADCO then converted the extracted netCDF data to comma-delimited (CSV) files in the SMAT-CE input file format; the CSV outputs for File $\overline{A2}$ and File $\overline{X2'}$ were then ready for SMAT-CE.
5. Run SMAT-CE version 1.6 using the File $\overline{A2}$ and File $\overline{X2'}$ with observed IMPROVE data as inputs and with the settings in Table 7-1. In this SMAT-CE run, LADCO used the advanced option “Create forecast IMPROVE visibility file” to output the future year (2028) daily species extinction values at each IMPROVE monitor for each of the 20% best and the 20% most impaired days. With this configuration, SMAT-CE generated a “Forecast IMPROVE Daily Data.csv” file, which we used in the next step for calculating the visibility contributions for each PSAT tag.
6. We then used R to prepare the raw SMAT-CE for easy import to a spreadsheet for plotting and tabulation of the results.

LADCO created a comprehensive spreadsheet for each 2028 simulation that included dynamic plotting features with information on natural conditions, baseline visibility, base year and projected year visibility conditions at the Class I areas. We combined this information with the glidepath results described in the previous section.

LADCO's CAMx PSAT visibility forecasts are available in an electronic docket to this TSD in the following spreadsheets:

LADCO 2011-based 2028 Class I Area Visibility Forecasts (6.6 Mb XLSX file)

LADCO 2016-based 2028 Class I Area Visibility Forecasts (2.2 Mb XLSX file)

8.2 2011 Platform PSAT Results

This section presents the results from the LADCO CAMx 2011-based 2028 PSAT configuration that are included in the spreadsheets described in the previous section.

8.2.1 Source Region Tracer Results

The LADCO CAMx 2028_{2011} PSAT modeling estimated the state, biogenic, initial and boundary condition (ICBC), and international (Canada and Mexico) anthropogenic emissions source contributions to visibility in the U.S. Class I areas (Table 8-3 and Figure 8-1). CAMx estimated the average light extinction in 2028 across all of the LADCO region Class I areas to be about 50 Mm^{-1}. CAMx estimated that about 24% of the extinction is due to Rayleigh scattering, 20% from ICBC (mostly from boundary condition), 7-14% from the residing state, about 6% from biogenic emissions, and about 3% from the international anthropogenic emissions, mostly from Canada. The remainder of the extinction comes from other states. Figure 8-1 illustrates the results in Table 8-3 as a stacked bar plot. An aggregation of the PSAT source region tags to regional planning organization (RPO) area for the LADCO's Class I areas is shown in Figure 8-2. Natural sources such as Rayleigh, sea salt, biogenic and fire emissions are projected to contribute 28-36 % of the light extinction coefficients in the LADCO's Class I areas, while the LADCO and CenSARA RPOs are projected to contribute 23-24% and 8-13% of the extinction, respectively.

Table 8-3. 2028_{2011} tracer contributions to b_{ext} on the most impaired days at the LADCO Class I areas

Source region tags	Source contributions to 2028 visibility at IMPROVE Sites (Mm^{-1})					Percent source contributions to 2028 visibility at IMPROVE Sites (%)			
IMPROVE Sites	**ISLE1**	**SENE1**	**BOWA1**	**VOYA2**		**ISLE1**	**SENE1**	**BOWA1**	**VOYA2**
Total Bext	**50.5**	**60.7**	**45.3**	**47.7**					
Rayleigh	12.0	12.0	11.0	12.0		24%	20%	24%	25%
Sea salt (SS)	0.2	0.2	0.1	0.2		0%	0%	0%	1%
Biogenic	3.2	3.7	2.9	3.0		6%	6%	7%	6%
ICBC	10.0	11.1	8.9	8.9		20%	18%	20%	19%
Fire	1.5	1.1	1.6	2.5		3%	2%	3%	5%
Int'l anthropogenic	2.0	2.4	1.5	1.6		4%	4%	3%	3%
Tribal	0.0	0.0	0.0	0.0		0%	0%	0%	0%
Offshore	0.1	0.1	0.0	0.0		0%	0%	0%	0%
West	0.6	0.8	0.8	0.7		1%	1%	2%	1%
Northeast	0.4	1.2	0.2	0.2		1%	2%	0%	0%
Southeast	0.2	0.5	0.1	0.1		0%	1%	0%	0%
IL	2.3	3.4	0.8	1.0		5%	6%	2%	2%
WI	3.5	4.5	2.2	1.7		7%	7%	5%	4%
IN	1.2	2.9	0.5	0.6		2%	5%	1%	1%
OH	0.6	1.5	0.4	0.5		1%	3%	1%	1%
MN	2.4	1.7	6.2	6.5		5%	3%	14%	14%
MI	3.3	6.5	0.8	0.7		7%	11%	2%	2%
IA	1.3	1.3	1.8	1.7		3%	2%	4%	4%
MO	1.4	1.3	0.8	0.9		3%	2%	2%	2%
AR	0.3	0.4	0.2	0.3		1%	1%	1%	1%
LA	0.1	0.1	0.1	0.0		0%	0%	0%	0%
TX	1.3	0.5	1.2	1.0		3%	1%	3%	2%
OK	0.4	0.2	0.6	0.6		1%	0%	1%	1%
KS	0.3	0.4	0.5	0.5		1%	1%	1%	1%
NE	0.9	0.8	0.9	1.0		2%	1%	2%	2%
ND	0.7	0.7	0.8	0.9		1%	1%	2%	2%
SD	0.2	0.2	0.3	0.3		0%	0%	1%	1%
WV	0.1	0.3	0.1	0.1		0%	1%	0%	0%
KY	0.3	0.8	0.1	0.2		1%	1%	0%	0%
Aggregated by RPO									
Natural	4.7	4.9	4.5	5.5		9%	8%	10%	11%
LADCO	13.2	20.6	10.9	11.1		26%	34%	24%	23%
WRAP	1.5	0.8	1.9	1.9		2%	2%	5%	5%
CenSARA	6.0	5.0	6.0	6.0		12%	8%	13%	13%
VISTAS	0.6	1.7	0.3	0.4		1%	3%	1%	1%

Note: Natural (Sea Salt, Fire, Biogenic); LADCO (MN, MI, WI, IL, IN, OH); WRAP (ND, SD, West); CenSARA (IA, MO, AR, LA, TX, OK, KS, Northeast); VISTAS (WY, KY, Southeast)

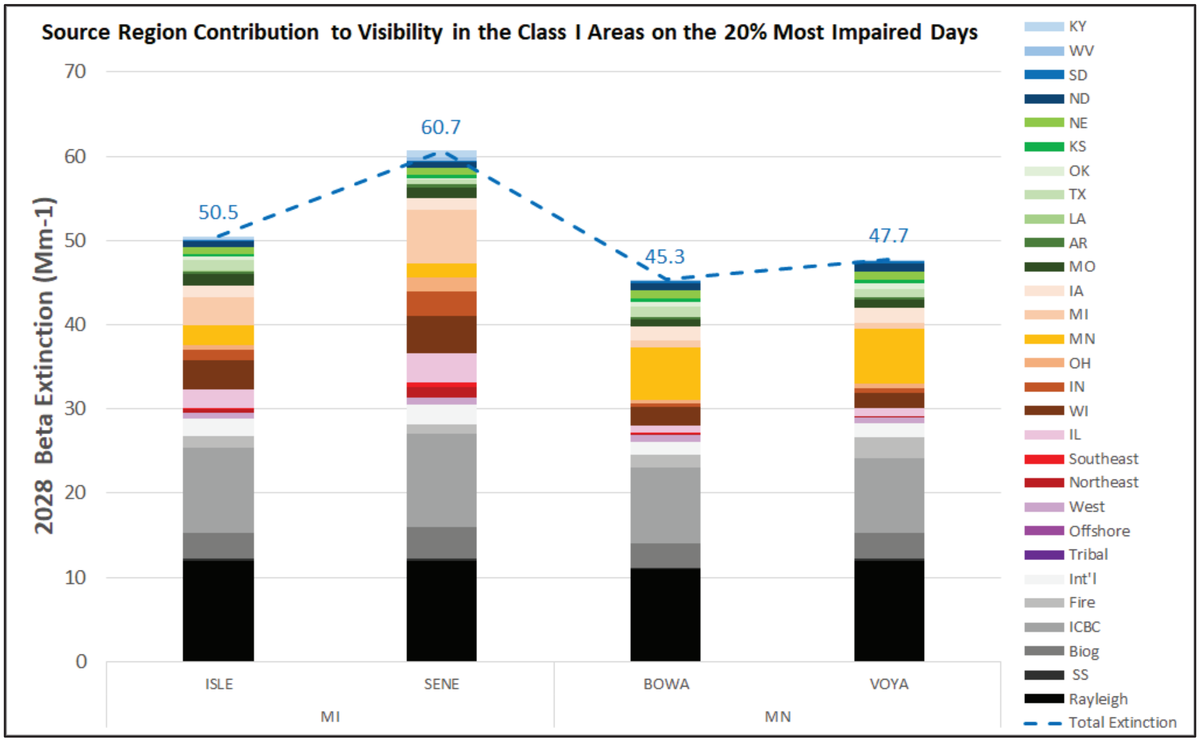

Figure 8-1. State and regional 2028_{2011} tracer contributions to b_{ext} on the 20% most impaired days at the LADCO region class I areas

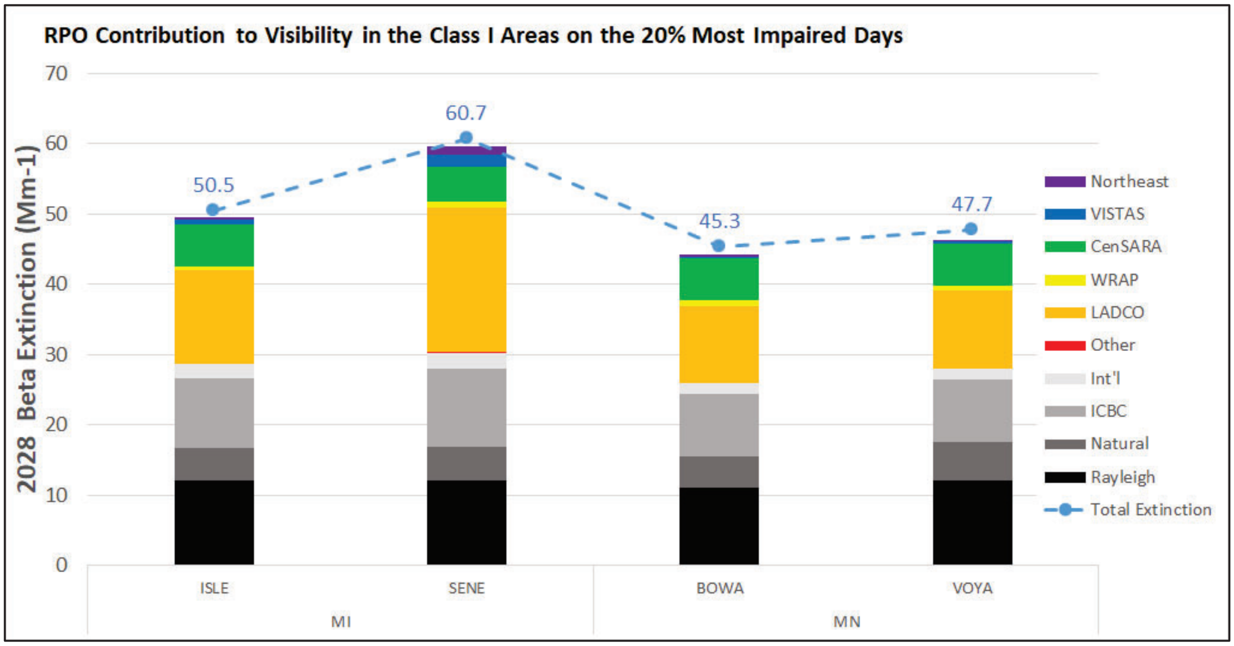

Figure 8-2. RPO 2028_{2011} tracer contributions to b_{ext} on the 20% most impaired days at the LADCO region class I areas

8.2.2 Speciated PM Tracer Results

In addition to quantifying the total contribution from each tracer at receptor areas in the model, the PSAT results can be used to quantify how much each PM species contributes to visibility conditions at the receptors. Figure 8-3 through Figure 8-14 are examples of PSAT tracer footprint plots. These plots show the maximum gridded concentrations of particulate nitrate and sulfate tracers on the 20% most impaired days at different Class I areas in the LADCO. The purpose of the footprint plot is to give a qualitative picture of the spatial signature of sources that contribute to haze impairment at Class I areas. In other words, these plots shows the maximum area of impact of each source region on sulfate and nitrate concentrations during the 20% most impaired days at the different Class I areas. Although PM concentrations do not linearly correspond with visibility impairment, they are a good qualitative surrogate for examining the linkages between emissions sources and downwind visibility impairment.

Figure 8-5 and Figure 8-6 show the maximum nitrate and sulfate tracer forecast (2028_{2011}) concentrations from sources in Minnesota during the 20% most impaired days at the Boundary Waters Canoe Area (BOWA). LADCO estimated that on the 20% most impaired days at BOWA[33], about 2-4 ug/m^3 nitrate and about 1-2 ug/m^3 sulfate concentrations originated from emissions sources in Minnesota. Figure 8-7 and Figure 8-8 show that the LADCO CAMx simulation estimated that a similar amount of nitrate and sulfate originate from the model boundary conditions.

The U.S. EPA's updated 2028 regional haze modeling study (U.S. EPA. 2019b) discussed that the impacts from both nitrate and sulfate are relatively large in the northern states. Based on the U.S. EPA's discussion on Canadian wintertime nitrate and sulfate impacts in the northern states, the modeled concentrations at the Class I areas in the LADCO region could have a minimum of 30-50% contributions from Canada anthropogenic emissions. Figure 8-3 and Figure 8-4 show that the LADCO 2028_{2011} predicted fairly small tracer impacts (<1 μg/m^3) at BOWA from Canadian sources of nitrate and sulfate.

Figure 8-5 through Figure 8-14 show home state maximum particulate nitrate and sulfate tracer concentrations on the 20% most impaired days at Voyageurs National Park, Isle Royale National Park

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[33] The tracer footprint plots use the 20% most impaired days from the base year from which the modeling is projected (i.e., 2011 or 2016)

and Seney National Wildlife area, respectively. These figures show sulfate and nitrate contributions on the order of 1-1.5 μg/m^3 from emissions in the home state to each monitor.

LADCO generated footprint plots for all of the Class I areas in and around the LADCO region from our 2011-based 2028 CAMx simulation. The plots are available as an electronic docket to this TSD and can be found on the LADCO website through the following link:

LADCO 2011-based 2028 PM tracer footprint plots

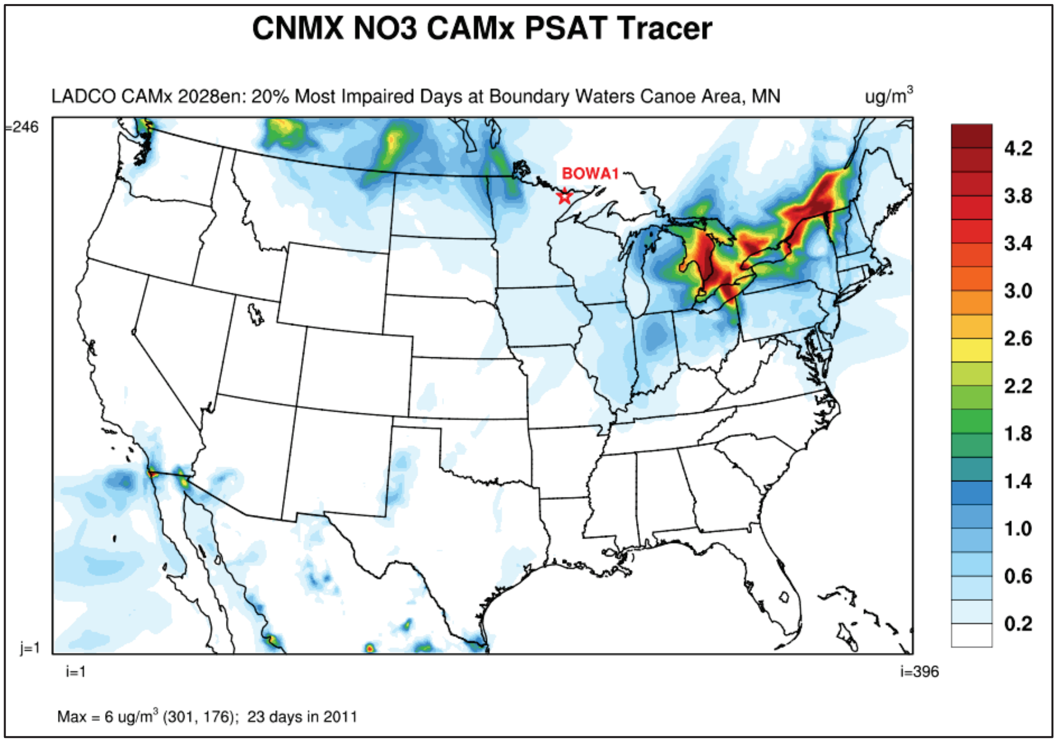

Figure 8-3. Maximum 2028$_{2011}$ nitrate tracer concentration from Canada and Mexico sources on the 20% most impaired days at Boundary Waters, MN

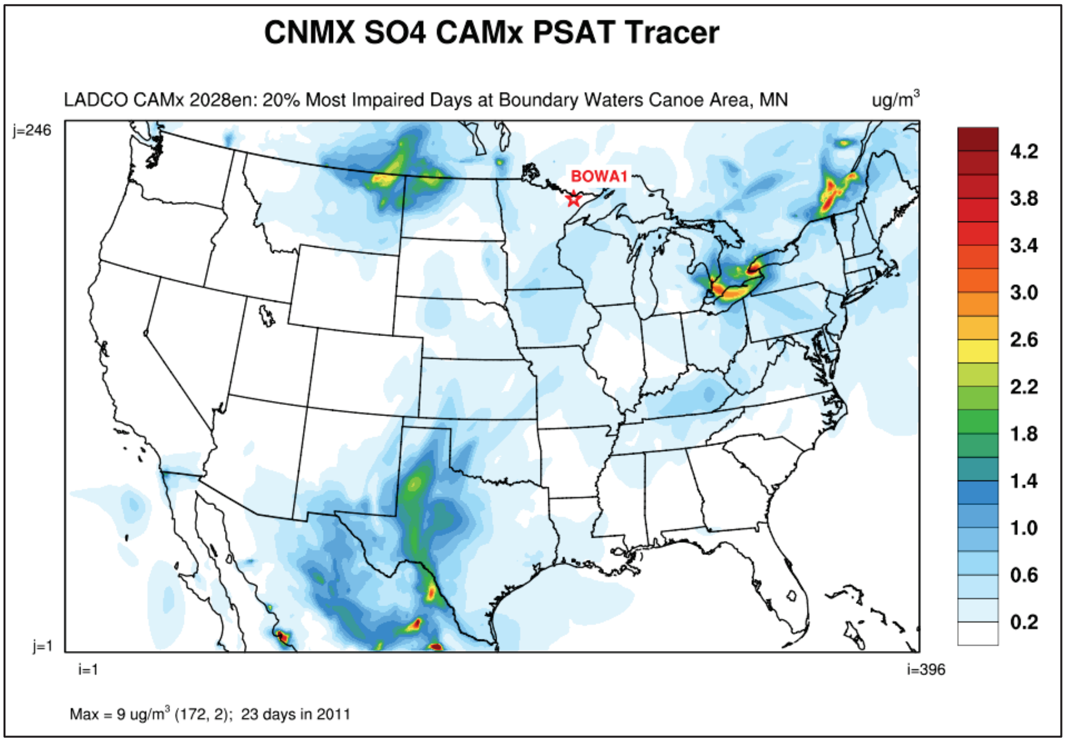

Figure 8-4. Maximum 2028$_{2011}$ sulfate tracer concentration from Canada and Mexico sources on the 20% most impaired days at Boundary Waters, MN

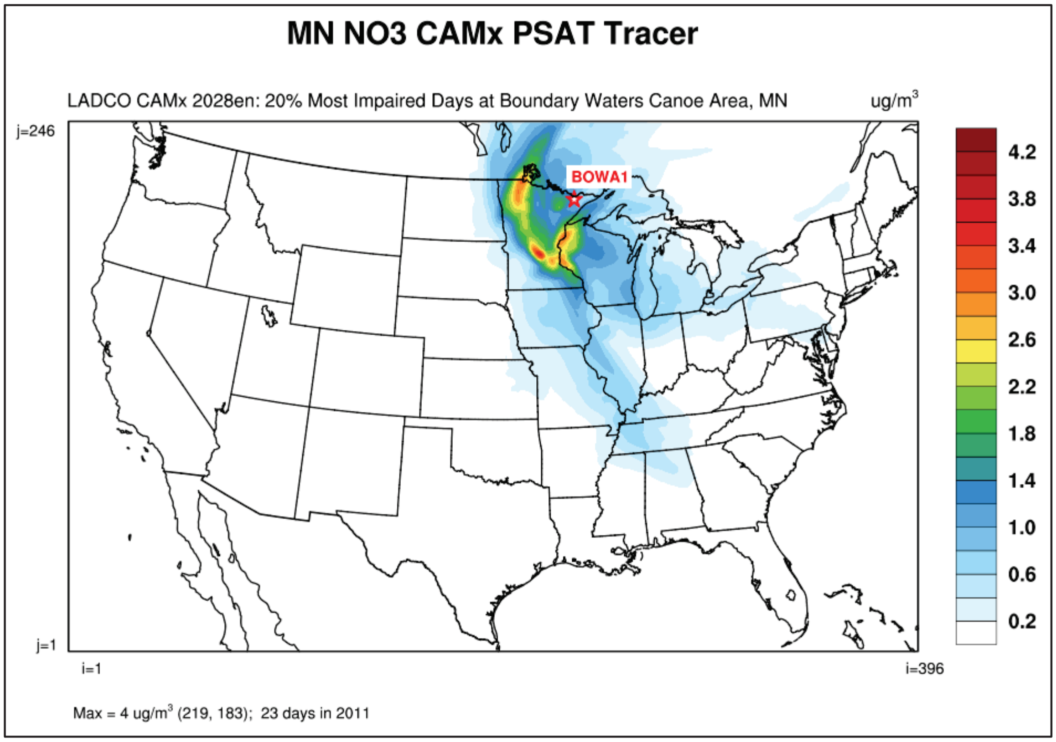

Figure 8-5. Maximum 2028_{2011} nitrate tracer concentration from MN sources on the 20% most impaired days at Boundary Waters, MN

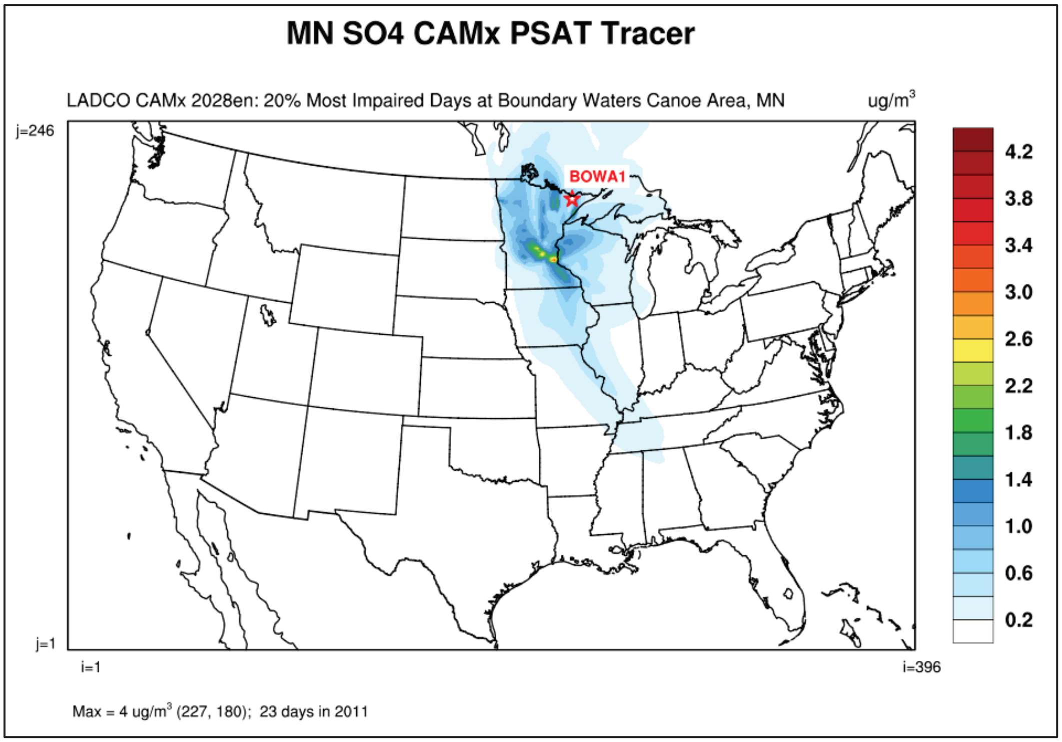

Figure 8-6. Maximum 2028_{2011} sulfate tracer concentration from MN sources on the 20% most impaired days at Boundary Waters, MN

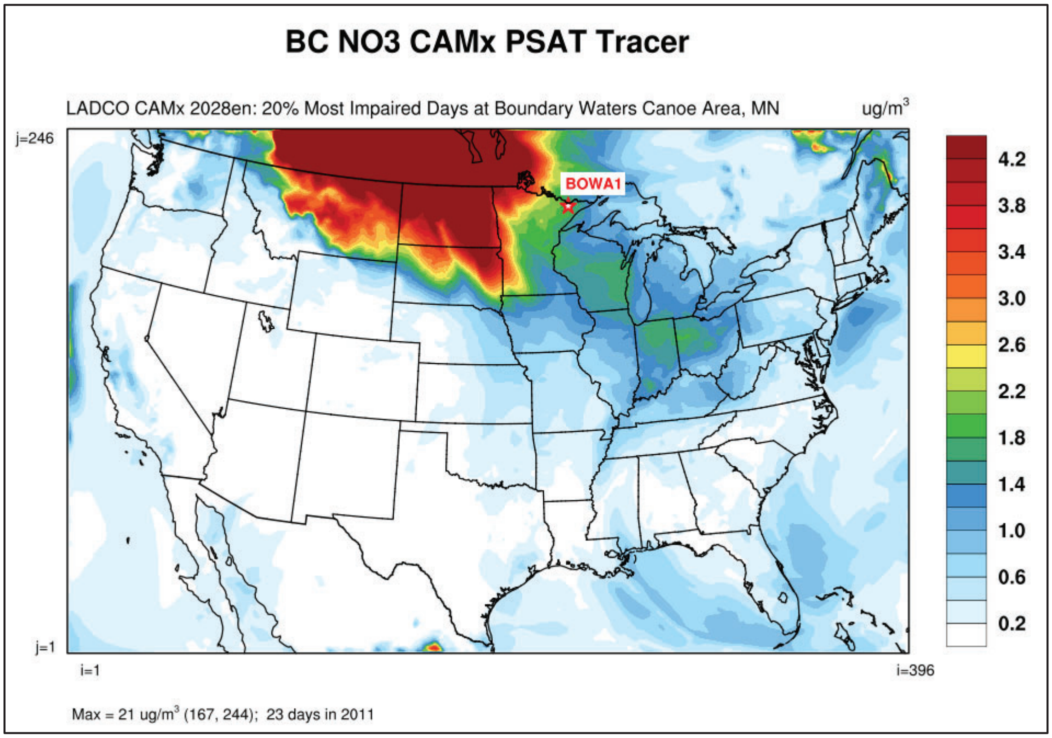

Figure 8-7. Maximum 2028$_{2011}$ nitrate tracer concentration from boundary condition on the 20% most impaired days at Boundary Waters, MN

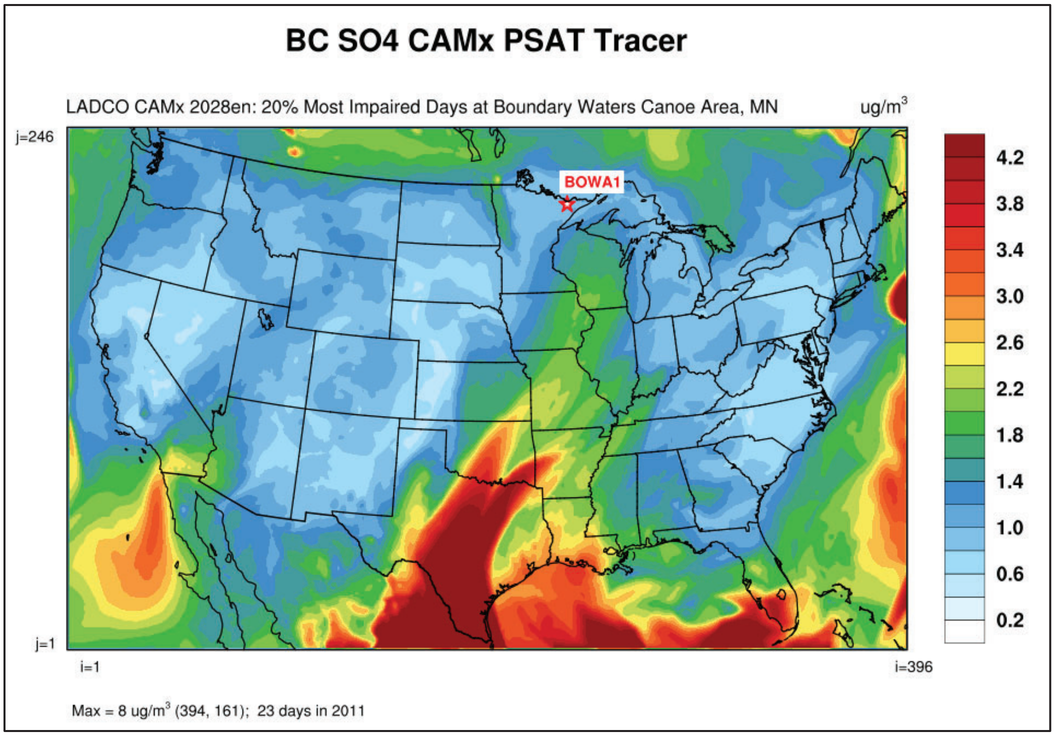

Figure 8-8. Maximum 2028$_{2011}$ sulfate tracer concentration from boundary condition on the 20% most impaired days at Boundary Waters, MN

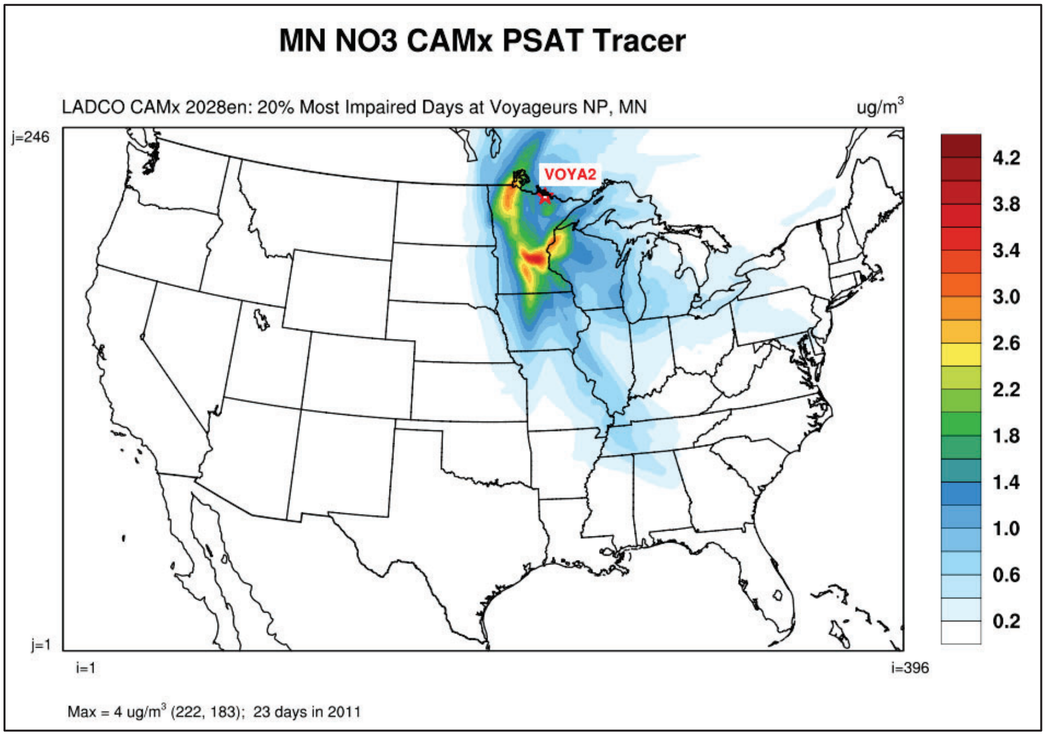

Figure 8-9. Maximum 2028$_{2011}$ nitrate tracer concentration from MN sources on the 20% most impaired days at Voyageurs NP, MN

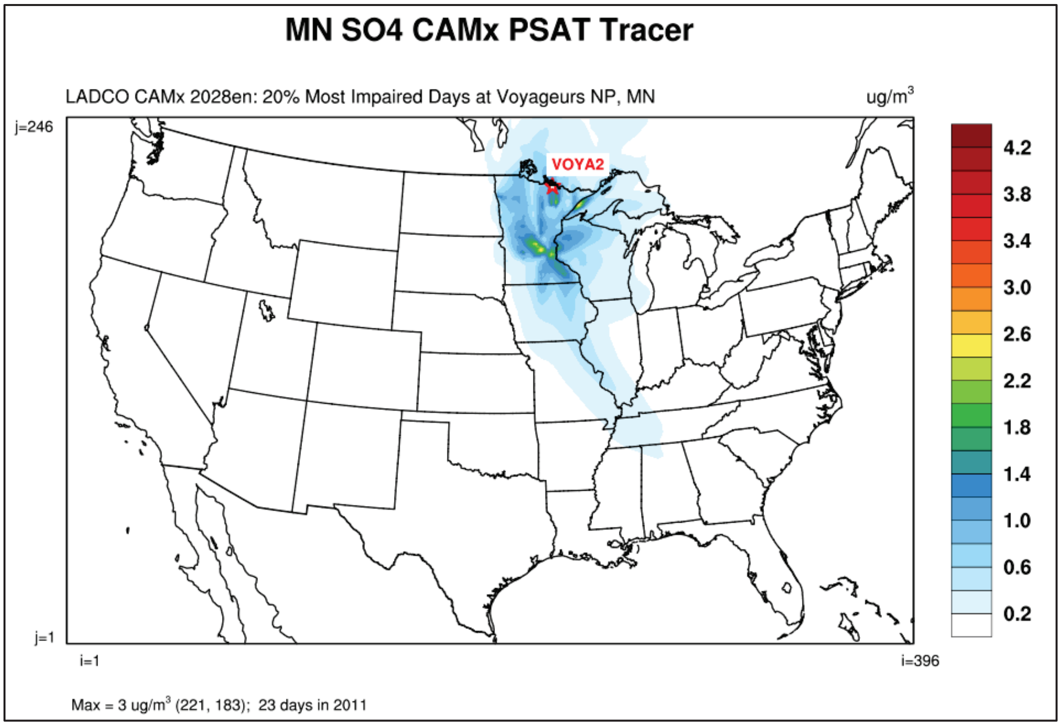

Figure 8-10. Maximum 2028$_{2011}$ sulfate tracer concentration from MN sources on the 20% most impaired days at Voyageurs NP, MN

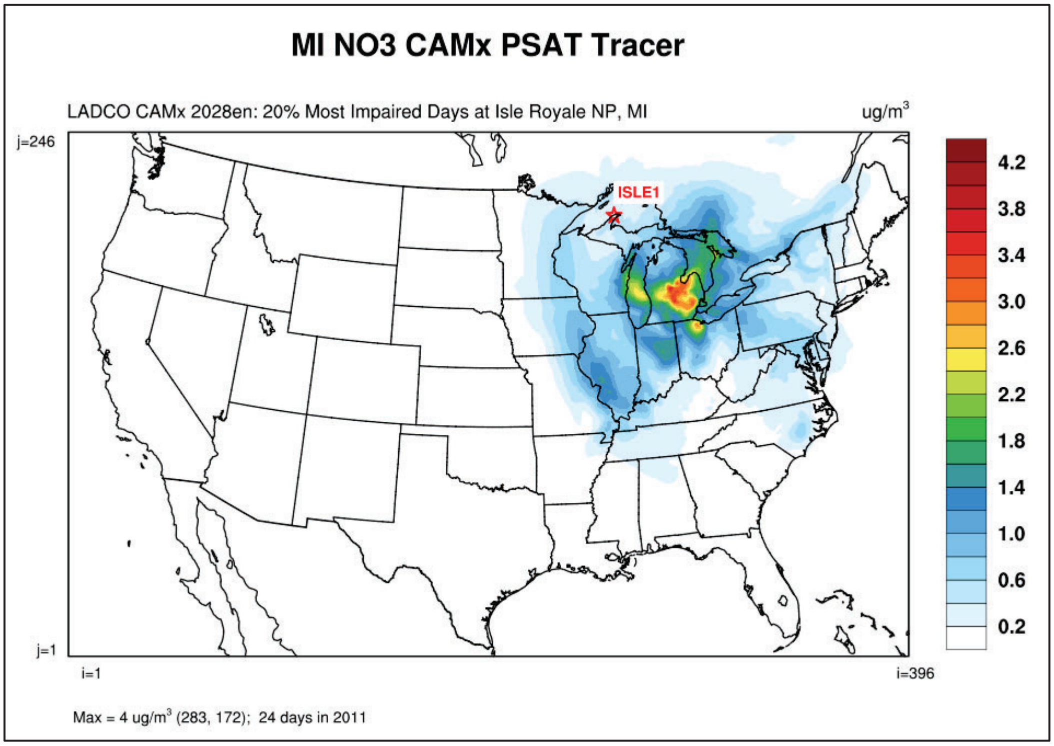

Figure 8-11. Maximum 2028_{2011} nitrate tracer concentration from MI sources on the 20% most impaired days at Isle Royale NP, MI

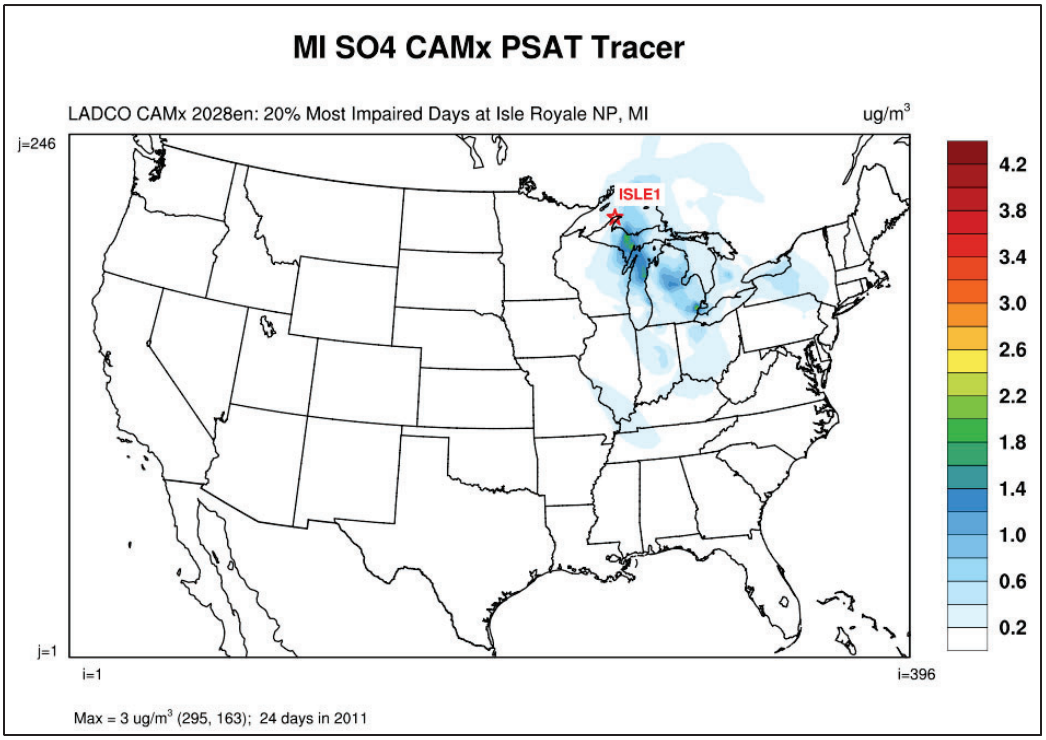

Figure 8-12. Maximum 2028_{2011} sulfate tracer concentration from MI sources on the 20% most impaired days at Isle Royale NP, MI

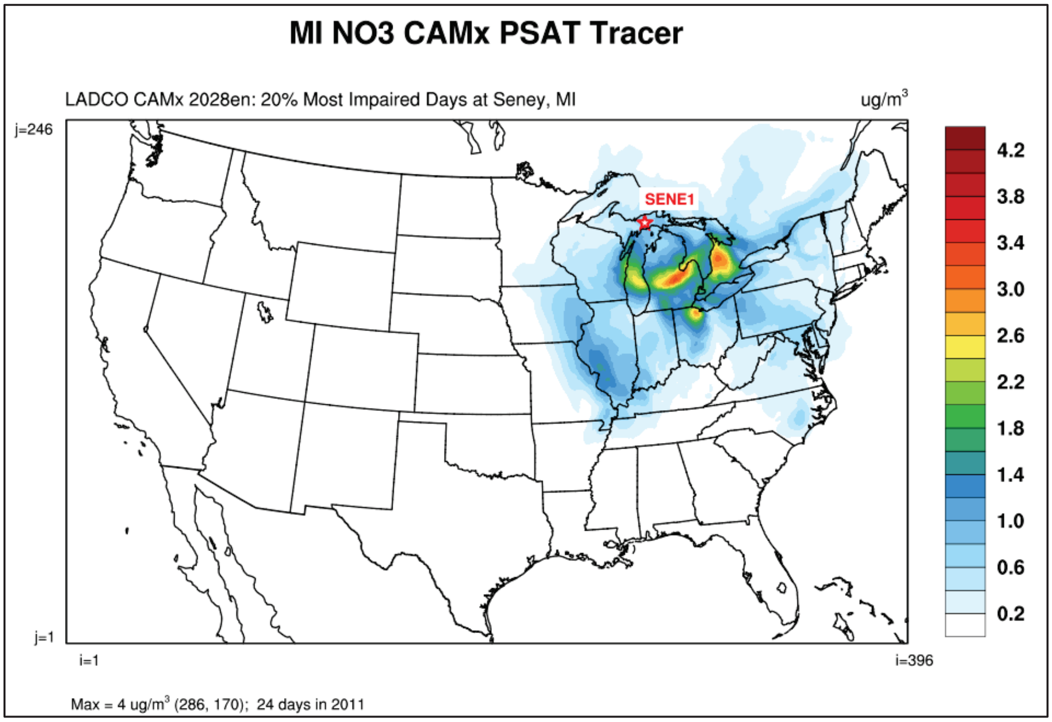

Figure 8-13. Maximum 2028_{2011} nitrate tracer concentration from MI sources on the 20% most impaired days at Seney, MI

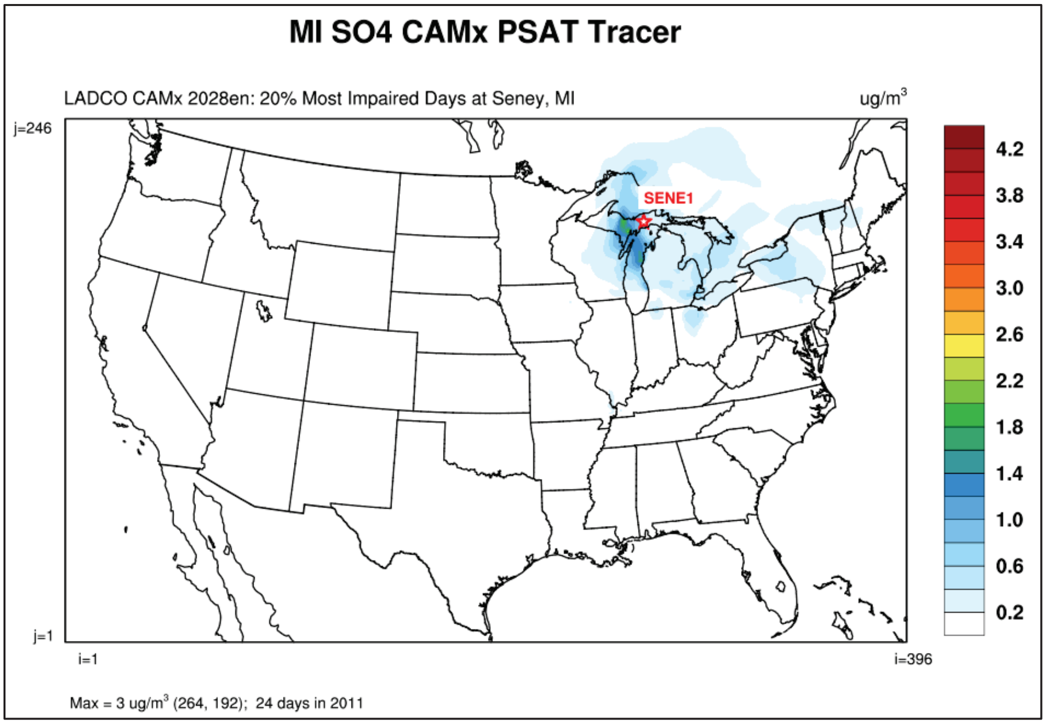

Figure 8-14. Maximum 2028_{2011} sulfate tracer concentration from MN sources on the 20% most impaired days at Seney, MI

The CAMx PSAT results can also be used to quantify the light extinction at the Class I areas by $PM_{2.5}$ composition. LADCO post-processed our CAMx 2028_{2011} modeling results to estimate individual $PM_{2.5}$ species contributions to total light extinction on the 20% most impaired days at the Class I areas. The speciated tracer result for the LADCO region Class I areas are shown in Table 8-4 and in Figure 8-15.

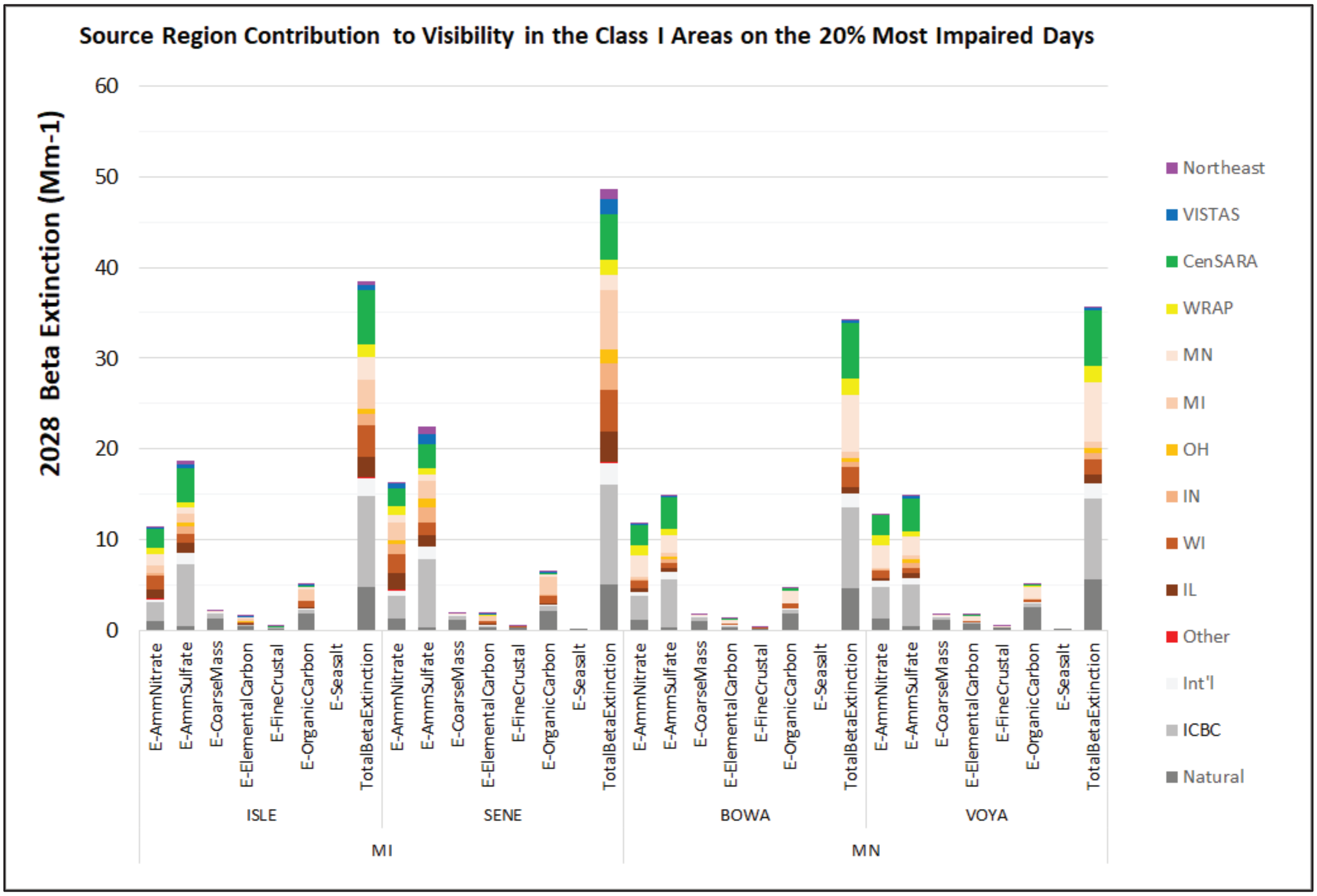

Figure 8-15. PM species tracer contributions to b_{ext} on the 20% most impaired days at the LADCO Class I areas (CAMx 2028_{2011})

Table 8-4. Speciated 2028_{2011} tracer contributions on the 20% most impaired days at the LADCO-region Class I areas

Area	Tracer	Natural	ICBC	Int'l	Other	IL	WI	IN	OH	MI	MN	WRAP	CenSARA	SE	NE	Total
ISLE	Total beta Ext	4.8	10.0	2.0	0.1	2.3	3.5	1.2	0.6	3.3	2.4	1.5	6.0	0.6	0.4	38.5
	NO_3	1.1	2.0	0.4	0.1	1.1	1.5	0.3	0.1	0.7	1.3	0.8	2.0	0.1	0.0	11.3
	SO_4	0.4	6.9	1.3	0.0	1.0	1.0	0.8	0.5	1.0	0.7	0.6	3.7	0.5	0.4	18.7
	CM	1.4	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.2
	EC	0.5	0.1	0.1	0.0	0.1	0.2	0.0	0.0	0.3	0.1	0.0	0.1	0.0	0.0	1.6
	FCRS	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	OC	1.9	0.4	0.1	0.0	0.1	0.7	0.0	0.0	1.2	0.3	0.0	0.1	0.0	0.0	5.1
	SS	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
SENE	Total beta Ext	5.1	11.1	2.4	0.1	3.4	4.5	2.9	1.5	6.5	1.7	1.7	5.0	1.7	1.2	48.7
	NO_3	1.3	2.5	0.6	0.1	1.8	2.1	1.1	0.4	2.0	0.8	0.9	1.9	0.5	0.2	16.4
	SO_4	0.4	7.5	1.3	0.0	1.3	1.3	1.7	1.0	2.0	0.6	0.7	2.8	1.0	0.9	22.5
	CM	1.3	0.3	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.9
	EC	0.4	0.1	0.1	0.0	0.1	0.2	0.1	0.0	0.5	0.1	0.0	0.1	0.0	0.0	1.9
	FCRS	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5
	OC	2.2	0.5	0.2	0.0	0.1	0.8	0.1	0.1	1.9	0.2	0.1	0.2	0.1	0.1	6.5
	SS	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
BOWA	Total beta Ext	4.6	8.9	1.5	0.0	0.8	2.2	0.5	0.4	0.8	6.2	1.8	6.0	0.3	0.2	34.3
	NO_3	1.2	2.6	0.4	0.0	0.4	0.9	0.1	0.0	0.3	2.3	1.1	2.3	0.0	0.0	11.7
	SO_4	0.4	5.3	0.8	0.0	0.3	0.7	0.4	0.3	0.4	1.9	0.6	3.5	0.2	0.2	15.0
	CM	1.1	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.7
	EC	0.4	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.0	1.4
	FCRS	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.4
	OC	1.9	0.4	0.1	0.0	0.0	0.5	0.0	0.0	0.1	1.3	0.1	0.2	0.0	0.0	4.6
	SS	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
VOYA	Total beta Ext	5.7	8.9	1.6	0.0	1.0	1.7	0.6	0.5	0.7	6.5	1.8	6.0	0.4	0.2	35.7
	NO_3	1.3	3.5	0.6	0.0	0.4	0.8	0.1	0.0	0.2	2.4	1.2	2.2	0.0	0.0	12.8
	SO_4	0.5	4.6	0.7	0.0	0.5	0.5	0.5	0.4	0.4	2.1	0.6	3.6	0.3	0.2	15.0
	CM	1.2	0.3	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	1.8
	EC	0.8	0.1	0.1	0.0	0.0	0.1	0.0	0.0	0.0	0.5	0.0	0.1	0.0	0.0	1.7
	FCRS	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.6
	OC	2.7	0.3	0.1	0.0	0.0	0.3	0.0	0.0	0.1	1.3	0.1	0.2	0.0	0.0	5.1
	SS	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2

8.3 2016 Platform Results

This section presents the results from the LADCO CAMx 2016-based 2028 PSAT configuration that are included in the spreadsheets described in the previous section.

8.3.1 Source Region Tracer Results

The LADCO CAMx 2028_{2016} PSAT modeling estimated the state, Indiana point source, biogenic, initial and boundary condition (ICBC), and international (Canada and Mexico) anthropogenic emissions source contributions to visibility in the U.S. Class I areas (Table 8-5 and Figure 8-16). LADCO redefined the tracers for the 2028_{2016} simulation to support analyses requested by our member states, and to eliminate tracers that had a small (<1 Mm^{-1}) estimated impact on visibility in the 2028_{2011} simulation. In particular, the 2016-based simulation excluded tracers for some of the states surrounding the LADCO region, and included tracers for specific point sources and sectors in Indiana. The 2028_{2016} simulation results include an estimated OC contribution to beta light extinction because the 2028_{2016} did not include the CAMx organic aerosol tracer. LADCO calculated the species “OC estimated” as the difference of total beta extinction from the core CAMx model and the sum of all of the PSAT tracers (including Rayleigh).

CAMx estimated the average light extinction in 2028 across all of the LADCO region Class I areas to be about 47 Mm^{-1}. CAMx estimated that about 25.5% of the extinction is due to Rayleigh scattering, 22% from ICBC (almost entirely from the model boundary conditions), 3.5-10.5% from the residing state, and about 4.6% from the international anthropogenic emissions, mostly from Canada. The average biogenic contribution of 3% does not include the contribution from organic carbon aerosols as these species were not explicitly tracked in this simulation. The relative contribution from biogenics to light extinction at the LADCO Class I areas is at least double the 2028_{2016} estimate as biogenic emissions are the primary source of organic aerosols. The majority of the remainder of the light extinction contribution comes from other states.

Figure 8-16 illustrates the results in Table 8-5 as a stacked bar plot. An aggregation of the PSAT source region tags to regional planning organization (RPO) area for the LADCO Class I areas is shown in Figure 8-17.

Table 8-5. 2028_{2016} tracer contributions to b_{ext} on the most impaired days at the LADCO Class I areas

Source region tags	Source contributions to 2028 visibility at IMPROVE Sites (Mm^{-1})					Percent source contributions to 2028 visibility at IMPROVE Sites (%)			
IMPROVE Sites	**ISLE1**	**SENE1**	**BOWA1**	**VOYA2**		**ISLE1**	**SENE1**	**BOWA1**	**VOYA2**
Total Bext	**48.6**	**57.4**	**40.5**	**41.0**					
Rayleigh	12.0	12.0	11.0	12.0		24.7%	20.9%	27.2%	29.2%
Sea salt (SS)	0.3	0.2	0.2	0.3		0.5%	0.4%	0.5%	0.7%
Biogenic	1.4	1.8	1.2	1.3		2.9%	3.1%	2.9%	3.1%
ICBC	10.5	9.9	9.7	10.0		21.5%	17.2%	23.9%	24.4%
OC Estimated	4.2	5.1	3.6	3.5		8.6%	8.9%	8.9%	8.6%
Fire	0.9	0.9	0.9	0.4		1.9%	1.5%	2.1%	0.9%
Int'l anthropogenic	1.7	2.7	1.7	2.3		3.5%	4.8%	4.3%	5.7%
Offshore	0.2	0.2	0.1	0.1		0.5%	0.4%	0.1%	0.1%
West	1.6	1.9	1.9	1.8		3.4%	3.2%	4.6%	4.4%
Northeast	0.1	0.3	0.1	0.1		0.2%	0.5%	0.2%	0.2%
Southeast	0.4	1.3	0.2	0.2		0.8%	2.2%	0.6%	0.5%
CenSARA Other	2.4	1.8	1.9	1.5		4.9%	3.2%	4.6%	3.6%
IA	1.4	1.5	0.9	0.9		2.9%	2.6%	2.3%	2.1%
MO	1.4	1.7	0.8	0.6		3.0%	3.0%	2.1%	1.6%
TX	0.6	0.3	0.3	0.3		1.1%	0.6%	0.8%	0.7%
IL	2.0	3.6	0.6	0.4		4.0%	6.3%	1.6%	1.0%
WI	2.3	3.5	0.9	0.4		4.8%	6.2%	2.3%	1.0%
MI	1.7	3.4	0.1	0.2		3.5%	6.0%	0.3%	0.5%
OH	0.2	1.2	0.2	0.2		0.4%	2.0%	0.4%	0.5%
MN	2.4	1.7	3.9	4.4		5.0%	3.0%	9.6%	10.6%
IN (Total)	0.9	2.3	0.2	0.2		1.9%	4.0%	0.6%	0.5%
IN (Nonpoint)	0.3	0.7	0.1	0.1		0.6%	1.2%	0.2%	0.2%
IN (Rockport EGU)	0.0	0.1	0.0	0.0		0.1%	0.1%	0.0%	0.0%
IN (Gibson EGU)	0.0	0.1	0.0	0.0		0.1%	0.1%	0.0%	0.0%
IN (other EGU)	0.2	0.5	0.0	0.0		0.4%	0.8%	0.1%	0.1%
IN (Cement)	0.0	0.0	0.0	0.0		0.0%	0.1%	0.0%	0.0%
IN (Iron & Steel)	0.3	0.7	0.0	0.1		0.6%	1.2%	0.1%	0.1%
IN (Plastics & Resins)	0.0	0.0	0.0	0.0		0.0%	0.1%	0.0%	0.0%
IN (Aluminum)	0.0	0.0	0.0	0.0		0.0%	0.0%	0.0%	0.0%
IN (Other Point)	0.1	0.2	0.0	0.0		0.2%	0.4%	0.1%	0.0%
Other Anthro	0.0	0.0	0.0	0.0		0.0%	0.0%	0.0%	0.0%
Aggregated by RPO									
Natural	2.3	2.7	2.0	1.6		5%	5%	5%	4%
LADCO	9.6	15.7	6.0	5.8		20%	27%	15%	14%
WRAP	1.6	1.9	1.9	1.8		3%	3%	5%	4%
CenSARA	5.8	5.4	4.0	3.3		12%	9%	10%	8%
VISTAS	0.4	1.3	0.2	0.2		1%	2%	1%	0%

Note: Natural (Sea Salt, Fire, Biogenic); LADCO (MN, MI, WI, IL, IN, OH); WRAP (ND, SD, West); CenSARA (IA, MO, AR, LA, TX, OK, KS, Northeast); VISTAS (WY, KY, Southeast)

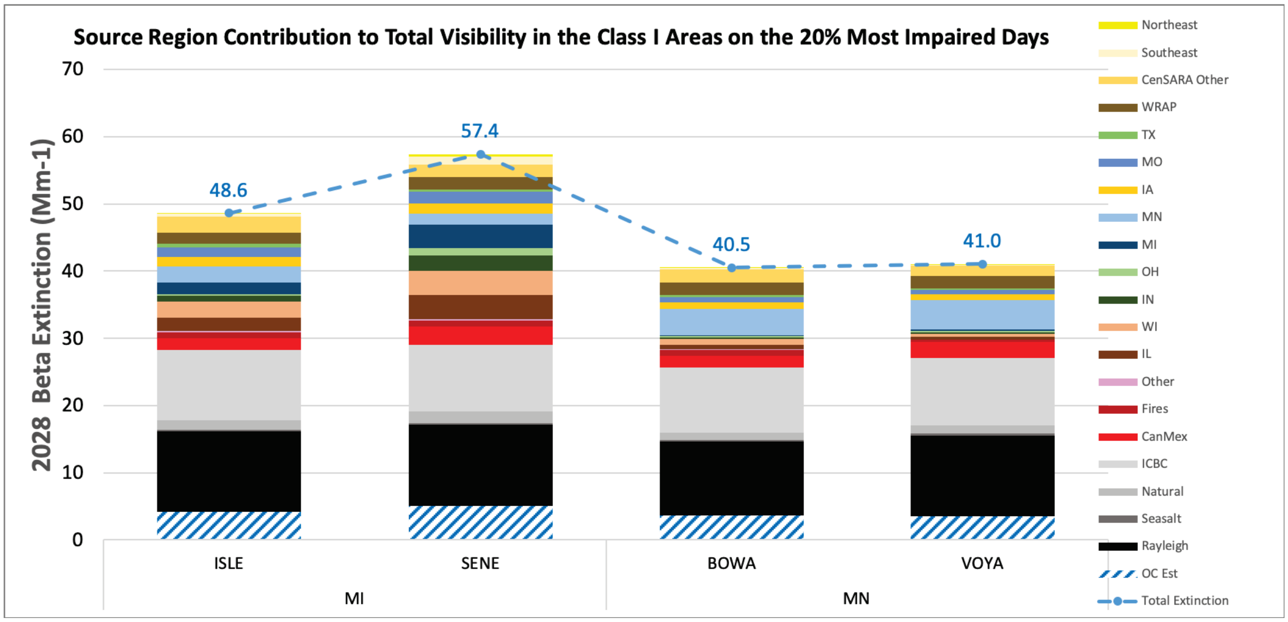

Figure 8-16. State and regional 2028_{2016} tracer contributions to b_{ext} on the 20% most impaired days at the LADCO region class I areas

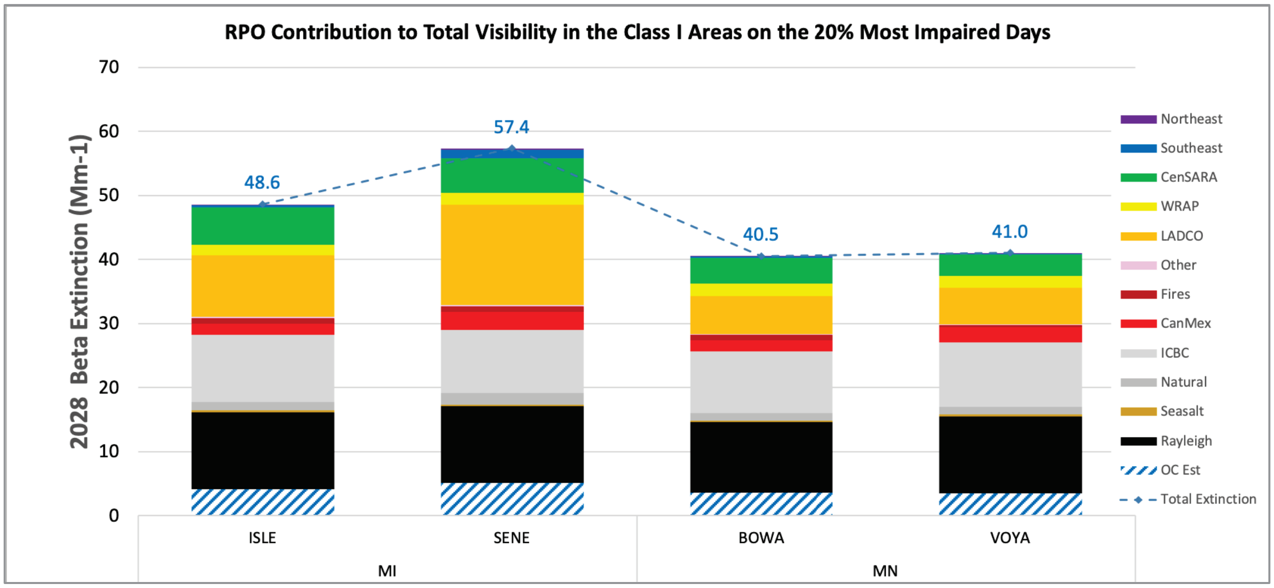

Figure 8-17. RPO 2028_{2016} tracer contributions to b_{ext} on the 20% most impaired days at the LADCO region class I areas

8.3.2 Speciated PM Tracer Results

The PSAT results can also be used to quantify how much each PM species contributes to visibility conditions at the receptors. Figure 8-18 through Figure 8-21 are examples of PSAT tracer footprint plots from LADCO CAMx 2028_{2016}. These plots show the maximum gridded concentrations of particulate nitrate and sulfate tracers on the 20% most impaired days at different Class I areas in the LADCO. These plots shows the maximum area of impact of each source region on sulfate and nitrate concentrations during the 20% most impaired days at the different Class I areas. Although PM concentrations do not linearly correspond with visibility impairment, they are a good qualitative surrogate for examining the linkages between emissions sources and downwind visibility impairment.

Figure 8-20 and Figure 8-21 show the maximum nitrate and sulfate tracer forecast (2028_{2016}) concentrations from sources in Minnesota during the 20% most impaired days at the Boundary Waters Canoe Area (BOWA). LADCO estimated that on the 20% most impaired days at BOWA[34] in 2028, about 0.5-1.5 ug/m^3 nitrate and about 0.5-1.0 ug/m^3 sulfate concentrations will be attributed from emissions sources in Minnesota. Figure 8-18 and Figure 8-19 show that the LADCO 2028_{2016} CAMx simulation estimated that a similar amount of nitrate and sulfate at BOWA originate from Canadian sources as Minnesota sources.

As with the 2011-based 2028 modeling, LADCO generated footprint plots for all of the Class I areas in and around the LADCO region from our 2016-based 2028 CAMx simulation. The plots are available as an electronic docket to this TSD and can be found on the LADCO website through the following link:

LADCO 2016-based 2028 PM tracer footprint plots

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[34] The tracer footprint plots use the 20% most impaired days from the base year from which the modeling is projected (i.e., 2011 or 2016)

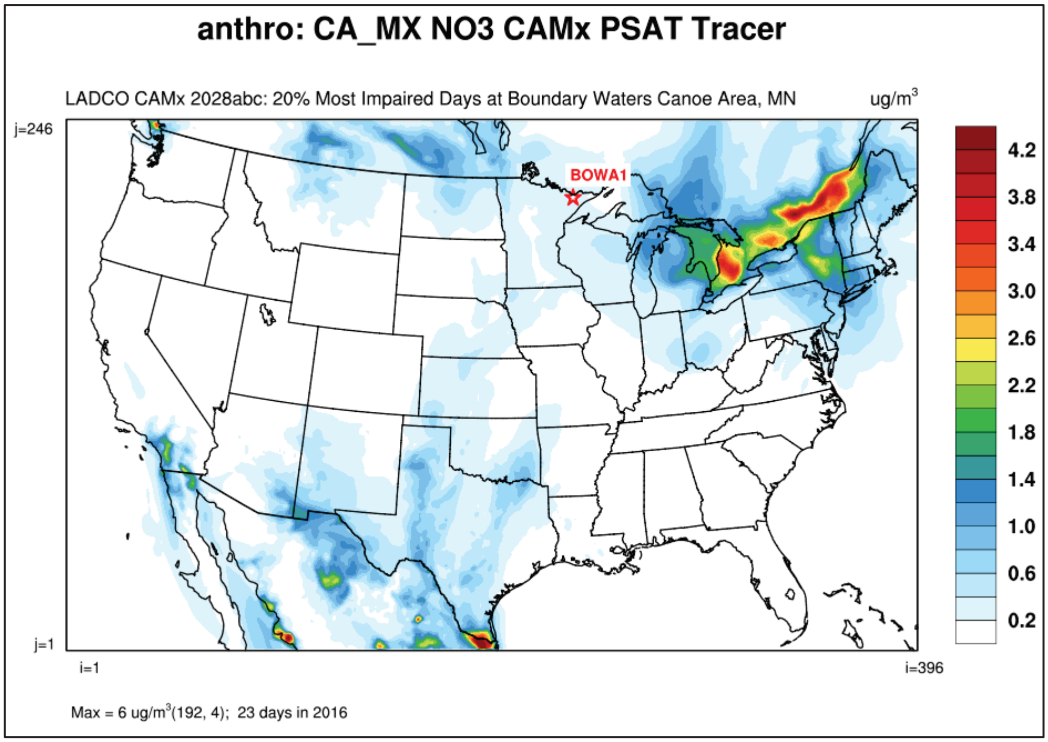

Figure 8-18. Maximum 2028$_{2016}$ nitrate tracer concentration from Canada and Mexico sources on the 20% most impaired days at Boundary Waters, MN

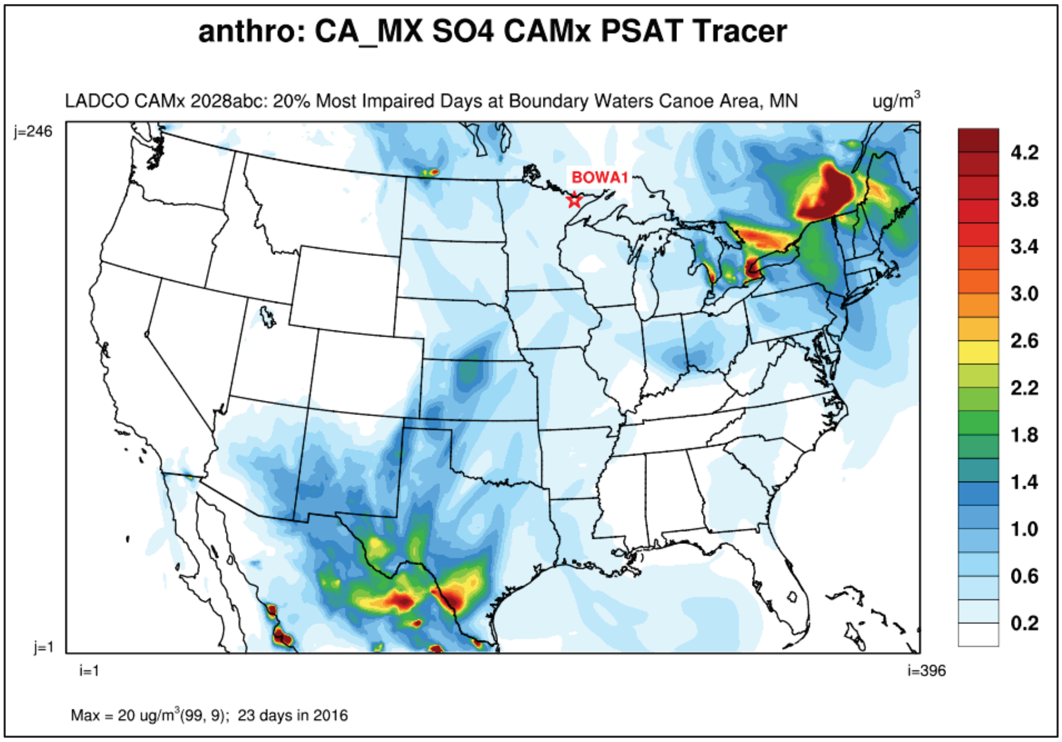

Figure 8-19. Maximum 2028$_{2016}$ sulfate tracer concentration from Canada and Mexico sources on the 20% most impaired days at Boundary Waters, MN

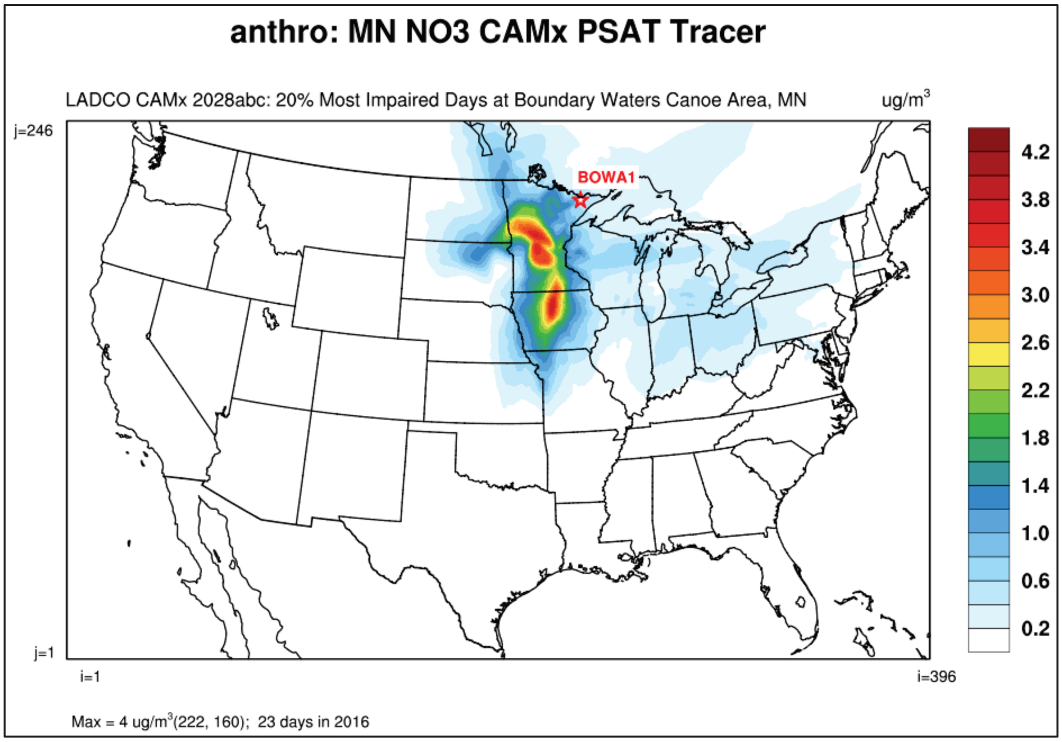

Figure 8-20. Maximum 2028_{2016} nitrate tracer concentration from MN sources on the 20% most impaired days at Boundary Waters, MN

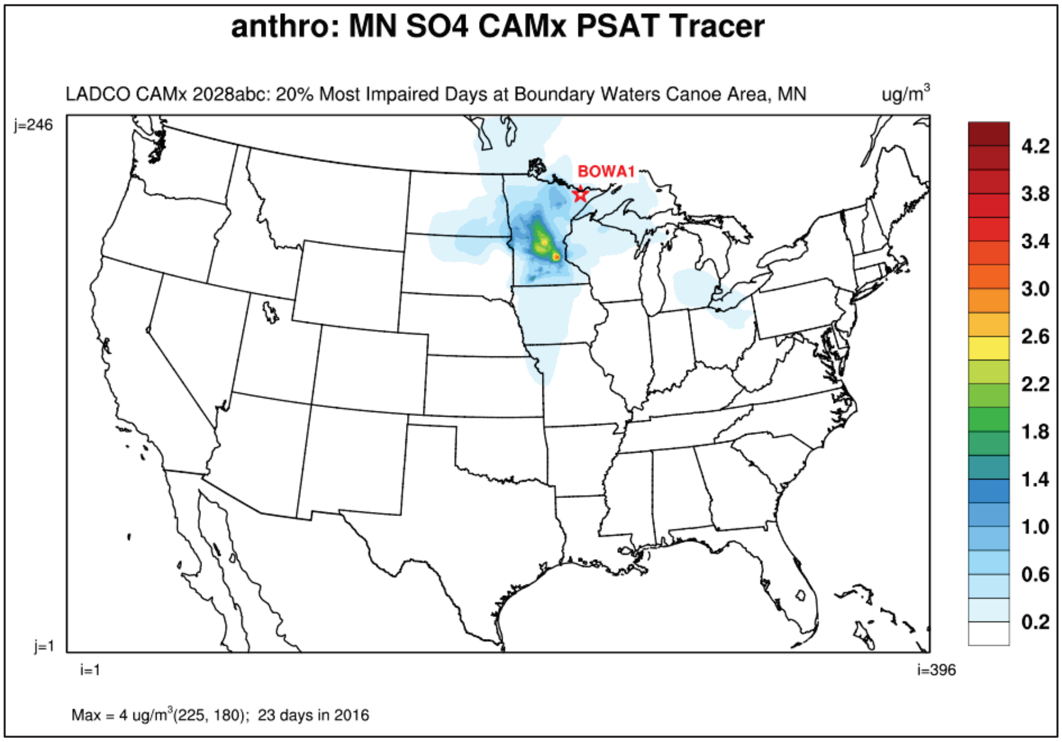

Figure 8-21. Maximum 2028_{2016} sulfate tracer concentration from MN sources on the 20% most impaired days at Boundary Waters, MN

LADCO also used the CAMx PSAT results to quantify the light extinction at Class I areas by $PM_{2.5}$ composition in 2028. LADCO post-processed our CAMx 2028_{2016} modeling results to estimate individual $PM_{2.5}$ species contributions to total light extinction on the 20% most impaired days at the Class I areas. The speciated tracer result for the LADCO region Class I areas are shown in Table 8-6 and in Figure 8-15.

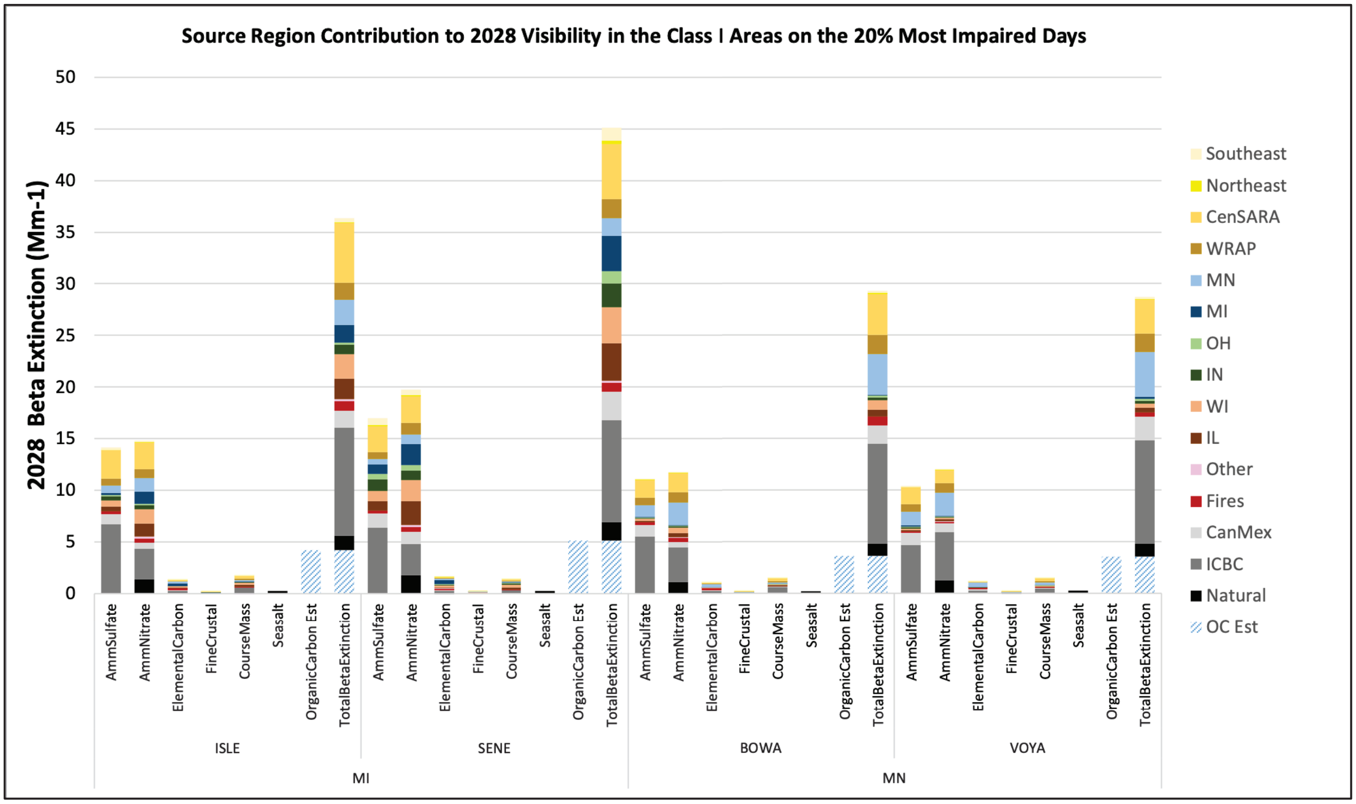

Figure 8-22. PM species tracer contributions to b_{ext} on the 20% most impaired days in 2028 at the LADCO Class I areas (CAMx 2028_{2016})

Table 8-6. Speciated 2028_{2016} tracer contributions on the 20% most impaired days at the LADCO-region Class I areas

Area	Tracer	OC_{est}	Natural	ICBC	Int'l	Fires	Other	IL	WI	IN	OH	MI	MN	WRAP	Cen	SE	NE	Total
ISLE	Total beta Ext	4.2	1.4	10.5	1.7	0.9	0.2	2.0	2.3	0.9	0.2	1.7	2.4	1.6	5.8	0.4	0.1	36.4
	NO_3	0.0	1.4	3.0	0.6	0.4	0.2	1.3	1.3	0.4	0.1	1.2	1.4	0.8	2.6	0.1	0.1	14.8
	SO_4	0.0	0.0	6.7	1.0	0.3	0.0	0.4	0.6	0.4	0.1	0.2	0.7	0.6	2.8	0.2	0.0	14.1
	CM	0.0	0.0	0.6	0.1	0.0	0.0	0.2	0.2	0.0	0.0	0.1	0.1	0.1	0.3	0.0	0.0	1.7
	EC	0.0	0.0	0.3	0.1	0.2	0.0	0.1	0.1	0.0	0.0	0.2	0.2	0.0	0.1	0.0	0.0	1.3
	FCRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	OC	4.2	0.0	0.0	0.0	0.0	0.0			0.0					0.0	0.0	0.0	4.2
	SS		0.3															0.3
SENE	Total beta Ext	5.1	1.8	9.9	2.7	0.9	0.2	3.6	3.5	2.3	1.2	3.4	1.7	1.9	5.4	1.3	0.3	45.1
	NO_3	0.0	1.8	3.0	1.2	0.4	0.2	2.3	2.1	1.0	0.5	2.0	1.0	1.1	2.6	0.5	0.2	19.8
	SO_4	0.0	0.0	6.3	1.4	0.2	0.0	0.9	1.0	1.1	0.5	0.9	0.5	0.7	2.5	0.7	0.1	17.0
	CM	0.0	0.0	0.3	0.0	0.0	0.0	0.2	0.2	0.1	0.1	0.1	0.0	0.1	0.2	0.0	0.0	1.4
	EC	0.0	0.0	0.2	0.1	0.2	0.0	0.1	0.2	0.1	0.0	0.4	0.1	0.0	0.1	0.0	0.0	1.6
	FCRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2
	OC	5.1	0.0	0.0	0.0	0.0	0.0			0.0					0.0	0.0	0.0	5.1
	SS		0.2															0.2
BOWA	Total beta Ext	3.6	1.2	9.7	1.7	0.9	0.1	0.6	0.9	0.2	0.2	0.1	3.9	1.9	4.0	0.2	0.1	29.3
	NO_3	0.0	1.1	3.3	0.5	0.4	0.1	0.4	0.5	0.1	0.1	0.1	2.2	1.0	1.9	0.1	0.0	11.8
	SO_4	0.0	0.0	5.5	1.1	0.3	0.0	0.1	0.2	0.1	0.1	0.0	1.1	0.7	1.7	0.1	0.0	11.2
	CM	0.0	0.0	0.6	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.2	0.1	0.3	0.0	0.0	1.5
	EC	0.0	0.0	0.3	0.1	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.3	0.0	0.1	0.0	0.0	1.1
	FCRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2
	OC	3.6	0.0	0.0	0.0	0.0	0.0			0.0					0.0	0.0	0.0	3.6
	SS		0.2															0.2
VOYA	Total beta Ext	3.5	1.3	10.0	2.3	0.4	0.1	0.4	0.4	0.2	0.2	0.2	4.4	1.8	3.3	0.2	0.1	28.7
	NO_3	0.0	1.2	4.7	0.9	0.1	0.0	0.2	0.2	0.1	0.1	0.1	2.2	0.9	1.3	0.1	0.0	12.0
	SO_4	0.0	0.0	4.6	1.2	0.1	0.0	0.1	0.1	0.1	0.1	0.1	1.3	0.7	1.6	0.1	0.0	10.4
	CM	0.0	0.0	0.4	0.1	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.3	0.1	0.3	0.0	0.0	1.4
	EC	0.0	0.0	0.3	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1	0.0	0.0	1.1
	FCRS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.2
	OC	3.5	0.0	0.0	0.0	0.0	0.0			0.0					0.0	0.0	0.0	3.5
	SS		0.3															0.3

9 Conclusions and Significant Findings

LADCO presents in this TSD the results from two regional air quality modeling platforms for quantifying and evaluating future year haze conditions pursuant to tracking progress during the second planning period for the Regional Haze Rule.

Significant findings in this report include:

Trends in PM Concentrations and Regional Haze (Section 2)

- $PM_{2.5}$ design values at all monitors in the LADCO region are currently below the levels of both $PM_{2.5}$ NAAQS. In particular, the 2019 24-hour DVs are at least five $\mu g/m^3$ below the level of the NAAQS. The highest concentrations in the LADCO region are in the urban areas, and the lowest concentrations are in the far northern parts of the region, including near LADCO's Class I areas.
- Both the annual and 24-hour $PM_{2.5}$ design values for the LADCO states decreased by 33% to 51% between 2002 and 2019.
- Concentrations of all of the measured $PM_{2.5}$ species have decreased at the regional surface monitors since 2001, with the largest reductions (70%) from ammonium sulfate aerosols and the smallest reductions (7%) from organic carbon.
- From 2000 to 2018, visibility on the most impaired days at the LADCO region Class I areas improved by 18% to 26%. Visibility improvements were even greater on the clearest days, with improvements of 26% to 34%.
- Concentrations of ammonium sulfate have undergone particularly large reductions over the past two decades. As a result, ammonium nitrate and organic carbon have become relatively more important contributors to fine particulate matter and haze in the LADCO region.

Air Quality Modeling (Section 3)

- LADCO used 2011 and 2016 as modeling base years from which to project visibility conditions in 2028. LADCO selected these modeling years because they were available as modeling platforms that included projections to 2028 during the current regional haze implementation period.

Air Quality Modeling Performance Evaluation (Section 6)

- The LADCO CAMx 2011 and 2016 modeling results are comparable to the U.S. EPA 2011 and 2016 modeling platforms that the Agency used for regional haze modeling
- Both of the LADCO base year CAMx simulations achieved either the model performance goals or criteria for most of the $PM_{2.5}$ species in the winter and spring seasons
- The LADCO CAMx simulations generally better estimated $PM_{2.5}$ at the more rural IMPROVE sites compared to the CSN sites (i.e., lower NMB and NME at IMPROVE vs CSN).
- CAMx did not simulate the carbonaceous or organic aerosol well in either of the base years.
- The LADCO CAMx simulations performed relatively well in estimating spring and winter season nitrate and sulfate at the IMPROVE monitors in both 2011 and 2016.

Future Year Haze Projections (Section 7)

- The visibility conditions at the Class I areas in the LADCO region were predicted to improve on average by about 2 dv in 2028 as compared to the 2011 base year, and about 0.8 dv improvement relative to the 2016 base year.
- Predicted 2028 visibility conditions based on the 2016 modeling platform shows that the visibility in the Class I areas in Minnesota and Michigan is about 1.4 dv below the unadjusted glidepath line (i.e., URP). Accounting for the adjustment due to the international contribution, LADCO estimated 2028 visibility on the 20% most impaired days to be about 2.6 dv below the URP line.

2028 Source-Receptor Modeling Results (Section 8)

- LADCO's 2011-based 2028 projection modeling estimated that natural sources such as Rayleigh, sea salt, biogenic and fire emissions will contribute 28-33 % of the light extinction coefficients in the LADCO's Class I areas, while the LADCO and CenSARA RPOs will contribute 23-24% and 8-13% of the extinction, respectively.
- LADCO's 2016-based 2028 projection modeling estimated that natural sources such as Rayleigh, sea salt, biogenic and fire emissions will contribute 28-36 % of the light extinction coefficients in the LADCO's Class I areas, while the LADCO and CenSARA RPOs will contribute 14-27% and 8-13% of the extinction, respectively.

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FINAL

Four-Factor Analysis for Regional Haze in the Northern Midwest Class I Areas

Methodology for Source Selection, Evaluation of Control Options, and Four Factor Analysis

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Table of Contents

Table of Figures

List of Acronyms

AFGD	Advanced Flue Gas Desulfurization
APCD	Air Pollution Control Division
BART	Best Available Retrofit Technology
CAA	Clean Air Act
CAIR	Clean Air Interstate Rule
$CaSO_3$	Calcium sulfite
$CaSO_4$	Calcium sulfate
CO	Carbon Monoxide
CO2	Carbon Dioxide
CPI	Consumer Price Index
DEP	Department of Environmental Protection
DEQ	Department of Environmental Quality
DNR	Department of Natural Resources
DSI	Dry Sorbent Injection
EIA	Energy Information Administration
EPA	Environmental Protection Agency
FGD	Flue Gas Desulfurization
FGR	Flue Gas Recirculation
ICI	Industrial, Commercial, Institutional
HEIS	High Energy Ignition Systems
LADCO	Lake Michigan Air Directors Consortium
LNB	Low NOx Burners
MACT	Most Achievable Control Technology
MARAMA	Mid-Atlantic Regional Air Management Association
N_2	Nitrogen gas
NCASI	National Council for Air and Stream Improvement
NESCAUM	Northeast States for Coordinated Air Use Management
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	Ammonia
NOx	Nitrogen Oxides
NSCR	Non-Selective Catalytic Reduction

NSPS	New Source Performance Standards
OFA	Over-Fired Air
PM	Particulate Matter
RICE	Reciprocating Internal Combustion Engine
RSCR	Regenerative Selective Catalytic Reduction
SCR	Selective Catalytic Reduction
SD	Spray Dry
SIP	State Implementation Plan
SNCR	Selective Non-Catalytic Reduction
SO_2	Sulfur Dioxide
ULNB	Ultra Low NOx Burners
WRAP	Western Regional Air Partnership
VOC	Volatile Organic Compounds

1 Executive Summary

The Regional Haze regulations set forth under 40 CFR 51.308(d)(1) require States to achieve reasonable progress toward natural visibility conditions. The national visibility goal in Class I areas is defined in the CAA Section 169A(a)(1) as “the prevention of any future, and the remedying of any existing, impairment of visibility…”, and is expected to be satisfied by 2064 with a return to natural visibility conditions. States containing Class I areas must set Reasonable Progress Goals (RPGs) to define future visibility conditions that are expected (but not required) to be equal to, or better, than visibility conditions expected by the uniform rate of progress at any future year until natural conditions are achieved.

The first State Implementation Plans (SIPs) under the regional haze program were due in 2007 and focused on establishing RPGs for the planning period ending in 2018. The current effort being undertaken by LADCO with support from Amec Foster Wheeler is to complete a four factor analysis of control technologies specific to large sources of pollutants that contribute to regional haze. This effort and the results are in support of establishing RPGs for Midwestern States for the implementation period ending 2028.

Following draft guidance from EPA in establishing RPGs, States must set a baseline from which reasonable progress towards visibility improvement will be measured. The next task is to identify key pollutants affecting visibility impairment at Class I areas. LADCO has identified nitrogen oxides (NOx) and sulfur dioxide (SO_2) as major pollutants contributing to visibility impairment in Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.

In order to determine the key source regions and source types contributing to visibility impairment at each Class I area, LADCO member states evaluated their emission inventories to identify large individual sources and source categories of NOx and SO_2. Based on information from the contribution assessment, LADCO selected the following source categories for analysis in this project:

- Industrial, commercial, and institutional boilers at paper mills and sugar beet manufacturing facilities;
- Cement plants
- Lime plants
- Pipeline transportation of natural gas

In addition to the source category analysis, LADCO States and EPA identified 10 specific facilities from these source categories for review. The 10 facilities were selected based on emissions of NOx and SO_2, and Q/d analysis to determine their impact on Class I areas. We examined the current control status and planned controls for these individual facilities in this analysis.

This document presents the results of an analysis of the economic and non-air quality environmental impacts of potential control scenarios that could be implemented by LADCO States to reduce emissions from the above source categories in order to make reasonable progress toward meeting visibility improvement goals. The purpose of this analysis is to present information that can be used by States to develop policies and implementation plans to address reasonable progress goals. Control technologies to achieve reasonable progress goals are evaluated with respect to four factors listed in the Clean Air Act (Section 169A):

- Cost,
- Compliance timeframe,
- Energy and non-air quality environmental impacts, and
- Remaining useful life for affected sources.

The “four factor” analysis was applied to control options identified for each of the selected source categories. Kilns at cement and lime plants were analyzed together due to the similarity of the two source categories.

The table below presents a summary of the four factor analysis for the source categories analyzed. Detailed information on control technologies assessed in this effort is presented in the main body of this document.

Table 1-1 Summary of Results from the Four Factor Analysis

Source Category	Regional Haze Pollutant Analyzed	Average Cost in 2015 dollars (per ton of pollutant reduction)	Compliance Timeframe	Energy and Non-Air Quality Environmental Impacts	Remaining Useful Life
ICI Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities	NOx	\$450-\$17,000	2-5 years following SIP submittal	Efficiency loss, increased fuel consumption, solid waste disposal, reagent storage, and ammonia slip	10-30 years
	SO_2	\$400-\$4,700	2-5 years following SIP submittal	Solid waste disposal, wastewater issues, and efficiency loss	10-30 years
Kilns at Lime and Cement Plants	NOx	\$200-\$21,100	2-5 years following SIP submittal	Efficiency loss, increased fuel consumption, solid waste disposal, reagent storage, and ammonia slip.	10-30 years
	SO_2	\$1,500-\$88,800	2-5 years following SIP submittal	Solid waste disposal, wastewater issues, and efficiency loss	10-30 years
Pipeline Transportation of Natural Gas	NOx	\$220-\$9,200	2-5 years following SIP submittal	Efficiency loss and increased fuel consumption	15 years

2 Introduction

2.1 Background

The Regional Haze regulations set forth under 40 CFR 51.308(d)(1) require States to achieve reasonable progress toward natural visibility conditions. The national visibility goal in Class I areas is defined in the CAA Section 169A(a)(1) as “the prevention of any future, and the remedying of any existing, impairment of visibility…”, and is expected to be satisfied by 2064 with a return to natural visibility conditions. States containing Class I areas must set Reasonable Progress Goals (RPGs) to define future visibility conditions that are expected (but not required) to be equal to, or better, than visibility conditions expected by the uniform rate of progress at any future year until natural conditions are achieved.

The first State Implementation Plans (SIPs) under the regional haze program were due in 2007 and focused on establishing RPGs for the planning period ending in 2018. The current effort being undertaken by LADCO with support from Amec Foster Wheeler is to complete a four factor analysis of control technologies specific to large sources of pollutants that contribute to regional haze. This effort and the results are in support of establishing RPGs for Midwestern States for the implementation period ending 2028.

Following draft guidance from EPA in establishing RPGs, States must set a baseline from which reasonable progress towards visibility improvement will be measured. The next task is to identify key pollutants affecting visibility impairment at Class I areas. LADCO has identified nitrogen oxides (NOx) and sulfur dioxide (SO_2) as major pollutants contributing to visibility impairment in Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin.

In order to determine the key source regions and source types contributing to visibility impairment at each Class I area, LADCO member states evaluated their emission inventories to identify large individual sources and source categories of NOx and SO_2 that contribute to visibility impairment on the 20 percent best and worst days. Based on information from the contribution assessment, LADCO selected the following source categories for analysis in this project:

- Industrial, commercial, and institutional boilers at paper mills and sugar beet manufacturing facilities;
- Cement plants
- Lime plants
- Pipeline transportation of natural gas

In addition to the planned reductions that will be included as part of the State SIPs for regional haze, federal programs will also have significant benefits in reducing regional haze by 2028 and beyond. A list of EPA’s national and regional rules as well as voluntary programs that will assist in the reduction of fine particle pollution are as follows:

- Clean Air Interstate Rule (CAIR)
- Clean Air Visibility Rule
- The Acid Rain Program
- NO_X SIP Call
- 2004 Clean Air Nonroad Diesel Rule
- 2007 Clean Diesel Trucks and Buses Rule
- Tier 2 Vehicle Emission Standards and Gasoline Sulfur Program
- Emission standards for other engines (highway and non-highway use)
- National Clean Diesel Campaign
- The Great American Woodstove Changeout

More information and links to the programs listed above can be found on the following website: http://www3.epa.gov/pm/reducing.html.

2.2 Determination Of Emission Source Categories And Individual Sources Most Responsible For Regional Haze In LADCO Class I Areas

Particles in the $PM_{2.5}$ size range are directly responsible for visibility reduction, however, in many cases these particles are not directly emitted as particulate matter, but instead are formed through the reaction of other pollutants such as NOx and SO_2. $PM_{2.5}$ formed through reaction is known as secondary $PM_{2.5}$. Source apportionment and other analyses documented in LADCO's emissions inventory assessment and contribution assessment indicated that a number of source categories have impacts on visibility at LADCO's Class I areas resulting from emissions of these $PM_{2.5}$ precursor pollutants and the resulting formation of haze.

2.2.1 Approach to Demonstrating Reasonable Progress

Based on the contribution assessment conducted by LADCO States, the following source categories were selected for analysis in this project:

- Industrial, commercial, and institutional boilers at paper mills and sugar beet manufacturing facilities;
- Cement plants
- Lime plants
- Pipeline transportation of natural gas

This document presents the results of an analysis of the economic and non-air quality environmental impacts of potential control scenarios that could be implemented by LADCO States to demonstrate reasonable progress toward meeting visibility improvement goals. The purpose of this analysis is to present information that can be used by States to develop policies and implementation plans to address reasonable progress goals. Control technologies to achieve reasonable progress goals are evaluated with respect to four factors listed in the Clean Air Act (Section 169A):

- Cost,
- Compliance timeframe,
- Energy and non-air quality environmental impacts, and
- Remaining useful life for affected sources.

The "four factor" analysis was applied to control options identified for each of the selected source categories. Category analyses are presented for industrial, commercial, and institutional boilers at paper mills and sugar beet manufacturing facilities; kilns at cement and lime plants; and pipeline transportation of natural gas. Kilns at cement and lime plants were analyzed together due to the similarity of the two source categories. Only NOx emissions were considered from pipeline transportation of natural gas.

Additionally, we have assembled current and planned controls for 10 specific sources selected by the LADCO states and based on information from State agencies and EPA. The purpose of selecting these sources is to find out whether the sources that have the greatest impacts on Class I areas in or near the LADCO six-state region are already controlled or will be controlled by 2028.

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3 Source Category Analysis for Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

3.1 Source Category Description

The emission inventory and contribution assessment performed by LADCO demonstrated that NOx and SO_2 emissions were key contributors to visibility impairment in Class I areas in the LADCO States. Boilers used to produce steam for electricity generation as well as boiler units used in industrial, commercial, and institutional settings are among the most significant contributors of NOx and SO_2 in any inventory. Emissions of these pollutants is highly dependent on many emission unit-specific factors including type of fuel and in-place emissions controls. Also, emissions of these pollutants from boilers used for electricity generation have been the focus of many prior control initiatives. For the purpose of the current four-factor analysis, LADCO selected boilers at pulp and paper mills and sugar beet manufacturing facilities for review. Boilers at these facilities are typically among the largest of non-EGU boilers and therefore have the highest emissions potential.

Pulp and paper and sugar beet manufacturing facilities have high steam demands and typically have access to a large variety of industry-specific fuels (e.g. wood waste, black liquor solids, other biofuels). As a result, these facilities employ large boilers configured to burn multiple fuels including coal, natural gas, wood waste, fuel oils, biogas, black liquor solids, etc. Due to the size of these boilers and their corresponding emissions potential, most of the units are fitted with controls for one or more of NOx, SO_2 and particulate matter. Many of these units are also subject to New Source Review (NSR) or Prevention of Significant Deterioration (PSD) limits for these pollutants that vary depending on when the boiler was last subject to PSD review due to a modification.

The use of a wide variety of fuels is an important characteristic of the Industrial, Commercial, Institutional (ICI) boiler category. While many boilers are capable of co-firing liquid or gaseous fuels in conjunction with solid fuels, boilers are usually designed for optimum combustion of a single specific fuel. Changes to the fuel type may, therefore, reduce the capacity, duty cycle, or efficiency of the boiler.

Boiler design also plays a role in the uncontrolled emission rate. Most ICI boilers are of three basic designs: water tube, fire tube, or cast iron. The fuel-firing configuration is a second major identifier of boiler design for solid fuels. Stoker boilers are the oldest technology and are still widely used for solid-fueled boilers. Pulverized coal boilers succeeded stokers as a more efficient method of burning coal and are used in larger boiler designs. Circulating fluidized bed (CFB) boilers are the most recent type of boiler for solid fuel combustion and are becoming more commonplace. CFB boilers are capable of burning a variety of fuels, and are more efficient and less polluting than stoker or pulverized coal boilers.

3.2 Clean Air Act Regulations Controlling ICI Boilers

Emissions from ICI boilers are currently governed by multiple State and federal regulations under Titles I, III, and IV of the Clean Air Act. Each of these regulatory programs is discussed in the following paragraphs.

Title I regulates criteria pollutants by requiring local governments to adopt State Implementation Plans (SIPs) that set forth their strategy for achieving reductions in the particular criteria pollutant(s) for which they are out of attainment. The SIP requirements includes Reasonably Available Control Technology (RACT) requirements, but more stringent requirements may be imposed depending on the locale's degree of non-attainment with ambient air standards.

Title I also imposes New Source Performance Standards (NSPS) on certain specified categories of new and modified large stationary sources. In 1986, EPA codified the NSPS for industrial boilers (40 CFR part 60, subparts Db and Dc) and revised portions of them in 1998 to reflect improvements in control methods for the reduction of NO_X emissions. Subpart Db applies to fossil fuel-fired ICI units greater than 100 MMBTU per hour that were constructed or modified after June 19, 1984. Subpart Dc applies to fossil fuel-fired ICI units from 10 to 100 MMBTU per hour that were constructed or modified after June 9, 1989.

In addition, Title I subjects new and modified large stationary sources that increase their emissions to permitting requirements that impose control technologies of varying levels of stringency. NSR prescribes control technologies for new plants and for plant modifications that result in a significant increase in emissions, subjecting them to Best Available Control Technology (BACT) in attainment areas and to the Lowest Achievable Emission Rate (LAER) in non attainment areas. Control strategies that constitute BACT and LAER evolve over time and are reviewed on a case by case basis in State permitting proceedings.

On September 13, 2004, EPA published a final rule under Title III of the CAA to substantially reduce emissions of toxic air pollutants from ICI boilers. These Maximum Achievable Control Technology (MACT) standards apply to ICI boilers located at major sources of hazardous air pollutants (HAPs). There are many options for complying with the MACT standards, ranging from continued use of existing control systems to fuel switching to the installation of a fabric filter and wet scrubber technologies. Thus, the control technologies used to reduce the level of HAP emitted from affected sources are also expected to reduce emissions of PM, and to a lesser extent, SO_2 emissions.

On January 31, 2013, EPA published a final version of the Major Source Boiler MACT. Compliance with the Boiler MACT is required by January 31, 2016 with the opportunity to apply for up to one year compliance extension to January 31, 2017 for major sources of hazardous air pollutants. The focus of the Boiler MACT is to reduce emissions of hazardous air pollutants (HAPs). Emissions of HAPs from boilers is affected by fuel type and combustion conditions and is tied to emissions of particulate matter and carbon monoxide. Emissions controls for boilers subject to the Boiler MACT may impact emissions of NOx and SO_2.

Title IV of the CAA addresses acid rain by focusing primarily on power plant emissions of SO_2. Title IV includes an Opt-in Program that allows sources not required to participate in the Acid Rain Program the opportunity to enter the program on a voluntary basis and receive their own acid rain allowances. The Opt-in Program offers sources such as ICI boilers a financial incentive to voluntarily reduce its SO_2 emissions. By reducing emissions below allowance allocation, an opt-in source will have unused allowances, which it can sell in the SO_2 allowance market.

The regulation of ICI boilers by various CAA programs has resulted in a variety of unit level emission limits resulting from SIP, NSPS, NSR, or MACT requirements. Overlaid on these unit level requirements are system-wide allowances of the NO_X SIP call and the Acid Rain SO_2 opt-in program. Thus, the specific emission limits and control requirements for a given ICI boiler vary and depend on boiler age, size, and geographic location.

3.3 NOx from Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

3.3.1 NOx Emissions and Control Options

Nitrogen oxides are a by-product of combustion. Nitrogen is inherently contained in fuels and in the air and does not react at low temperatures. During combustion, the high temperatures cause the nitrogen and oxygen in the air to react and form NOx. The amount of NOx formed is dependent on many factors including the type of fuel combusted, temperature, and residence time of the air. NOx formation can be classified into the following four categories: thermal NOx, fuel NOx, feed NOx, and prompt NOx. Thermal NOx is formed from nitrogen and oxygen in the air as a result of high temperature. Thermal NOx formation has a positive correlation with temperature. Fuel NOx is the result of nitrogen contained in organic fuels releasing and reacting with oxygen. Some fuels, such as natural gas, typically have no bound nitrogen, however, others such as coal or oil can contain high amounts. Feed NOx is caused by reaction of the nitrogen in feed materials in a process, such as the constituents of cement, in a high temperature environment. Feed NOx is not usually a concern for boilers. Prompt NOx is formed as atmospheric nitrogen, atmospheric oxygen, and hydrocarbons from the fuel rapidly react. It is a minor contributor to overall NOx formation.

Due to the multiple factors affecting NOx formation from combustion, there are different methods of reducing or controlling NOx emissions. The potential control types analyzed in this report can be categorized into the following two categories: combustion modifications and post-combustion NOx controls. Combustion modifications are changes to one or more controllable variables in the combustion process itself, such as temperature and combustion air residence time. Post-combustion NOx controls utilize add-on control technologies to decrease the amount of formed NOx before the combustion air is release to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the Prevention of Significant Deterioration (PSD) program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of boiler, fuel(s) used, heat input capacity, and mode of operation.

A summary of the potential NOx control options is provided in Table 3-1.

Table 3-1 Potential NOx Control Options for Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

Technology	Description	Applicability	Performance
Boiler Tuning/ Optimization[4]	Adjust air to fuel ratio	Potential control measure for all boilers	5-15% reduction in NOx
LNB[2,5]	Low NOx burners	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	40-50% reduction in NOx
ULNB[1,2]	Ultra low NOx burners	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	45-85% reduction in NOx
LNB + FGR[1,2]	Low NOx burners and flue gas recirculation	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	50-70% reduction in NOx
LNB + OFA[2,5]	Low NOx burners and over-fired air	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	40-60% reduction in NOx
SCR[1,2]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas in the presence of a catalyst.	Potential control measure for all boilers; dependent on flue gas temperature and boiler configuration	70-90% reduction in NOx
SNCR[2,3]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas.	Potential control measure for all boilers; dependent on flue gas temperature and boiler configuration	10-70% reduction in NOx
RSCR[2,3,4]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas in the presence of a catalyst and heat exchangers.	Potential control measure for all boilers; dependent on boiler configuration	60-75% reduction in NOx

Table references:

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3.3.1.1 Combustion Modification

Boiler Tuning/Optimization

One method of combustion modification to control NOx from boilers is “tuning,” also known as optimization. The air to fuel ratio for combustion is analyzed and adjusted to lower NOx emissions. This may also result in more efficient combustion and better boiler performance. The reduction efficiency possible through boiler tuning is dependent on how “de-tuned” the boiler was prior to optimization, but 5 to 15 percent reduction of NOx can be achieved.

Low/Ultra Low NOx Burners

Low NOx burner (LNB) technology utilizes alternate burner designs to reduce the formation of NOx. Temperature, residence time, and oxygen levels can be altered from traditional burner designs. LNBs utilize staged combustion, where fuel is introduced to an oxygen-rich, low temperature zone, and any uncombusted fuel is burned in a lower oxygen zone. In addition, the surface area of LNBs is increased to lower flame temperature and reduce thermal NOx production. Ultra Low NOx Burners (ULNB) often use similar designs and can decrease NOx emissions to up to 85 percent, and LNBs can decrease NOx emissions on average by 40 to 50 percent (LADCO, 2005). LNBs are often combined with other combustion modification controls like flue gas recirculation and over-fired air.

LNBs can result in significantly lower efficiencies, depending on the boiler and burners chosen. Suitability of LNBs must be carefully analyzed for each individual boiler.

Flue Gas Recirculation

Flue gas recirculation (FGR) returns a portion of post-combustion stack gas to the burners. This lowers the oxygen content of the combustion air and decreases the flame temperature, thus less thermal NOx is formed. FGR is often combined with LNBs and can reduce emissions by 50 to 72 percent for coal and oil fired boilers (NESCAUM, 2008). Retrofitting an FGR system to a boiler is sometimes challenging or infeasible, depending on the unit.

Over-fired Air

Over-fired air (OFA) is a form of staged combustion that works by directing a portion of the combustion air from the last burners to ports downstream. This creates a more fuel-rich environment near the burners. Less thermal NOx is formed due to lowered temperatures at the combustion zones and less oxygen near the burners. OFA can be combined with LNBs to reduce NOx emissions by 40 to 60 percent.

3.3.1.2 Post-Combustion NOx Controls

Selective Non-Catalytic Reduction

Selective Non-Catalytic Reduction (SNCR) removes NOx by injecting urea or another reducing agent into the flue gas. The reagent reacts with NOx to form nitrogen gas (N_2) and water. Temperatures between 1,700 and 2,000 °F are optimal for the reaction. SNCR systems can reduce NOx emissions by 30 to 60 percent. The use of LNBs with an SNCR system can increase the reduction efficiency to 50 to 90 percent of NOx (LADCO, 2005).

Selective Catalytic Reduction

Selective Catalytic Reduction (SCR) is similar to SNCR in that it removes NOx by injecting a reducing agent (typically ammonia) into the flue gas; however, SCR utilizes a catalyst. The catalyst lowers the activation energy needed for the reaction of NOx and ammonia to form nitrogen gas and water. As a result, SCRs are appropriate for boilers with lower flue gas temperatures. Depending on the catalyst used, temperatures of 470 to 1000 °F are required for proper reduction of NOx (LADCO, 2005). Below this range, unreacted ammonia is released to the atmosphere, and above this range, ammonia oxidizes to form additional NOx. A properly maintained SCR system can reduce NOx emissions by 70 to 90 percent, more than an SNCR system, but have lower operating costs and higher capital costs (NESCAUM, 2008). A boiler operator may also install ULNB with an SCR system to decrease NOx emissions by up to 95 percent (LADCO, 2005).

Regenerative Selective Catalytic Reduction

Regenerative Selective Catalytic Reduction (RSCR™) is an alternative to SCR for smaller boilers or boilers with particulate control equipment upstream of the control device. An SCR system requires a minimum flue gas temperature of 470 °F which may not be possible for some boiler systems. An RSCR system utilizes ceramic heat exchangers and a burner to bring the flue gas up to a suitable temperature for the reaction of NOx and ammonia (or similar reducing agent) to occur. NOx reduction efficiencies of 60 to 75 percent of can be achieved.

3.3.2 Four Factor Analysis of Potential NOx Control Scenarios for Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

A four factor analysis approach has been utilized to analyze the potential control options presented in Table 3-1.

3.3.2.1 Cost of Compliance

Information on cost effectiveness of retrofitting controls onto boilers has been compiled from various sources. It is important to note that the values provided are estimated and actual retrofit control costs may be higher or lower depending on the utilization and size of the individual boiler as well as specific capital costs associated with the design.

Combustion modifications are generally low cost in comparison to post-combustion controls. Costs from boiler tuning include engineering and contractor costs to measure the oxygen and carbon monoxide concentrations in the flue gas and adjust the air to fuel mixture appropriately. LNBs and ULNBs are generally cost effective but the impacts on boiler efficiency must be considered. Associated costs are from engineering, the burners and related equipment, and labor costs for installation. Costs from retrofitting FGR or OFA can vary greatly depending on the boiler design. Engineering, equipment such as piping and fans, and labor costs make up the bulk of the costs. If extensive changes to the boiler are required to retrofit FGR or OFA, the costs can easily exceed cost effective levels.

Post-combustion NOx controls are generally much more cost intensive than combustion modifications, but can provide significantly higher reductions in NOx. The applicability of each type of post-combustion control should be carefully assessed for each unit. Considerations include space constraints, flue gas temperature, if fly ash is sold (the reducing agent may contaminate fly ash depending on the system chosen), and load swings of the boiler. For boilers with high temperature flue gas streams, an SNCR system may be considered. No reactor is required for SNCR as the urea or other reducing agent can be injected directly into the flue. This reduces capital costs for the system; however, operating costs are higher due to lower efficiency and more reagent use. For boilers with flue gas stream temperatures lower than those required for SNCR system, SCR and RSCR systems may be viable. They have high capital costs as a result of the dedicated reactor and catalyst required for each system; however, reagent costs are lower than for an SNCR system and NOx reduction efficiency is greatly increased. (NESCAUM, 2008).

Table 3-2 summarizes the cost effectiveness and factors affecting cost of each control option addressed in this analysis, as well as potential applicability to the specific facilities analyzed as part of this report. Costs have been converted into

2015 dollars using Consumer Price Index (CPI) data through August 2015. Please note that some costs may have increased or decreased since the original analyses; however, this analysis has only used past data available. A confidential key to the unit IDs is provided on the informational disc included with this report.

Table 3-2 Cost Effectiveness for NOx Control Options for ICI Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
Boiler Tuning/ Optimization[4]	None	Low	Engineering and contractor costs	All pulp and paper mill and beet manufacturing facility boilers
LNB[2,5]	None	$450-$3,700	Equipment, installation, and engineering	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03
ULNB[1,2]	None	$650-$2,200	Equipment, installation, and engineering	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03
SCR[1,2]	Ammonia injection system	$2,600-$17,000	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	All pulp and paper mill and beet manufacturing facility boilers; dependent on temperatures
SNCR[2,3]	Urea injection system	$1,500-$4,400	Equipment, installation, engineering, energy use, waste removal, and reduction agent	All pulp and paper mill and beet manufacturing facility boilers; dependent on temperatures
RSCR[2,3,4]	Ammonia injection system	$1,800-$5,300	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	All pulp and paper mill and beet manufacturing facility boilers; dependent on temperatures

Table 3-2 Cost Effectiveness for NOx Control Options for ICI Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
LNB + FGR[1,2]	None	$1,200-$4,300	Equipment, installation, construction and engineering	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03
LNB + OFA[2,5]	None	$700-$3,700	Equipment, installation, construction and engineering	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03
LNB + SNCR[1]	Urea injection system	$1,700-$4,500	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03
ULNB + SCR[1]	Ammonia injection system	$2,900-$5,100	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	03-01, 03-02, 06-01, 06-02, 08-01, 08-02, 09-01, 09-02, 10-02, 10-03

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Midwest Regional Planning Organization Boiler BART Engineering Analysis*. LADCO. March 2005.
2. *Applicability and Feasibility of NOx, SO_2, and PM Emissions Control Technologies for ICI Boilers*. NESCAUM. November 2008.
3. *EPA Cost Estimates for NOx Controls on Pulp and Paper Boilers are too Low by 100->300%.* NESCAUM.
4. *BART Determination – Georgia Pacific Broadway Mill, Green Bay Wisconsin.* Wisconsin DNR. July 2011.
5. *Assessment of Control Options for BART-Eligible Sources.* NESCAUM and MANE-VU. March 2005.

3.3.2.2 Time Necessary for Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. MACT standards typically allow three years for compliance, and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Combustion modifications and post-combustion NOx controls require significant time for engineering, construction, and facility preparedness. Two to five years after SIP approval would typically be appropriate, depending on the size of the unit and control options selected. Substantially less time would be required for boiler optimization and tuning which can be implemented within a few months to a year.

3.3.2.3 Energy and Non-Air Impacts

Combustion modification and post-combustion NOx controls can impact energy use and the environment in forms other than air quality. Non-air environmental impacts include solid, liquid, and/or hazardous waste generation and deposition of atmospheric pollutants on land or water. Some control technologies may result in nuisances in the form of noise pollution or odor.

Combustion modifications can have significant impacts on energy use, positively or negatively. Boiler tuning, LNB/ULNBs, OFA, and FGR can reduce the efficiency of a boiler as the air to fuel ratio increases and temperature decreases. This increases fuel usage and, as a result, costs. OFA and FGR systems increase energy use in the form of fans and compressors. Facilities that sell fly ash may be affected due to the higher CO concentrations making the fly ash unsuitable for sale (NESCAUM, 2008).

Post-combustion NOx controls may also impact energy use for boilers. SCR, SNCR, and RSCR systems reduce thermal efficiency by using thermal energy in the reaction of NOx and reagent. Fans, compressors, injection equipment, and related processes utilize energy and increase costs. For SCR, SNCR, and RSCR systems, the reagent (usually ammonia or urea) can contaminate fly ash, making it unsalable.

3.3.2.4 Remaining Useful Life at the Source

The remaining useful life of an individual boiler can vary greatly depending on the age of the boiler, size of the unit, maintenance frequency, and other factors. Life expectancies for most industrial, commercial, and institutional boilers at pulp and paper mills and sugar beet manufacturing facilities are between 10 and 30 years or more.

REFERENCES

The Lake Michigan Air Directors Consortium (LADCO). *Midwest Regional Planning Organization Boiler Best Available Retrofit Technology Engineering Analysis.* March 30, 2005.

Northeast States for Coordinated Air Use Management (NESCAUM). *Applicability and Feasibility of NOx, SO_2, and PM Emissions Control Technologies for Industrial, Commercial, and Institutional (ICI) Boilers.* November 2008.

NESCAUM. *EPA Cost Estimates for NOx Controls on Pulp and Paper Boilers are too Low by 100->300%.*

NESCAUM and MANE-VU. *Assessment of Control Options for BART-Eligible Sources.* March 2005.

U.S. EPA. *EPA Air Pollution Control Cost Manual.* “Chapter 1 – Selective Noncatalytic Reduction.” Draft. June 2015.

U.S. EPA. 2015. *EPA Air Pollution Control Cost Manual*. “Chapter 2 – Selective Catalytic Reduction.” Draft. June 2015.

Wisconsin DNR. BART Determination – Georgia Pacific Broadway Mill, Green Bay Wisconsin. July 2011.

3.4 SO_2 from Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

3.4.1 SO_2 Emissions and Control Options

Sulfur dioxide is formed in boilers when the sulfur in fossil fuels oxidizes. Unlike NOx, the only mechanism of SO_2 generation is directly related to the sulfur content of fuel – temperature has no effect. Nearly all of the sulfur contained in the fuels is converted to SO_2. As a result, the simplest way to reduce SO_2 emissions is to switch to a lower sulfur fuel. For instances where this is impractical, post-combustion SO_2 controls may be employed to remove the SO_2 already created. Potential control types can be categorized into the following three categories: pre-combustion SO_2 controls, combustion modifications, and post-combustion SO_2 controls.

Pre-combustion SO_2 controls include fuel substitution. This assessment does not analyze the cost effectiveness of fuel switching as the costs are highly variable, and feasibility is dependent on individual boiler characteristics and functions. A description with reduction efficiencies is provided, however.

Combustion modifications are changes to one or more controllable variables in the combustion process itself. Retrofit combustion modifications exist but are very invasive and may be possible for only a small number of existing boilers. One such modification is conversion to fluidized bed whereby fuel is combusted in a bed of ash, limestone, and other materials. The limestone in the bed captures most of the SO_2 and reduces emissions significantly. Fluidized bed conversion has not been analyzed in this report due to the highly unit specific nature of such a conversion.

Post-combustion SO_2 controls utilize add-on control technologies to decrease the amount of formed SO_2 before the combustion air is released to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the Prevention of Significant Deterioration (PSD) program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of boiler, fuel(s) used, heat input capacity, and mode of operation.

Table 5-1Pre-combustion and post-combustion SO_2 controls are described in the next two sections. Table 3-3 summarizes appropriate SO_2 control options for ICI boilers.

Table 3-3 Potential SO_2 Control Options for Boilers at Pulp and Paper Mills and Beet Manufacturing Facilities

Technology	Description	Applicability	Performance
Conventional Dry Flue Gas Desulfurization (FGD) – Dry Sorbent Injection[1]	An absorbent reagent such as lime slurry is introduced into the flue gas stream through direct injection to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	35-50% reduction in SO_2
Conventional Dry Flue Gas Desulfurization (FGD) – Spray Dryer[1,2]	An absorbent reagent such as lime, calcium hydrate, limestone or soda ash is introduced into the flue gas stream through spray in an absorption tower to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	90-95% reduction in SO_2
Advanced Flue Gas Desulfurization (AFGD)[2]	A slurry reagent is sprayed onto cooled/humidified flue gas to absorb SO_2, creating calcium sulfate that is oxidized to create wallboard-grade gypsum	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	95-99% reduction in SO_2
Wet Flue Gas Desulfurization (FGD)[1,2,3]	A scrubbing reagent such as caustic, crushed limestone, or lime is introduced into the flue gas stream to absorb SO_2, creating liquid or sludge waste	Potential control measure for all boilers; dependent on fuels burned, boiler use, and boiler configuration	90-99% reduction in SO_2

Table references:

1. *Applicability and Feasibility of NOx, SO_2, and PM Emissions Control Technologies for ICI Boilers*, NESCAUM, November 2008.
2. *Midwest Regional Planning Organization Boiler BART Engineering Analysis*, LADCO, March 2005.
3. *BART Determination - Georgia Pacific Broadway Mill, Green Bay Wisconsin*, Wisconsin DNR, July 2011.

3.4.1.1 Pre-Combustion SO_2 Controls

Fuel Substitution

The most direct way to control SO_2 from boilers is by changing the fuel used. The percent reduction possible depends on what fuel is currently used and what fuel will be used in the future. According to the U.S. Energy Information Administration, the most used coal types are typically between 0.8 and 5 percent sulfur by weight. Fuel oils can have 1 to 2 percent sulfur by weight for residual and less than 0.5 percent sulfur by weight for distillate, and petroleum coke has as much as 6 percent sulfur by weight (MARAMA, 2007). Tire derived fuel (TDF) contains approximately 1.6 percent sulfur by weight, similar to that of a medium-sulfur content coal (NCASI, 2010). The sulfur content of wood is very low, and pipeline natural gas has virtually zero sulfur. To change from one fuel to another, many factors must be considered on an individual unit basis. Switching fuels can be relatively simple or very complicated, depending on the capacity, burners, type of use, and other factors. Switching to a lower sulfur coal potentially results in increased transportation costs and cost of coal. Heat content of fuel also varies significantly between fuel types and subtypes. Changes to the fuel system may also result in significant costs. Another consideration is that controls for particulate may already exist on a boiler and would become unnecessary depending on the fuel switch, thus putting additional financial burden onto a single facility.

3.4.1.2 Post-Combustion SO_2 Controls

Flue Gas Desulfurization

Flue gas desulfurization (FGD) is the process of scrubbing SO_2 out of the combustion air. There are two basic processes of FGD – wet and dry. Dry FGD can be further categorized as conventional and advanced. Each of these FGD systems utilize the same basic principle to remove SO_2. An alkaline chemical such as limestone or lime reacts with SO_2 to form solid calcium sulfite ($CaSO_3$) and calcium sulfate ($CaSO_4$), which is collected. Descriptions of the different types of FGD are below.

Conventional Dry FGD

Conventional dry FGD includes dry sorbent injection (DSI) and spray dryers (SDs). In DSI, lime, calcium hydrate, limestone or soda ash is injected into the flue gas stream producing solid particles of $CaSO_3$ and $CaSO_4$. In boilers, injection can take place in the furnace, economizer, or in a low-temperature duct. The particles generated by DSI and excess reagent are removed from the gas stream using a particulate control device. SO_2 removal efficiency depends on absorbent injection location, temperature, degree of mixing, and retention time. SO_2 reduction through dry sorbent injection on boilers ranges from 35 to50 percent (NESCAUM, 2008). In an SD system, lime slurry is sprayed onto flue gas within an absorption tower.

SO_2 is absorbed into the slurry, forming a mixture of calcium sulfite and calcium sulfate. The water evaporates before the droplets reach the bottom of the tower due to the liquid-to-gas ratio. The dry solids created due to evaporation are collected with a fabric filter or ESP. SO_2 reduction by spray dryers on boilers ranges from 90 to 95 percent (LADCO, 2005).

It must be noted that flue gases at or near adiabatic saturation temperatures can cause the baghouse filter cake to become saturated with moisture and plug both the filters and the dust removal system. In addition, the lime slurry would not dry properly and would plug up the dust collection system. However some argue that SO_2 removal actually occurs on the filter cake. Ultimately, it is important that boiler exit gas temperatures are above adiabatic saturation temperatures (LADCO, 2005).

When coal is used as fuel, low to medium sulfur coals work best for conventional dry FGD because it inhibits high solids generation. Solids need to be kept under a certain threshold within the slurry to allow for atomization and to limit particulate emissions. Therefore, when higher sulfur fuels are used, wet FGD is preferred, which is described later in this section.

Advanced Flue Gas Desulfurization

Advanced flue gas desulfurization (AFGD) systems utilize a single absorber to accomplish three actions at once. Before entering the absorber, incoming flue gas is cooled and humidified with process wet suppression. As the quenched flue gas enters the absorber, reagent slurry is distributed via two tiers of fountain like sprays and onto a polymer grid packing that promotes gas/liquid contact. This is where SO_2 absorption, neutralization, and partial oxidation begins. The products formed are calcium sulfite and calcium sulfate. Slurry with absorbed SO_2 falls into the slurry reservoir below where unreacted acids are neutralized further by injected dry limestone powder. After going through the polymer grid packing, the flue gas continues onto a large gas/liquid disengagement zone above the slurry reservoir where the SO_2 has been absorbed and finally exiting through a horizontal mist eliminator.

Air is injected into the slurry in the reservoir through mixing with the use of an air rotary sparger which oxidizes the primary product, calcium sulfite, into gypsum. Fixed air spargers are also used to supplement complete oxidation. Slurry is recycled back to the absorber grid while the gypsum is drawn from the reservoir, dewatered, and washed to remove chlorides. The liquid generated by dewatering is returned to the reservoir with a slipstream headed to the wastewater evaporation system to be injected into the hot flue gas prior to the ESP which is located before the absorber. The gypsum created is wallboard quality gypsum which can be added in the final grinding process regulate concrete setting time. Particulate collected in the ESP consists of water evaporates and dissolved solids that can be collected for disposal or sale. SO_2 reduction through AFGD ranges from 95 to 99.5% (LADCO, 2005).

Wet Flue Gas Desulfurization

Wet FGD systems are most commonly used on boilers to treat the flue gas. SO_2 emissions can be reduced by 90 to 99% through the use of a wet FGD system (LADCO, 2005). Caustic, crushed limestone, and lime are used as scrubbing agents in wet FGD. In the presence of these agents, SO_2 from the exhaust gases is absorbed into the contact liquid. When caustic is used, liquid waste is produced and add-on waste collection equipment is minimal. When lime or limestone is used, additional steps and equipment are required to stabilize the watery calcium sulfite or calcium sulfate sludge produced. Fly ash is typically used to stabilize the calcium sulfite sludge. Calcium sulfate sludge can be dewatered but in order to create the calcium sulfate, an air injection blower is needed to supply oxygen necessary for the reaction to occur.

When directly applied to the exhaust gas stream, calcium sulfate scaling and cementitious buildup can occur when used for acid gas control. To prevent these issues from happening, a particulate control device can be installed. However, if the particulate control device fails this could impact the downstream wet scrubber.

3.4.2 Four Factor Analysis of Potential SO_2 Control Scenarios for Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

A four factor analysis approach has been utilized to analyze the potential control options presented in Table 3-3.

3.4.2.1 Cost of Compliance

Information on cost effectiveness of retrofitting controls onto boilers has been compiled from various sources. It is important to note that the values provided are estimated and actual retrofit control costs may be higher or lower depending on the utilization and size of the individual boiler as well as specific capital costs associated with the design.

Pre-combustion (e.g., fuel substitution) and combustion modifications (i.e. conversion to fluidized bed) were not discussed in detail in this assessment due to highly variable costs determined by individual boiler characteristics and functions.

Post-combustion SO_2 control costs can be impacted by scrubbing agent used, additional equipment required for promoting SO_2 reduction reactions, and the associated energy costs. Lime is generally the least expensive and most readily available. For the AFGD process, spargers and blowers are necessary to oxidize the waste product and additional equipment are required to dewater the gypsum hydrate. In order to keep the flue gas at an acceptable temperature in dry FGD, equipment like an evaporative cooler, a heat exchanger, or a heat recovery boiler will be needed. These additions will increase the costs with purchase, installation, and associated energy costs. However, costs may be offset with the sale of gypsum generated by AFGD. Wet FGD systems also provide another level of particulate control.

Table 3-4 summarizes the cost effectiveness and factors affecting cost of each control option addressed in this analysis. Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015. Please note that some costs may have decreased since the original analyses; however, this analysis has only used past data available.

Table 3-4 Cost Effectiveness for SO_2 Control Options for ICI Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities
Conventional Dry Flue Gas Desulfurization (FGD) – Dry Sorbent Injection[1]	Direct flue gas application, lime/calcium hydrate/limestone/soda ash injection, PM control device	$400-$1,200	Equipment, installation, engineering, reagent, and waste removal	All pulp and paper mill and beet manufacturing facility boilers
Conventional Dry Flue Gas Desulfurization (FGD) – Spray Dryer[1,2]	Absorption tower, lime slurry injection, PM control device	$1,900-$4,200	Equipment, installation, engineering, reagent, and waste removal	All pulp and paper mill and beet manufacturing facility boilers
Advanced Flue Gas Desulfurization (FGD)[2]	Lime slurry injection, PM control device	$1,500-$3,700	Equipment, installation, engineering, reagent, energy use, waste removal, and byproduct resale	All pulp and paper mill and beet manufacturing facility boilers
Wet Flue Gas Desulfurization (FGD)[1,2,3]	Caustic/crushed limestone/lime slurry, scrubber vessel pressure drop, air injection blower, PM control device	$2,200-$4,700	Equipment, installation, engineering, reagent, energy use, and waste removal	All pulp and paper mill and beet manufacturing facility boilers

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Applicability and Feasibility of NOx, SO_2, and PM Emissions Control Technologies for ICI Boilers*, NESCAUM, November 2008.
2. *Midwest Regional Planning Organization Boiler BART Engineering Analysis*, LADCO, March 2005.
3. *BART Determination - Georgia Pacific Broadway Mill, Green Bay Wisconsin*, Wisconsin DNR, July 2011.

3.4.2.2 Time Necessary for Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. MACT standards typically allow three years for compliance and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Combustion modifications and post-combustion NOx controls require significant time for engineering, construction, and facility preparedness. Two to five years would typically be appropriate, depending on the size of the unit and control options selected.

3.4.2.3 Energy and Non-Air Impacts

Post-combustion SO_2 controls can impact energy use and the environment in forms other than air quality. Non-air environmental impacts include solid, liquid, and/or hazardous waste generation and deposition of atmospheric pollutants on land or water. Dry FGD generates particulate that is collected by PM control devices that will need to be disposed. Wet FGD generates wastewater and sludge that increases a facility's wastewater treatment and solid waste management burdens. Even though AFGD generally creates commercial grade gypsum, gypsum that does not meet industry standards can be created due to fuels used.

Post-combustion SO_2 controls may also impact energy use for boilers. Wet FGD tends to consume more energy due to an operational pressure drop in the scrubber vessel. When systems utilize more reagent for the associated process, more energy consumption occurs. For some technologies, a flue gas reheater may be essential to the system thus increasing energy use.

3.4.2.4 Remaining Useful Life at the Source

The remaining useful life of an individual boiler can vary greatly depending on the age of the boiler, size of the unit, maintenance frequency, and other factors. Life expectancies for most boilers at pulp and paper mills and beet manufacturing facilities are between 10 and 30 years or more.

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The Lake Michigan Air Directors Consortium (LADCO). *Midwest Regional Planning Organization Boiler Best Available Retrofit Technology Engineering Analysis.* March 30, 2005.

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Wisconsin DNR. BART Determination – Georgia Pacific Broadway Mill, Green Bay Wisconsin. July 2011.

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4 Analysis of Selected Industrial, Commercial, and Institutional Boilers at Pulp and Paper Mills and Sugar Beet Manufacturing Facilities

4.1 Source Category Description

LADCO identified ten major facilities that contribute significant levels of NOx and SO_2 in the northern Midwest region. Amec Foster Wheeler was directed by LADCO to evaluate these ten individual facilities with respect to four key source categories that contribute to visibility impairment: ICI boilers at pulp and paper mills and sugar beet manufacturing facilities, cement plants, lime plants, and pipeline transportation of natural gas. Of these ten facilities, seven are pulp and paper mills or sugar beet manufacturing facilities with ICI boilers. Table 4-1 and Table 4-2 list ICI boiler units that were identified for each facility utilizing a confidential unit ID for which a key is provided in the informational disc included with this report. Baseline NOx and SO_2 emissions are provided for each unit.

4.2 Information Obtained from State Agencies

For the selected ICI boilers, Amec Foster Wheeler obtained current facility permits that were available online to evaluate the status of each unit. LADCO members provided supplemental information when permits were not readily available. Emissions inventory data for each facility were provided by each corresponding state.

Table 4-1 Source Category NOx Information Provided by LADCO

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	NOx Controls	Existing NOx Control Requirements	Baseline NOx Emissions (tpy)	Baseline Year
01-01	Boiler	202	Coal	Existing: None	None	263	2011
02-01	Boiler	660	Wood refuse, coal, natural gas	Existing: Over-fired air (OFA)	1. Heat Input Limit of 0.2 lb/mmBtu when firing NG; 0.70 lb/mmBtu (wood/coal) 2. 436.8 pound per hour (pph) when firing natural gas, wood, coal or any combination of these fuels including CVGs and/or DVGs	438	2011
03-01	Boiler	240	Pulverized coal, natural gas, biogas, No. 6 fuel oil	Existing: None	None	318	2011
03-02	Boiler	186	Pulverized coal, natural gas	Existing: None	Heat input limit of 0.2 lb/mmBtu when firing NG; 0.4 lb/mmBtu when firing No. 6 fuel oil; 0.7 lb/mmBtu when firing coal	91	2011
03-03	Boiler	227	Natural gas, biogas	Existing: Low-NOx burners	Heat input limit of 0.17 lb/mmBtu	47	2011
06-01	Boiler	356	Coal	Existing: None	Coke fines, used oil, and used oil sorbents fuel usage limits	360	2013

Table 4-1 Source Category NOx Information Provided by LADCO

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	NOx Controls	Existing NOx Control Requirements	Baseline NOx Emissions (tpy)	Baseline Year
06-02	Boiler	356	Coal	Existing: None	Coke fines, used oil, and used oil sorbents fuel usage limits	353	2013
08-01	Boiler	Unknown	Coal, wood	Existing: None	Heat input limit of 0.7 lb/mmBtu	219	2013
08-02	Boiler	Unknown	Coal, wood	Existing: None	Heat input limit of 0.7 lb/mmBtu	204	2013
09-01	Boiler	412.3	Coal, wood, NCG	Existing: None	Heat input limit of 0.8 lb/mmBtu	762	2011
09-02	Boiler	412.3	Coal, wood, NCG	Existing: None	Heat input limit of 0.8 lb/mmBtu	757	2011
10-01	Boiler	204	Bark, wood waste, paper pellets, natural gas, residual fuel oil, paper broke, TDF, sludge	Existing: None	None	40	2011
10-02	Boiler	192.4	Coal, pet coke, natural gas, No. 6 fuel oil, paper broke, TDF	Existing: None	None	391	2011
10-03	Boiler	379	Coal, pet coke, natural gas, No. 6 fuel oil, paper broke, TDF	Existing: None	None	1072	2011

Table 4-2 Source Category SO_2 Information Provided by LADCO

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	SO_2 Controls	Existing SO_2 Control Requirement	Baseline SO_2 Emissions (tpy)	Baseline Year
01-01	Boiler	202	Coal	Current: None Future: Sorbent Dry Absorber (SDA)	Sulfur content limit of 1.5% by weight	808	2011
02-01	Boiler	660	Wood refuse, coal, natural gas	Current: None	1. SO_2 limit of 476 pounds per hour (pph) 2. SO_2 limit of 1,016 pph when incinerating CVGs from the lime kiln to the boiler 3. Heat input limit of 1.2 lb/mmBtu when firing coal	401	2011
03-01	Boiler	240	Pulverized coal, natural gas, biogas, No. 6 fuel oil	Current: None	Heat input limit of 1.67 lb/mmBtu when firing coal; 1.11 lb/mmBtu when firing No. 6 fuel oil	632	2011
03-02	Boiler	186	Pulverized coal, natural gas	Current: None	Heat input limit of 1.67 lb/mmBtu when firing coal; 1.11 lb/mmBtu when firing No. 6 fuel oil	387	2011
06-01	Boiler	356	Coal	Current: None	Coke fines, used oil, and used oil sorbents fuel usage limits	312	2013
06-02	Boiler	356	Coal	Current: None	Coke fines, used oil, and used oil sorbents fuel usage limits	290	2013
08-01	Boiler	Unknown	Coal, wood	Current: None	Heat input limit of 1.2 lb/mmbtu	71	2013
08-02	Boiler	Unknown	Coal, wood	Current: None	Heat input limit of 1.2 lb/mmbtu	51	2013

Table 4-2 Source Category SO_2 Information Provided by LADCO

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	SO_2 Controls	Existing SO_2 Control Requirement	Baseline SO_2 Emissions (tpy)	Baseline Year
09-01	Boiler	412.3	Coal, wood, NCG	Current: None	1. Heat Input Limit of 1.2 lb/mmBtu when burning only wood waste and/or coal 2. Heat Input Limit of 1.2 lb/mmBtu when burning NCG, HVLC gas, and/or stripper off-gases 3. Heat Input Limit of 1.2 lb/mmBtu when burning used oil sorbents in combination with wood waste and/or coal 4. Heat Input Limit of 1.2 lb/mmBtu when burning used oil sorbents in combination with NCG, HVLC gas, and/or stripper off-gases	993	2011
09-02	Boiler	412.3	Coal, wood, NCG	Current: None	1. Heat Input Limit of 1.2 lb/mmBtu when burning only wood waste and/or coal 2. Heat Input Limit of 1.2 lb/mmBtu when burning NCG, HVLC gas, and/or stripper off-gases 3. Heat Input Limit of 1.2 lb/mmBtu when burning used oil sorbents in combination with wood waste and/or coal 4. Heat Input Limit of 1.2 lb/mmBtu when burning used oil sorbents in combination with NCG, HVLC gas, and/or stripper off-gases	915	2011

Table 4-2 Source Category SO_2 Information Provided by LADCO

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	SO_2 Controls	Existing SO_2 Control Requirement	Baseline SO_2 Emissions (tpy)	Baseline Year
10-02	Boiler	192.4	Coal, pet coke, natural gas, No. 6 fuel oil, paper broke, TDF	Current: None Future: Sorbent Injection System (for HCl control) with mandatory baghouse use	1. Heat input limit of 7 lb/mmBtu over 24 hours and 5.5 lb/mmBtu over 30 days 2. Combined SO_2 limit of 3865.4 lb/hr (over 24 hours) for No. 9 and No. 11 boilers 3. Sulfur content limit for No. 6 FO of 2.5% by weight 4. Sulfur content limit for coal blends of 4.4% by weight 5. Combined heat input limit of 1.7 lb/mmBtu for No. 9 and No. 11 boilers if the stack height is between 175 and 290 feet	1,786	2011
10-03	Boiler	379	Coal, pet coke, natural gas, No. 6 fuel oil, paper broke, TDF	Current: None Future: Sorbent Injection System (for HCl control) with mandatory baghouse use	1. Heat input limit of 7 lb/mmBtu over 24 hours and 5.5 lb/mmBtu over 30 days 2. Combined SO_2 limit of 3865.4 lb/hr (over 24 hours) for No. 9 and No. 11 boilers 3. Sulfur content limit for No. 6 FO of 2.5% by weight 4. Sulfur content limit for coal blends of 4.4% by weight 5. Combined heat input limit of 1.7 lb/mmBtu for No. 9 and No. 11 boilers if the stack height is between 175 and 290 feet	4,899	2011

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5 Source Category Analysis for Kilns Located at Cement and Lime Plants

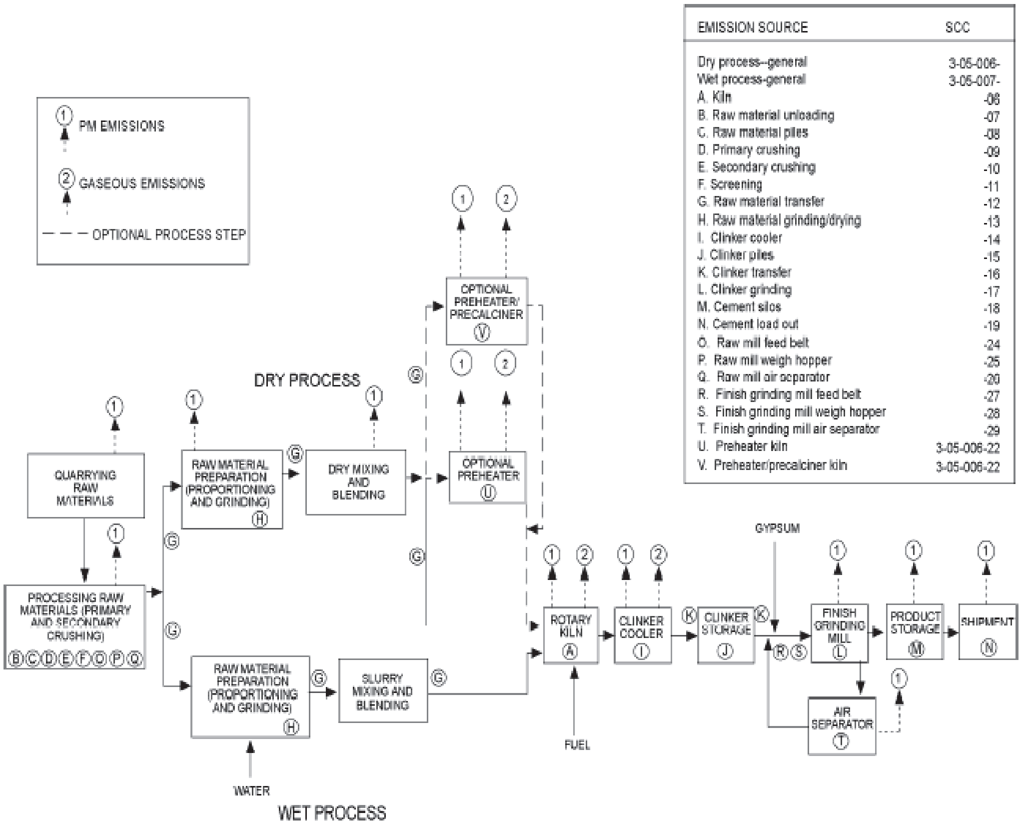
5.1 Source Category Description

The emission inventory and contribution assessment performed by LADCO demonstrated that NOx and SO_2 emissions were key contributors to visibility impairment in Class I areas in the LADCO States. Specifically, kilns located at cement and lime plants were identified as large contributors of both pollutants.

Portland cement is a main ingredient for concrete and other common building materials. Portland cement is mainly composed of clinker, a material formed by heating limestone and other ingredients to temperatures over 1,400ºC (2,650ºF). High combustion temperatures require large amounts of fuel and can result in significant emissions of SO_2 and NO_X. Crushing of ingredients and finished clinker can release dust and particles. Ammonia is sometimes produced during the heating of limestone.

Figure 5.1 shows a process flow diagram of a Portland cement facility. The process flow diagram (taken from AP-42) shows both wet and dry Portland cement processes.

Figure 5.1 Portland Cement Process Flow Diagram



EMISSION SOURCE	SCC
Dry process--general	3-05-006-
Wet process-general	3-05-007-
A. Kiln	-06
B. Raw material unloading	-07
C. Raw material piles	-08
D. Primary crushing	-09
E. Secondary crushing	-10
F. Screening	-11
G. Raw material transfer	-12
H. Raw material grinding/drying	-13
I. Clinker cooler	-14
J. Clinker piles	-15
K. Clinker transfer	-16
L. Clinker grinding	-17
M. Cement silos	-18
N. Cement load out	-19
O. Raw mill feed belt	-24
P. Raw mill weigh hopper	-25
Q. Raw mill air separator	-26
R. Finish grinding mill feed belt	-27
S. Finish grinding mill weigh hopper	-28
T. Finish grinding mill air separator	-29
U. Preheater kiln	3-05-006-22
V. Preheater/precalciner kiln	3-05-006-22

EPA. January, 1995. AP-42 Section 11.6 – “Portland Cement Manufacturing”.

The pyroprocessing step is the predominant source of gaseous pollutant emissions. In general, there are five different processes used in the Portland cement industry to accomplish the pyroprocessing step: the wet process, the dry process (long dry process), the semidry process, the dry process with a preheater, and the dry process with a preheater/precalciner.

In the long dry process, all of the pyroprocessing activity occurs in the rotary kiln. Dry process pyroprocessing systems have been improved in thermal efficiency and productive capacity through the addition of one or more cyclone-type preheater vessels in the gas stream exiting the rotary kiln. This system is called the preheater process. The vessels are arranged vertically, in series, and are supported by a structure known as the preheater tower. Hot exhaust gases from the rotary kiln pass countercurrently through the downward-moving raw materials in the preheater vessels. Compared to the simple rotary kiln (long dry process), the heat transfer rate is significantly increased, the degree of heat utilization is greater, and the process time is markedly reduced by the intimate contact of the solid particles with the hot gases. The improved heat transfer allows the length of the rotary kiln to be reduced. An added benefit of the preheater operation is that hot gases from the preheater tower are used to help dry raw materials in the raw mill. Because the catch from the mechanical collectors, fabric filters, and/or electrostatic precipitators (ESP) that follow the raw mill is returned to the process, these devices are also considered to be production units as well as pollution control devices.

Additional thermal efficiencies and productivity gains have been achieved by diverting some of the fuel to a calciner vessel at the base of the preheater tower. This system is called the preheater/precalciner process.

The final component of the pyroprocessing system is the clinker cooler. The clinker cooler serves two main purposes. First, this portion of the process:

- recoups up to 30% of the heat input to the kiln system;
- locks in desirable product qualities by freezing mineralogy; and
- makes it possible to handle the cooled clinker with conventional conveying equipment.

The more common types of clinker coolers are reciprocating grate, planetary, and rotary. In these coolers, the clinker is cooled from about 1,100°C to 90°C (2000°F to 200°F) by ambient air that passes through the clinker and into the rotary kiln for use as combustion air. However, in the reciprocating grate cooler, lower clinker discharge temperatures are achieved by passing an additional quantity of air through the clinker. Because this additional air cannot be used in the kiln for efficient combustion, it is vented to the atmosphere, used for drying coal or raw materials, or used as a combustion air source for the precalciner.

The second portion of the clinker process, a series of blending and grinding operations, completes the transformation of clinker into finished cement. Up to 5% gypsum or natural anhydrite is added to the clinker during grinding to control the cement setting time, and other specialty chemicals are added as needed to impart specific product properties. This finish milling is accomplished almost exclusively in ball or tube mills. Typically, finishing is conducted in a closed-circuit system, with product sizing by air separation.

Coal is the fuel of choice in cement kilns, primarily because of its low cost, but also because the coal ash contributes to the product. In addition to conventional fuels, many Portland cement facilities are employing the use of petroleum derived coke (petcoke) blended with coal to fire kilns. Our analysis of facilities in the LADCO states showed use of petcoke along with coal and other fuels.

Lime kilns are similar to cement kilns. The kiln is the heart of the lime manufacturing plant, where various fossil fuels (such as coal, petroleum coke, natural gas, and fuel oil) are combusted to produce the heat needed for calcination. There are five different types of kilns used in lime manufacturing: rotary, vertical, double-shaft vertical, rotary hearth, and fluidized bed. The most popular is the rotary kiln, however the double-shaft vertical kiln is an emerging new kiln technology gaining in acceptance primarily due to its energy efficiency. Similar to cement plants, rotary kilns at lime manufacturing plants may also have preheaters to improve energy efficiency. Additionally, energy efficiency is improved by routing exhaust from the lime cooler to the kiln. SO_2 emissions from lime predominately originate from compounds in the limestone feed material and fuels and are formed from the combustion of fuels and the heating of feed material in the kiln.

All types of kilns at lime manufacturing plants use external equipment to cool the lime product, except vertical (including double-shaft) kilns, where the cooling zone is part of the kiln. Ambient air is most often used to cool the lime (although a few use water as the heat transfer medium), and typically all of the heated air stream exiting the cooler goes to the kiln to be used as combustion air for the kiln. The exception to this is the grate cooler, where more airflow is generated than is needed for kiln combustion, and consequently a portion (about 40%) of the grate cooler exhaust is vented to the atmosphere. EPA has estimated that there are about five to ten kilns in the United States that use grate coolers. The emissions from grate coolers include lime dust (PM) and trace metallic HAPs found in the lime dust, but not typically SO_2.

5.2 NOx from Kilns Located at Cement and Lime Plants

5.2.1 <u>NOx Emissions and Control Options</u>

Kilns emit a mixture of fuel and thermal NOx with a small portion coming from feed and prompt NOx. Predominance of thermal and fuel NOx in cement and lime kiln combustion depends on fuel being used and kiln design. Nitrogen content in fuel, fuel efficiency, and combustion temperatures impact NOx creation.

Due to multiple factors affecting NOx formation from combustion, there are different methods of reducing or controlling NOx emissions in kilns. The potential control types can be categorized into the following three categories: pre-combustion NOx controls, combustion modifications, and post-combustion NOx controls. Pre-combustion NOx controls include fuel substitution. This assessment does not analyze fuel switching as the costs are highly variable, and feasibility is dependent on individual kiln characteristics and functions. Combustion modifications in kilns are changes to one or more controllable variables in the combustion process itself, such as restriction of oxygen, flame temperature and/or residence time. Post-combustion NOx controls utilize add-on control technologies to decrease the amount of formed NOx before the combustion air is released to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the PSD program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of kiln, fuel(s) used, heat input capacity, and mode of operation.

For cement kilns, control technology options identified for NOx include tuning/optimization, LNB, indirect firing, mid-kiln firing, SCR, RSCR, and SNCR. For lime manufacturing kilns, process tuning and/or optimization are currently the best control options. Cement kiln NOx control options cannot be applied to lime manufacturing kilns due to smaller scale operation, different raw materials, and process conditions. Table 5-1 summarizes appropriate NOx control options for cement and lime manufacturing kilns.

Table 5-1 Potential NOx Control Options for Cement and Lime Manufacturing Kilns

Technology	Description	Applicability	Performance
Tuning/Optimization[3]	Process optimizing such as flame shaping and temperature profile	Potential control measure for all cement and lime manufacturing kilns	Varies
LNB[1]	Advanced burner design that controls oxygen, flame temperature, and/or residence time	Potential control measure for all cement and lime manufacturing kilns	10-20% reduction in NOx (for cement kilns; no data was found for lime kilns)
LNB + Indirect Firing[1,2]	Advanced burner design that controls oxygen, flame temperature, and/or residence time with controlled fuel feed	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	10-40% reduction in NOx
Mid-Kiln Firing[3]	Injecting solid fuel (usually TDF) into mid-point of kiln system	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	11-55% reduction in NOx
LNB + Mid-Kiln Firing[1]	Advanced burner design that controls oxygen, flame temperature, and/or residence time with fuel injection at mid-point of kiln system	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	45% reduction in NOx
SCR[1,2,4,5]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas in the presence of a catalyst	Potential control measure for all preheater and preheater/precalciner cement kilns; dependent on fuels burned, kiln use, and kiln configuration	70 – 90% reduction in NOx
RSCR[4]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas in the presence of a catalyst and heat exchangers	Potential control measure for all preheater and preheater/precalciner cement kilns; dependent on fuels burned, kiln use, and kiln configuration	75% reduction in NOx
SNCR[4]	A reducing agent such as ammonia is introduced into the flue gas stream to form nitrogen gas	Potential control measure for all preheater and preheater/precalciner cement kilns; dependent on fuels burned, kiln use, and kiln configuration	45% reduction in NOx

Table references:
1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Supplementary Information for Four Factor Analyses by WRAP States*, WRAP and WGQ, May 2009.
4. *Control Technology Analysis for Carolinas Cement Company LLC*. Environmental Quality Management, Inc., Feb 2008.
5. *Attachment to Letter, RE: National Association of Clean Air Agencies*. Docket ID No. EPA-HQ-OAR-2007-0877, Sep 2008.

5.2.1.1 Combustion Modifications

Tuning/optimization

Kiln tuning and optimization is a baseline NOx control that applies to both cement and lime manufacturing. This pre-combustion control includes improving fuel efficiency and tweaking with the kiln design to reduce NOx emissions. Tuning/optimization is currently the most cost effective control for lime manufacturing kilns. Efficiency and cost effectiveness of this pre-combustion NOx control is difficult to quantify as designs and processes are highly variable.

Low NOx Burners (LNB)/Indirect Firing

LNB reduce NOx formation by controlling oxygen, flame temperature, and/or residence time. There are two general types of LNB: staged fuel and staged air. Staged fuel LNBs separate the combustion zone into a lean primary combustion region and a secondary combustion region. In the first zone, combustion takes place in excess oxygen, a small amount of fuel, and low burner temperatures. The remainder of the fuel is injected into the second zone and is mixed diffusively (as opposed to turbulently) with any remaining oxygen from the first combustion step for best NOx reduction results. Staged fuel LNBs work particularly well for coal and natural gas kilns which exhibit higher thermal NOx formation. Staged air LNB increases residence time and thus is more effective for fuel oil kilns which produce higher fuel NOx emissions. LNBs can be used on all types of cement and lime manufacturing kilns except for vertical kilns (used in lime manufacturing) which are flameless.

Indirect firing systems are a type of combustion modification that utilizes pulverized fuel and transports the fuel to the burner via a dense phase conveying system which reduces air volume. This process creates a fuel rich flame which in turn decreases oxygen that is necessary in NOx formation. LNB can be used in collaboration with indirect firing and has control efficiencies of 10 to 40 percent. When only LNB is applied to cement kilns, a reduction in 10-20 percent is observed (LADCO, 2005). No specific data was found for lime manufacturing kilns in respect to LNB. Indirect firing with LNB can be used on all systems in cement production. However, indirect firing has not been shown to reduce formation of NOx in lime kilns (National Lime Association, 2005).

Mid-Kiln Firing

In mid-kiln firing, fuel is injected near the mid-point of the kiln using a feed fork, pivoting doors, and a drop tube that extends into the kiln wall. Fuel injection occurs once in a revolution. Typically, fuel with low fuel NOx is used (e.g. TDF). This combustion modification reduces the heat needed thus leading to a reduction in thermal NOx formation. Mid-kiln firing has been used in long wet and dry kilns but can also be used in preheater and preheater/precalciner systems. With preheater and preheater/precalciner systems, fuel is introduced into the riser duct using a drop chute with an airlock which causes combustion to be initiated in the riser duct which is located between the calciner and rotary kiln. Combustion continues within the rotary kiln section away from the high temperatures of the main kiln burner. Mid-kiln firing on its own can reduce NOx from 11 to 55 percent depending on fuel used and kiln design (EC/R Incorporated, 2009). Paired with a LNB, up to a 45 percent reduction has been noted (LADCO, 2005).

Mid-kiln firing cannot be applied to lime manufacturing kilns as the control can negatively impact the lime product. It will increase carry-over of unburned carbon into the product thus reducing its use in certain applications (National Lime Association, 2005).

5.2.1.2 Post-Combustion NOx Controls

Selective Catalytic Reduction (SCR)

In SCR, anhydrous ammonia is injected into NOx containing exhaust gas and directed through a catalyst bed to reduce NOx to nitrogen and water. Catalysts typically used include vanadium pentoxide, zeolite, or titanium dioxide. To complete the reaction, a temperature range of 480° - 800°F is required. Due to this temperature requirement, SCR application works best for preheater and/or precalciner kilns and can be applied to other types of cement kilns. The catalyst bed can be placed after the preheater tower before or after the PM control device. SCR placement is important and leads to control design decisions. If the SCR is placed at the preheater tower, temperature requirements are met but the catalyst is subject to fouling by particulate, alkalis, lime, and sulfur dioxide in cement kiln gases. Fouling can cause the catalyst to become unreactive, thus allowing injected ammonia to escape through the system which is known as ammonia slip. There are sulfur tolerant SCR catalysts available that can limit SO_2 oxidation to less than 1 percent (LADCO, 2005). Particulate accumulation can be reduced with soot blowers. If the SCR is placed after the PM control device, reheating of exhaust gases will be required for the catalyst reaction. Application of SCR on cement kilns does not currently exist in North America but a long-term pilot project (Kirchdorf, Austria) along with three industrial applications (Solnhofen, Germany, Monselice, Italy, and Sarche di Calavino, Italy) exist in Europe (Environmental Quality Management, Inc., 2008). SCR NOx reduction observed ranges from 70 to 90 percent.

Regenerative Selective Catalytic Reduction (RSCR)

RSCR™ is SCR with heat recovery. Industrial scale utility boilers burning biomass fuels have been shown to successfully utilize RSCR to control NOx emissions. When installed on utility boilers, a heat exchanger system increases flue gas temperature before the gases enter the combustion chamber. Within the combustion chamber the temperature increases prior to entering the catalyst bed. Ammonia solution is injected prior to the catalyst. Babcock Power, Inc. has developed a RSCR system that is placed after the primary PM control. RSCR has not been applied to cement kilns but could be applied assuming technology transfer with a calculated 75 percent NOx reduction (Environmental Quality Management, Inc., 2010). RSCR application would work best for preheater and/or precalciner kilns because of the temperature requirement.

Selective Non-Catalytic Reduction (SNCR)

SNCR is another control option that is dependent on kiln type. Ammonia-containing solution (e.g. anhydrous ammonia, aqueous ammonia, or urea) is injected into the preheater tower for NOx reduction. Optimum temperature ranges from 1600° to 2000°F which must be maintained for the reaction to occur. At lower temperatures, the reaction rates slow and increases the chance of ammonia slip, although it is noted that a minimum of 5 ppm ammonia slip may still occur during normal SNCR processes (Environmental Quality Management, Inc., 2008). If temperatures exceed the optimal range, the reactions do not occur and ammonia or urea reagent will oxidize and result in even greater NOx emissions. SNCR secondary reactions can form precipitate which can foul the preheater and interrupt kiln processes. Exercising caution with ammonia input quantity and adding wet scrubbing can help reduce ammonia emissions.

As is the case with SCR, SNCR works best when applied with preheater and preheater/precalciner kilns with NOx reductions of 45 percent (Environmental Quality Management, Inc., 2008). SNCR has been used in both Europe and the US. SNCR is used in two precalciner plants in Sweden and at least 17 preheater plans mostly in Germany (Environmental Quality Management, Inc., 2010). The low cost ammonia reagent generally used in Europe is photowater, a waste product of film development containing 5.0 percent ammonia. In the US, SNCR systems are used in several preheater/precalciner plants with ammonia water or urea solution being used as the reagent.

5.2.2 Four Factor Analysis of Potential NOx Control Scenarios for Cement and Lime Kilns

5.2.2.1 Cost of Compliance

To compare the various control options, information has been compiled on the cost effectiveness of retrofitting controls. As a rule of thumb, cost effectiveness increases with the amount of cement or lime produced by the facility.

For this assessment, cost effectiveness was pulled from various sources, compiled into a general range, and converted into 2015 dollars. This information is summarized in Table 5-2. Please note that the ranges will vary less than what is shown depending on the size and type of kiln.

Factors contributing to capital costs include installation costs, control hardware, and additional add-ons required due to site-specific conditions. LNB with mid-kiln/indirect firing generally will be more cost effective than the current post combustion control options. When LNB is applied to preheater/precalciner kilns, costs are generally lower than long dry kilns. However due to less pollutants emitted from preheater/precalciner kilns than dry kilns, the cost values are slightly higher for the former type when comparing similar sized facilities. With mid-kiln firing, operating costs could be offset by refuse tipping fees for TDF. Site specific factors can impose additional costs.

An SCR system includes catalyst materials; the ammonia system including a vaporizer, storage tank, blower or compressor, and various valves, indicators, and controls; the ammonia injection grid; the SCR reactor housing (which contains the catalyst); transition ductwork; and a continuous emissions monitoring system. The decision to use aqua ammonia or urea instead of anhydrous ammonia can play a small role in affecting costs because. Aqua ammonia and urea have higher capital and operating costs. The SCR system may require additional particulate removal equipment and associating ductwork depending on site specific factors. If the exhaust gas temperature range entering the SCR does not meet the optimal catalyst temperature requirements, modifications may have to be made to increase/decrease the temperature. Additional gas cleaning may be required to maintain the SCR as well as a bypass installation to protect the SCR during startup, shutdown, and malfunction which could potentially foul the catalyst. A preheater/precalciner kiln is generally more cost effective when compared to a dry kiln.

Table 5-2 Cost Effectiveness for NOx Control Options for Cement and Lime Manufacturing Kilns

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
Tuning/Optimization[3]	None	Low	Engineering and contractor costs	04-01, 05-01
LNB[1]	None	No data	Equipment, installation, and engineering	04-01, 05-01
LNB + Indirect Firing[1,2]	Specific temperature range, oxygen levels, and flame length	$200-$21,100	Equipment, installation, and engineering	05-01
Mid-Kiln Firing[3]	Specific fuel injection location	$600-$3,600	Equipment, installation, and engineering	05-01
LNB + Mid-Kiln Firing[1]	Specific temperature range, specific fuel injection, oxygen levels, and flame length	No data	Equipment, installation, and engineering	05-01
SCR[1,2,4,5]	Specific temperature range; PM reduction, ammonia injection, catalyst bed	$600-$17,700	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	05-01
RSCR[4]	Specific temperature range, PM reduction, ammonia injection, catalyst, heat recovery, preheater kiln	$5,500	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	None
SNCR[4]	Specific temperature range; PM reduction, ammonia injection, preheater kiln	$1,400	Equipment, installation, engineering, energy use, waste removal, and reduction agent	None

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Supplementary Information for Four Factor Analyses by WRAP States*, WRAP and WGQ, May 2009.
4. *Control Technology Analysis for Carolinas Cement Company LLC*. Environmental Quality Management, Inc., Feb 2008.
5. *Attachment to Letter, RE: National Association of Clean Air Agencies*. Docket ID No. EPA-HQ-OAR-2007-0877, Sep 2008.

5.2.2.2 Time Necessary for Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. MACT standards typically allow three years for compliance and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Under the NOx SIP Call for Phases I and II, EPA allowed for three and a half and two years, respectively, after the SIP submittal date for compliance. Combustion modifications and post-combustion NOx controls require significant time for engineering, construction, and facility preparedness. After SIP submittal, a two year period is assumed to be adequate for pre-combustion controls and a three year period for post combustion control installation. Substantially less time would be required for boiler optimization and tuning which can be implemented within a few months to a year.

5.2.2.3 Energy and Other Impacts

When SCR, RSCR, and SNCR conditions are not met (e.g., temperature range), the required reactions to promote NOx reduction do not occur thus leading to ammonia slip or an increase in particulate emissions. In the presence of a catalyst, the increase in particulate emissions can potentially foul the catalyst. With ammonia slip, ammonia is permitted through the stack to react with sulfur and nitrogen oxides to form particulate, thus, contributing to regional haze. Ammonia slip can also contaminate surface waters by deposition. For SCR, RSCR, and SNCR, storage of anhydrous ammonia is accompanied with more environmental and safety risk than with aqueous ammonia or urea storage. Additionally, spent catalyst beds will need to be changed periodically resulting an increase in waste disposal.

With LNB, flame efficiency can be impacted thus increasing fuel consumption. Vendors claim that new LNB designs do not lower fuel efficiency so a small increase in fuel consumption may occur. If catalyst bed or reaction temperatures are not met for post-combustion controls, additional fuel or electrical power may be required to heat or cool the gas stream.

5.2.2.4 Remaining Equipment Life

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, the remaining useful life of each emission unit is a minimum of at least 10 years. With proper maintenance and upkeep, some units can operate for 20-30 years more.

REFERENCES

EC/R Incorporated. *NOx Control Technologies for the Cement Industry*. September 19, 2000.

Environmental Quality Management, Inc. *Control Technology Analysis Prepared for Carolinas Cement Company LLC.* February 25, 2008.

The Lake Michigan Air Directors Consortium (LADCO). *Midwest Regional Planning Organization Cement Best Available Retrofit Technology Engineering Analysis.* March 30, 2005.

Mid-Atlantic Regional Air Management Association, Inc (MARAMA). *Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I Areas*. July 9, 2007.

National Lime Association. *Re: Comments on VISTAS's Draft Regional Haze Modeling Protocol.* October 21, 2005.

5.3 SO_2 from Kilns Located at Cement and Lime Plants

5.3.1 SO_2 Emissions and Control Options

Sulfur dioxide is formed from sulfur in fuels and raw materials. Sulfur content in fuels and raw materials can vary according to geographic location. In contrast to industrial boilers, SO_2 emissions from cement and lime manufacturing kilns are not strongly dependent on fuel sulfur content but rather the amount of sulfide (e.g., pyrite) in kiln feedstocks and the molar ratio of total sulfur to total alkali input to the system. Oxidizing or reducing conditions and their location within the kiln as well as temperature profile in the kiln system can impact SO_2 emissions. Additionally, inherent reduction of SO_2 emissions occurs in both cement and lime production due to the alkaline nature of cement and limestone which promotes direct absorption of SO_2 into the product.

Potential control types can be categorized into the following three categories: pre-combustion SO_2 controls, combustion modifications, and post-combustion SO_2 controls. Pre-combustion SO_2 controls include fuel substitution. This assessment does not analyze the cost effectiveness of fuel switching because costs are highly variable and SO2 emissions are not strongly dependent on sulfur content in fuel but rather on the sulfur content in kiln feedstock. Combustion modifications are changes to one or more controllable variables in the combustion process itself. Retrofit combustion modifications exist but are very invasive and may be possible for only a small number of existing kilns. For this reason, these modifications are not assessed in this report. Post-combustion SO_2 controls utilize add-on control technologies to decrease the amount of formed SO_2 before the combustion air is release to the atmosphere. It should be noted that certain physical or operational changes to a source may require analysis under the Prevention of Significant Deterioration (PSD) program. It should also be noted that the potentially applicable controls for any one source are highly dependent on the type of kiln, fuel(s) used, heat input capacity, and mode of operation.

SO_2 emission reductions may also result from attempts to reduce other pollutants (primarily NO_X), typically due to changes in the flame characteristics of combustion. For example, staged combustion with mid-kiln injection of a low-sulfur fuel may be considered for reducing SO_2 in cement kilns. Since these techniques are primarily used to reduce NO_X and because their efficiencies are typically more limited than other techniques they are not considered in additional detail here.

Table 5-3Table 5-1 summarizes appropriate SO_2 control options for cement and lime manufacturing kilns.

Table 5-3 Potential SO_2 Control Technologies for Cement and Lime Manufacturing Kilns

Technology	Description	Applicability	Performance
Conventional Dry Flue Gas Desulfurization (FGD) – Dry Sorbent Injection[1,2,3,4]	An absorbent reagent such as lime slurry is introduced into the flue gas stream through direct injection to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	25-50% reduction in SO_2
Conventional Dry Flue Gas Desulfurization (FGD) – Spray Dryer[1,5,6]	An absorbent reagent such as lime, calcium hydrate, limestone or soda ash is introduced into the flue gas stream through spray in an absorption tower to absorb SO_2, creating a dry solid which is caught in a downstream fabric filter or ESP	Potential control measure for all cement and lime manufacturing kilns; dependent on fuels burned, kiln use, and kiln configuration	90-95% reduction in SO_2
Advanced Flue Gas Desulfurization (FGD)[1]	A slurry reagent is sprayed onto cooled/humidified flue gas to absorb SO_2, creating calcium sulfate that is oxidized to create wallboard-grade gypsum	Potential control measure for all cement kilns; dependent on fuels burned, kiln use, and kiln configuration	95-99.5% reduction in SO_2
Wet Flue Gas Desulfurization (FGD)[1,2,3,4,5,6]	A scrubbing reagent such as caustic, crushed limestone, or lime is introduced into the flue gas stream to absorb SO_2, creating liquid or sludge waste	Potential control measure for all cement and lime manufacturing kilns; dependent on fuels burned, kiln use, and kiln configuration	40-99% reduction in SO_2

Table references:
1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Prevention of Significant Air Quality Deterioration Review Preliminary Determination - CEMEX Southeast, LLC,* Georgia EPD, December 2008.
4. *Control Technology Analysis for Carolinas Cement Company LLC*, Environmental Quality Management, Inc., February 2008.
5. *Technical Evaluation & Preliminary Determination - Jacksonville Lime LLC*, Florida DEP, December 2013.
6. *Subject: Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504).* VA DEQ, April 2014.

5.3.1.1 Flue Gas Desulfurization (FGD)

For cement kilns, control technology options identified for SO_2 include conventional dry FGD, wet FGD, and AFGD. For lime manufacturing kilns, both spray dry FGD and wet FGD control options have been suggested. Descriptions of each of these technologies are provided below. A summary of these controls is provided in Table 5-3.

Conventional Dry Flue Gas Desulfurization

There are two types of conventional dry FGD controls: dry sorbent injection (DSI) and spray dryer absorption (SDA) systems.

In DSI, lime, calcium hydrate, limestone or soda ash is injected into the flue gas stream producing solid particles of $CaSO_3$ or $CaSO_4$. These particles and excess reagent are removed from the gas stream using a particulate control device. SO_2 removal efficiency typically ranges from 25-50 percent and depends on absorbent injection location, temperature, degree of mixing, retention time, kiln type, and additional add-ons. Depending on site-specific processes, DSI systems can and have been applied to cement kilns. While technically feasible with lime kilns, there have not been any applications on lime kilns identified (VA DEQ, 2014).

In a SDA system, lime slurry is sprayed into an absorption tower where SO_2 is absorbed into the slurry, forming a mixture of calcium sulfite and calcium sulfate. The water evaporates before the droplets reach the bottom of the tower due to the liquid-to-gas ratio. The dry solids created due to the evaporation are collected with a fabric filter or ESP. When applied to cement kilns, spray dryers are expected to reduce SO_2 emissions by 90 to 95 percent (LADCO, 2005). A lime manufacturing facility indicates that 90 percent reduction takes place when spray dryers are applied to lime plant kilns (VA DEQ, 2014).

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, SDA systems are typically applied to preheater or preheater/precalciner kilns in the cement industry. In long dry kilns, two methods are used to cool down exhaust gases. Spray water is introduced into the feed end of the kiln or by dilution air-cooling once the gases leave the kiln. An SDA equivalent application for long dry kilns is to use a conditioning tower to replace the method of cooling and pair with an alkaline slurry system to reduce SO_2 emissions. For long wet kilns, an SDA system should be applied with care because the addition of the lime slurry may drop the exhaust gases temperature below acid adiabatic saturation temperatures, plugging and causing corrosion problems in the downstream particulate control device, duct work, and induced draft fan (LADCO, 2005).

It must be noted that exhaust gases that exit at or near the adiabatic saturation temperatures can create problems with dry FGD by causing the baghouse filter cake to become saturated with moisture and plug both the filters and the dust removal system. In addition, the lime slurry would not dry properly and would plug up the dust collection system. However some argue that SO_2 removal actually occurs on the filter cake. Ultimately it is important that exit gas temperatures are above the adiabatic saturation temperatures (LADCO, 2005).

Advanced Flue Gas Desulfurization (FGD)

AFGD utilizes a single absorber to accomplish three actions at once. Before entering the absorber, incoming flue gas is cooled and humidified with process wet suppression. As the quenched flue gas enters the absorber, reagent slurry is distributed via two tiers of fountain like sprays and onto a polymer grid packing that promotes gas/liquid contact. This is where SO_2 absorption, neutralization, and partial oxidation begins. The products formed are calcium sulfite and calcium sulfate. Slurry and absorbed SO_2 fall into the slurry reservoir where unreacted acids are neutralized further by injected dry limestone powder.

Meanwhile, air is injected into the slurry through mixing with the use of an air rotary sparger which oxidizes the primary product, calcium sulfite, into gypsum. Fixed air spargers are also used to supplement complete oxidation. Slurry is recycled back to the absorber grid while the gypsum is drawn from the reservoir, dewatered, and washed to remove chlorides. The liquid generated by dewatering is returned to the reservoir with a slipstream headed to the wastewater evaporation system to be injected into the hot flue gas prior to the ESP which is placed before the absorber. The gypsum created wallboard quality gypsum which can be added in the final grinding process regulate concrete setting time. Particulate collected in the ESP consist of water evaporates and dissolved solids that can be collected for disposal or sale.

After going through the polymer grid packing, the flue gas continues onto a large gas/liquid disengagement zone above the slurry reservoir where the SO_2 has been absorbed and finally exiting through a horizontal mist eliminator.

AFGD has not been used in cement kilns before. In the Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, MACTEC recommends the use of an AFGD system because it is similar to wet FGD and can produce commercial grade gypsum. AFGD control efficiency ranges from 95 to 99.5 percent (LADCO, 2005). No supporting information was found that indicated that present or potential use of AFGD in lime manufacturing kilns.

Wet Flue Gas Desulfurization (FGD)

Caustic, crushed limestone, and lime are used as scrubbing agents in wet FGD. In the presence of these agents, SO_2 from the exhaust gases is absorbed into the contact liquid. When caustic is used, liquid waste is produced and add-on waste collection equipment is minimal. When lime or limestone is used, additional steps and equipment are required to stabilize the watery calcium sulfite or calcium sulfate sludge produced. Fly ash is typically used to stabilize the calcium sulfite sludge.

Calcium sulfate sludge can be dewatered but in order to create the calcium sulfate, an air injection blower is needed to supply oxygen necessary for the reaction to occur. In cement kilns, SO_2 reduction efficiency ranges from 40 to 99 percent. A lime manufacturing facility indicates that 95 percent reduction takes place when wet FGD systems are applied to lime plant kilns (VA DEQ, 2014).

When directly applied to the exhaust gas stream, calcium sulfate scaling and cementitious buildup can occur when used for acid gas control. To prevent these issues from happening, a particulate control device can be installed. However, if the particulate control device fails this could impact the downstream wet scrubber.

5.3.2 Four Factor Analysis of Potential SO_2 Control Scenarios For Kilns

A four factor analysis approach has been utilized to analyze the potential control options presented in Table 5-3.

5.3.2.1 Cost of Compliance

Information on cost effectiveness of retrofitting controls onto kilns has been compiled from various sources. It is important to note that the values provided are estimated and actual retrofit control costs may be higher or lower depending on the utilization and production scale of the kiln as well as specific capital costs associated with the design.

Pre-combustion (e.g., fuel substitution) and combustion modifications were not discussed in detail in this assessment due to highly variable costs determined by individual kiln characteristics and functions.

Post-combustion SO_2 control costs can be impacted by scrubbing agent used, additional equipment required for promoting SO_2 reduction reactions, and the associated energy costs. Lime is generally less expensive and readily available. However, if other scrubbing agents are used this could increase costs. For the AFGD process, spargers and blowers are necessary to oxidize the waste product and additional equipment are required to dewater the gypsum hydrate. In order to keep the flue gas above adiabatic saturation in dry FGD, equipment like an evaporative cooler, a heat exchanger, or a heat recovery boiler will be needed. These additions will run up the costs with purchase, installation, and associated energy costs. However, costs may be offset with the sale of gypsum generated by AFGD. Wet FGD systems also provide another level of particulate control.

In assessing cost effectiveness of SO_2 controls for lime plants, PSD evaluations of two lime plants, Jacksonville Lime LLC (Florida) and Carmeuse Lime & Stone (Viriginia), were found. In each PSD analysis, both the state and the facility agreed that application of SO_2 controls may not be cost effective due to inherent scrubbing of SO_2 within the process.

Table 5-4 summarizes the cost effectiveness and factors affecting cost of each control option addressed in this analysis, as well as potential applicability to the specific facilities analyzed as part of this report. Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015. Please note that some costs may have decreased since the original analyses; however, this analysis has only used past data available. A confidential key to the unit IDs is provided on the informational disc included with this report. It must be pointed out that the cost effective ranges for cement kilns vary greatly. This range includes both long dry kilns and preheater/precalciner kilns, the latter of which exhibits higher cost per ton of SO_2.

Table 5-4 Cost Effectiveness for SO_2 Control Options for Cement and Lime Manufacturing Kilns

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
Conventional Dry Flue Gas Desulfurization (FGD) – Dry Sorbent Injection[1,2,3,4]	Direct flue gas application, lime/calcium hydrate/limestone/soda ash injection, PM control device	$2,400-$9,000 (cement)	Equipment, installation, engineering, reagent, and waste removal	05-01
Conventional Dry Flue Gas Desulfurization (FGD) – Spray Dryer[1,5,6]	Absorption tower, lime slurry injection, PM control device	$11,00 (lime) $2,300-$88,800 (cement)	Equipment, installation, engineering, reagent, and waste removal	04-01, 05-01
Advanced Flue Gas Desulfurization (FGD)[1]	Lime slurry injection, PM control device	$2,400-$47,100 (cement)	Equipment, installation, engineering, reagent, energy use, waste removal, and byproduct resale	05-01
Wet Flue Gas Desulfurization (FGD) [1,2,3,4,5,6]	Caustic/crushed limeston/lime slurry, scrubber vessel pressure drop, air injection blower, PM control device	$10,000 (lime) $1,500-$78,800 (cement)	Equipment, installation, engineering, reagent, energy use, and waste removal	04-01, 05-01

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Midwest Regional Planning Organization Cement BART Engineering Analysis*, LADCO, March 2005.
2. *BART Determination Support Document for Lafarge North America Seattle Plant*, Washington State Department of Ecology, October 2008.
3. *Prevention of Significant Air Quality Deterioration Review Preliminary Determination - CEMEX Southeast, LLC,* Georgia EPD, December 2008.
4. *Control Technology Analysis for Carolinas Cement Company LLC*, Environmental Quality Management, Inc., February 2008.
5. *Technical Evaluation & Preliminary Determination - Jacksonville Lime LLC*, Florida DEP, December 2013.
6. *Subject: Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504).* VA DEQ, April 2014.

5.3.2.2 Time Necessary for Compliance

Sources are generally given between two and five years to implement changes for compliance with new regulations. MACT standards typically allow three years for compliance and BART emission limitations require compliance no more than five years after regional haze SIP approval by the EPA. Combustion modifications and post-combustion controls require significant time for engineering, construction, and facility preparedness. Two to five years would typically be appropriate, depending on the size of the unit and control options selected.

5.3.2.3 Energy and Non-Air Impacts

Post-combustion SO_2 controls can impact energy use and the environment in forms other than air quality. Non-air environmental impacts include solid, liquid, and/or hazardous waste generation and deposition of atmospheric pollutants on land or water. Dry FGD generates particulate that is collected by PM control devices that will need to be disposed. Wet FGD generates wastewater and sludge that increases a facility's wastewater treatment and solid waste management burdens. Even though AFGD generally creates commercial grade gypsum, gypsum that does not meet industry standards can be created due to fuels used.

Post-combustion SO_2 controls may also impact energy use for kilns. Wet FGD tends to consume more energy due to an operational pressure drop in the scrubber vessel. When systems utilize more reagent for the associated process, more energy consumption occurs. For some technologies, a flue gas reheater may be essential to the system thus increasing energy use.

5.3.2.4 Remaining Useful Life at the Source

According to MARAMA's Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I areas, the remaining useful life of each emission unit is a minimum of at least 10 years. With proper maintenance and upkeep, some units can operate for 20-30 years more.

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Commonwealth of Virginia Department of Environmental Quality (VA DEQ). *Subject: Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504)*. April 22, 2014.

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Florida Department of Environmental Protection. *Technical Evaluation & Preliminary Determination; Applicant Jacksonville Lime LLC.* December 31, 2013.

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Mid-Atlantic Regional Air Management Association, Inc (MARAMA). *Assessment of Reasonable Progress for Regional Haze in MANE-VU Class I Areas*. July 9, 2007.

VA DEQ. *Subject: Engineering Evaluation of Prevention of Significant Deterioration Permit Application Submitted by Carmeuse Lime & Stone for its Winchester Facility (Registration No. 80504).* April 2014.

Washington State Department of Ecology. *BART Determination Support Document for Lafarge North America Seattle Plant.* October 2008.

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6 Analysis of Selected Kilns Located at Cement and Lime Plants

6.1 Source Category Description

LADCO identified ten major facilities that contribute significant levels of NOx and SO_2 in the northern Midwest region. Amec Foster Wheeler was directed by LADCO to evaluate these ten individual facilities with respect to four key source categories that contribute to visibility impairment: ICI boilers at pulp and paper mills and sugar beet manufacturing facilities, cement plants, lime plants, and pipeline transportation of natural gas. Of these ten facilities, two are cement and lime plant sources. Table 6-1 and Table 6-2 list cement and lime kiln units that were identified for each facility utilizing a confidential unit ID. Baseline NOx and SO_2 emissions are provided for each unit.

6.2 Information Obtained From State Agencies

For the selected cement and lime plants, Amec Foster Wheeler obtained current facility permits that were available online to evaluate the status of each unit. LADCO representatives provided supplemental information when permits were not readily available. Emissions inventory data for each facility were provided by each corresponding state.

Table 6-1 Point Source NOx Information Collected for Select Cement and Lime Kilns in the LADCO Region

Unit ID	Unit Description	Fuel(s)	NOx Controls[1]	Existing NOx Control Requirements[1]	Baseline NOx Emissions (tpy)	Baseline Year
04-01	Lime Kiln (Rotary with Preheater)	Coal, Pet Coke, No. 2 Fuel Oil, Propane	Existing: LNB (30% efficiency)	1. BACT NOx limit of 132.6 lb/hr (1.83 lb/ton stone feed) 2. NOx limit of 532 tpy	274	2011
05-01	Cement Kiln (Long Dry with Precalciner, Indirect Fired)	Coal, Pet Coke	Existing: SNCR and indirect firing	None[2]	1,996	2011

1. Michigan Department of Environmental Quality. Personal communication regarding existing and future NOx and SO_2 controls at a lime manufacturing facility and a cement facility between Thomas R. Julien (517-284-6750, julient@michigan.gov) and Bill M. Hodan, Amec Foster Wheeler, Americas – Environment & Infrastructure, via E-mail on September 18, 2015.
2. Thomas R. Julien of MI DEQ indicated (in the correspondence mentioned above) that EPA determined that BART for the cement facility includes operation of the existing SNCR system for 50% reduction in NOx. Future limits of 2.80 lb NOx/ton clinker (30 day rolling average), 2.40 lbs NOx /ton clinker (12-month average), and 7.50 lbs SO2/ton clinker (12-month average) will apply on January 1, 2017.

Table 6-2 Point Source SO_2 Information Collected for Select Cement and Lime Kilns in the LADCO Region

Unit ID	Unit Description	Fuel(s)	SO_2 Controls[1]	Existing SO_2 Control Requirements[1]	Baseline SO_2 Emissions (tpy)	Baseline Year
05-01	Cement Kiln (Long Dry with Precalciner, Indirect Fired)	Coal, Pet Coke	Existing: None	None	1,942	2011
04-01	Lime Kiln (Rotary with Preheater)	Coal, Pet Coke, No. 2 Fuel Oil, Propane	Existing: Stone preheater and fabric filter (90-95% efficiency)	BACT SO_2 limit of 55.2 lb/hr (0.83 lb/ton stone feed)	20	2011

1. Michigan Department of Environmental Quality. Personal communication regarding existing and future NOx and SO_2 controls at a lime manufacturing facility and a cement facility between Thomas R. Julien (517-284-6750, julient@michigan.gov) and Bill M. Hodan, Amec Foster Wheeler, Americas – Environment & Infrastructure, via E-mail on September 18, 2015.

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7 Source Category Analysis for Pipeline Transportation of Natural Gas

7.1 Source Category Description

Pipeline transportation of natural gas is dependent on compression stations located at key points within the pipeline network. The compression stations are required to maintain sufficient pressure to keep the natural gas flowing through the pipeline. These compression stations use Reciprocating Internal Combustion Engines (RICE) and turbines to generate power to run the compressors. Since natural gas is already available at compression stations it is the primary fuel used to drive these units. Use of RICE engines is the focus of our current evaluation since emissions from these engines result in a large contribution of NOx to the emission inventories in the LADCO states. These engines are typically characterized as spark ignition internal combustion engines and therefore are subject to NSPS Subpart JJJJ if they were put in place in 2007 or 2008 (depending on engine configuration and power rating). Engines subject to NSPS Subpart JJJJ are required to comply with NOx, CO, and VOC emissions limits. Additionally, any non-NSPS unit that is modified will become subject to NSPS JJJJ.

Since engines at compressor stations typically use natural gas for fuel, emissions of SO_2 are not large in comparison to other sources of SO_2 where higher sulfur fuels such as coal and fuel oils are used. Emissions of SO_2 and corresponding control options were not evaluated for this source category.

Most compression stations have emergency engines in place for backup power. These engines are not used often and their actual emissions of NOx and SO_2 are low. Most other emissions associated with natural gas compressor stations are due to emissions of natural gas (VOC).

7.2 NOx from Pipeline Transportation of Natural Gas

7.2.1 NOx Emissions and Control Options

Nitrogen oxides are a by-product of combustion. Nitrogen is inherently contained in fuels and in the air and does not react at low temperatures. During combustion, the high temperatures cause the nitrogen and oxygen in the air to react and form NOx. The amount of NOx formed is dependent on many factors including the type of fuel combusted, temperature, and residence time of the air. NOx formation from RICE at compressor stations can be classified into the following three categories: thermal NOx, fuel NOx, and prompt NOx. Thermal NOx is formed from nitrogen and oxygen in the air as a result of high temperature. Thermal NOx formation has a positive correlation with temperature. Fuel NOx is the result of nitrogen contained in organic fuels releasing and reacting with oxygen. Some fuels, such as natural gas, typically have no bound nitrogen, however, others such as fuel oil can contain high amounts. Prompt NOx forms as atmospheric nitrogen, atmospheric oxygen, and hydrocarbons from the fuel rapidly react. It is a minor contributor to overall NOx formation.

Pre-combustion NOx controls will not be evaluated as part of this analysis. A majority of the RICE at pipeline natural gas compressor stations are natural gas-fired and a lower nitrogen fuel suggestion is not feasible. There are two common combustion modifications that reduce NOx from RICE including air to fuel ratio adjustment and ignition/spark timing retard. Post-combustion NOx controls are also available for pipeline compressor station RICE and include non-selective catalytic reduction (NSCR), SNCR, and SCR. The applicability of each control technology is dependent on the type of engine - rich burn or lean burn - and the fuel combusted.

A summary of the control technologies analyzed in this report is provided in Table 7-1.

Table 7-1 Potential NOx Control Options for Pipeline Transportation of Natural Gas Sources

Technology	Description	Applicability	Performance
Air to Fuel Ratio Adjustment[1]	Increased air to fuel ratio lowers temperatures during combustion and reduces formation of thermal NOx.	Lean Burn RICE	5-30% reduction in NOx
Ignition/Spark Timing Retard[1]	Delaying the ignition event during a stroke lowers thermal NOx formation.	Lean Burn RICE	20% reduction in NOx
NSCR[1,2]	A three-way catalyst reduces NOx to nitrogen gas as well as lowers CO and VOC emissions.	Rich Burn RICE	80-95% reduction in NOx
SNCR[1]	A reducing agent such as ammonia is introduced to the exhaust gas stream to form nitrogen gas.	Rich and Lean Burn RICE	50-95% reduction in NOx
SCR[1]	A reducing agent such as ammonia is introduced into the exhaust gas stream to form nitrogen gas in the presence of a catalyst.	Lean Burn RICE	80-90% reduction in NOx

Table references:
1. *Colorado Visibility and Regional Haze State Implementation Plan for the Twelve Mandatory Class I Federal Areas in Colorado*, Appendix D. Colorado APCD. Jan 2011.
2. *A Pilot Project to Assess the Effectiveness of an Emission Control System for Gas Compressor Engines in Northeast Texas.* NETAC. Nov 2005.

7.2.1.1 Combustion Modifications

Air to Fuel Ratio Adjustment

Increasing the air to fuel ratio decreases thermal NOx emissions in lean burn engines by reducing the temperature. Fuel-injected engines have the most NOx reduction from air to fuel ratio adjustment. A turbocharger and air to fuel ratio controller are required to keep the engine operating efficiently due to the reduced fuel concentration. CO and VOC emissions increase as a result of the excess air. High energy ignition systems (HEIS) may be used to help with flame stability in low fuel, high air conditions (Colorado APCD, 2011). This combustion modification can decrease NOx emissions by 5 to 30 percent in lean burn RICE depending on engine and loading type. It is not suitable for rich burn engines.

Ignition/Spark Timing Retard

Delaying the ignition event during a stroke reduces thermal NOx emissions by increasing the volume in the cylinder at the time of ignition. For spark ignition engines, the timing of the spark is altered, and for compression engines, the timing of the fuel injection is altered. This control option is only suitable for lean burn engines. An electronic control system is required for RICE under variable loads to properly control ignition and injection. A reduction of 20 percent NOx can typically be expected (Colorado APCD, 2014).

7.2.1.2 Post-Combustion NOx Controls

Non-Selective Catalytic Reduction

In non-selective catalytic reduction (NSCR) systems, a catalyst reduces NOx to nitrogen gas (N_2). The catalyst used is referred to as a three-way catalyst as it oxidizes hydrocarbon (HC) to water (H_2O) and carbon monoxide (CO) to carbon dioxide (CO_2) and reduces NOx to N_2. According to a report prepared for Northeast Texas Air Care in 2005, NOx emissions can be reduced by 90 percent using this technology. CO and HC emissions can also be reduced by 90 percent and 70 percent, respectively. NSCR systems are highly effective on rich burn engines only, as the oxygen levels are too high in lean burn engines.

Selective Non-Catalytic Reduction

SNCR reduces NOx emissions by the injection of ammonia or urea into the exhaust stream. This reduces the NOx to N_2 and water. Lean burn and rich burn engines can utilize this technology to achieve NOx reductions of 50 to 95 percent. However, this technology is only appropriate for exhaust with temperatures greater the 1200 to 2000 °F, which may make it ineffective for variable load RICE such as those at natural gas compressor stations (EPA, 2000 and Colorado APCD, 2014). Ammonia slip occurs when the temperature of the exhaust gas is too low, like it would be during startup of the compressors.

Selective Catalytic Reduction

SCR removes NOx by injecting ammonia or another reducing agent into the exhaust gas before the gases pass a catalyst. The catalyst lowers the activation energy needed for the reaction of NOx and ammonia to form nitrogen gas and water. As a result, SCRs are appropriate for the lower exhaust gas temperatures and higher oxygen content exhaust of a lean burn engine. However, the same problem for SNCR systems exists for SCR systems in relation to variable load RICE such as those at natural gas compressor stations. The exhaust gas must be in a specific range to reduce NOx and this is problematic when the exhaust temperature is not constant. Temperatures lower than the recommended for the catalyst result in ammonia slip. A properly operating SCR system can reduce NOx emissions by 80 to 90 percent.

7.2.2 Four Factor Analysis of Potential NOx Control Scenarios for Pipeline Transportation of Natural Gas Sources

A four factor analysis approach has been utilized to analyze the potential control options presented in Table 7-1.

7.2.2.1 Cost of Compliance

Information on cost effectiveness of retrofitting controls onto RICE at natural gas compressor stations has been compiled from various sources. It is important to note that the values provided are estimated and actual retrofit control costs may be higher or lower depending on the individual RICE specifications, use, and rating.

The costs from combustion modifications are primarily associated with the required add-on equipment. For air to fuel ratio adjustment, a turbocharger and electronic air to fuel ratio controller are necessary to maintain adequate efficiency and NOx control. An electronic ignition control system is required to maintain NOx reductions with ignition/spark timing retard.

For post-combustion NOx controls, capital costs from the equipment and catalysts are the driving costs. There is little data on the cost effectiveness of retrofit SNCR systems for RICE due to the temperature constrictions making them less desirable than NSCR and SCR systems. SNCR would require reheating of the exhaust unlike NSCR and SCR.

Table 7-2 summarizes the cost effectiveness and factors affecting cost of each control option addressed in this analysis, as well as potential applicability to the specific facilities analyzed as part of this report. Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015. Please note that some costs may have increased or decreased since the original analyses; however, this analysis has only used past data available. A confidential key to the unit IDs is provided on the informational disc included with this report.

Table 7-2 Cost Effectiveness of NOx Control Options for Pipeline Transportation of Natural Gas Sources

Control Option	Specific Design Parameters Identified	Cost Effectiveness (2015 $/ton)[a]	Factors Affecting Cost	Potential Applicability to Specific Facilities (Unit ID)
Air to Fuel Ratio Adjustment[1]	None	$350-$9,200	Equipment (turbocharger, electronic air to fuel ratio controller), installation, and engineering	07-01, 07-02, 07-03
Ignition/Spark Timing Retard[1]	None	$350-$2,000	Equipment (electronic ignition control system), installation, engineering, and reduced efficiency	07-01, 07-02, 07-03
NSCR[1,2]	None	$220-$740	Equipment, installation, and engineering	None
SNCR[1]	None	No Data	Equipment, installation, engineering, energy use, waste removal, reduction agent, and catalyst	07-01, 07-02, 07-03
SCR[1]	None	$430-$4,900	Equipment, installation, engineering, energy use, waste removal, and reduction agent	07-01, 07-02, 07-03

[a] Costs have been converted into 2015 dollars using Consumer Price Index (CPI) data through August 2015.

Table references:

1. *Colorado Visibility and Regional Haze State Implementation Plan for the Twelve Mandatory Class I Federal Areas in Colorado*, Appendix D. Colorado APCD. Jan 2011.
2. *A Pilot Project to Assess the Effectiveness of an Emission Control System for Gas Compressor Engines in Northeast Texas.* NETAC. Nov 2005.

7.2.2.2 Time Necessary for Compliance

Facilities require time to design, purchase, and install selected control options in addition to the time needed to write and implement regulations. According to the Institute of Clean Air Companies, 13 months should be adequate for engineering to installation of SCR or SNCR systems for most RICE. Five years from conception to implementation would typically be appropriate, depending on the control options selected (Colorado APCD, 2014). Fuel and engine timing adjustments could be implemented within a year or two, depending on the age of the engine and availability of add-on electronics.

7.2.2.3 Energy and Non-Air Impacts

All of the NOx control technologies available impact the efficiency of an engine. Fuel consumption may increase by up to 5 percent for combustion modifications and by less than one percent for SCR systems (Colorado APCD, 2014). Post-combustion NOx controls reduce efficiency due to the pressure drop across the catalyst.

7.2.2.4 Remaining Useful Life at the Source

The remaining useful life of an individual RICE can vary greatly depending on many factors including the age, size, use, and maintenance frequency of the unit. No available data on the average life of existing RICE was found; however, in a four factor analysis prepared for the Western Regional Air Partnership (WRAP) in 2009, the projected lifetime of an SCR was used as a surrogate. The analysis assumed 15 years of life.

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Western Regional Air Partnership (WRAP) and Western Governors' Association (WGA). *Supplementary Information for Four Factor Analyses by WRAP States.* May 4, 2009.

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8 Analysis of Selected Pipeline Transportation of Natural Gas Facilities

8.1 Source Category Description

LADCO identified ten major facilities that contribute significant levels of NOx and SO_2 in the northern Midwest region. Amec Foster Wheeler was directed by LADCO to evaluate these ten individual facilities in respect to four key source categories that contribute to visibility impairment: ICI boilers at pulp and paper mills and sugar beet manufacturing facilities, cement and lime plants, and pipeline transportation of natural gas. Of these ten facilities, one facility falls under the pipeline transportation of natural gas. Table 8-1 lists high NOx contributing units that were identified utilizing a confidential unit ID. Baseline NOx emissions are provided for each unit. Facilities in this category do not significantly contribute and are not reviewed in terms of SO_2 emissions.

8.2 Information Obtained From State Agencies

For the selected natural gas pipeline transport facility, Amec Foster Wheeler obtained the facility's current permit that was available online to evaluate the status of each unit in addition to the facility's 2013 emissions inventory that was provided by the corresponding state.

Table 8-1 Point Source Information Collected for Select Pipeline Transportation of Natural Gas Facilities in the LADCO Region

Unit ID	Unit Description	Heat Input (MMBtu/hr)	Fuel(s)	NOx Controls	Existing NOx Control Requirements	Baseline NOx Emissions (tpy)	Baseline Year
07-01	RICE	14	Natural gas	Existing: None	None	42	2013
07-02	RICE	14	Natural gas	Existing: None	None	33	2013
07-03	RICE	28	Natural gas	Existing: None	None	45	2013

APPENDIX 3

Information for Wisconsin Point Source Facilities Over Q/d = 1

Background

Tables 1 and 2 provide specific information on Wisconsin's larger point sources (those over Q/d = 1), including control measures added from Round 1 to Round 2 and the associated nitrogen oxides (NOx) and sulfur dioxide (SO_2) emissions reflecting those controls. This information supports the summary point source information provided in Sections 3.3.3 (Changes in Emissions Since First Implementation Period and Progress Report), 3.5.1 (Emission Reductions Due to Ongoing Air Pollution Control Programs) and 3.5.3 (Source Retirement and Replacement Schedules) of Wisconsin's Round 2 haze State Implementation Plan (SIP). This information also helps to properly account for the control measures and associated emission reductions that should be credited towards reasonable progress for Round 2.

Table 1 – Wisconsin Point Source EGU Emissions and Control Measures.

Red font indicates emission reductions from 2018 Target to 2028 Projection due to additional control measures.
* Indicates control is beyond the control(s) reflected in Round 1 2018 Target emissions.
** Indicates control is beyond the control(s) reflected in both Round 1 2018 Target emissions and Round 2 LADCO 2028 Modeled emissions.

EPA FID (WDNR FID)	Facility Name (WDNR Facility Name)	Unit ID	2016 Q/d[a]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
				2018 Target[b]	2016	2028 Projected	2018 Target[b]	2016	2028 Projected	
7692911 (460033090)	WPL – Edgewater	B23	Shut down	---	Shut down	Shut down	---	Shut down	Shut down	Shut down in 2013
		B24	12.2	---	821	**Shut down**	---	2,983	**Shut down**	Repower from coal to natural gas by Jan. 2019 Retired Sep. 2018*
		B25	11.0	---	486	**Shut down**	---	2,998	**Shut down**	NOx: SCR @ 0.07 lbs/mmBtu by May 2013 SO_2: DFGD @ 0.07 lbs/mmBtu by Jan. 2017 Plan to retire 2022 (public announcement)*
7673611 (111003090)	WPL – Columbia	B21	5.6	---	1,668	**Shut down**	---	643	**Shut down**	NOx: LNB/OFA @ 0.15 lbs/mmBtu by July 2013 SO_2: DFGD @ 0.075 lbs/mmBtu by Jan. 2015

EPA FID (WDNR FID)	Facility Name (WDNR Facility Name)	Unit ID	2016 Q/d[a]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
				2018 Target[b]	2016	2028 Projected	2018 Target[b]	2016	2028 Projected	
										Plan to retire 2025 (public announcement)**
		B22	6.1	---	1,778	**Shut down**	---	736	**Shut down**	NOx: SCR/LNB/OFA @ 0.07 lbs/mmBtu by Jan. 2019 SO_2: DFGD @ 0.075 lbs/mmBtu by Jan. 2015 Plan to retire 2025 (public announcement)**
6330411 (241007690)	We Energies – Oak Creek (includes Elm Road)	B18	4.2	---	1,110	1,110	---	335	335	NOx: SCR @ 0.07 lbs/mmBtu SO_2: WFGD @ 0.03 lbs/mmBtu (CP #12-SDD-047)
		B19	4.1	---	1,108	1,108	---	282	282	
		B25	3.8	---	532	**Shut down**	---	14	**Shut down**	NOx: SCR @ 0.08 lbs/mmBtu by Jan. 2016 SO_2: WFGD @ 0.08 lbs/mmBtu by Jan. 2016 Plan to retire the 4 units 2024 (public announcement)**
		B26		---	387		---	10		
		B27		---	195		---	27		
		B28		---	342		---	38		
7509411 (230006260)	We Energies – Pleasant Prairie	B20	4.9	---	1,265	**Shut down**	---	575	**Shut down**	NOx: SCR @ 0.08 lbs/mmBtu by Jan. 2016 SO_2: WFGD @ 0.08 lbs/mmBtu by Jan. 2016 Retired April 2018*
		B21	3.9	---	949		---	512		
7078511 (737009020)	Wisconsin Public Service Corporation-Weston Plant	B03	3.4	---	306	308	---	762	48	NOx: ReACT @ 0.10 lbs/mmBtu by Jan. 2017* SO_2: ReACT @ 0.08 lbs/mmBtu by Jan. 2017* **Note:** 2028 Projected emissions based on 2019 actual emissions.

EPA FID (WDNR FID)	Facility Name (WDNR Facility Name)	Unit ID	2016 Q/d[a]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
				2018 Target[b]	2016	2028 Projected	2018 Target[b]	2016	2028 Projected	
		B04	4.3	---	700	700	---	575	575	NOx: SCR @ 0.06 lbs/mmBtu by April. 2013 SO_2: DFGD @ 0.08 lbs/mmBtu by April. 2013
4958511 (606034110)	Dairyland Power Coop Alma Site	B23	Shut down	---	Shut down	**Shut down**	---	Shut down	**Shut down**	Retired in 2015*
		B24		---			---			Retired in 2015*
	JP Madgett	B25	5.4	---	1,239	1,239	---	920	920	NOx: LNB/SCR; 0.14 lbs/mmBtu by Jan. 2015* SO_2: DSI @ 0.09 lbs/mmBtu by Jan. 2015*
5295111 (405031990)	WI Public Service Corp - JP Pulliam Plant	B26	3.5	---	99	**Shut down**	---	157	**Shut down**	Retired Oct. 2018*
		B27	1.0		302			591		
6228411 (802033320)	Xcel Energy Bay Front Generating Station	B20	3.6	---	155	155	---	45	45	NOx: OAF/SNCR; No short-term NOx limit SO_2: No Control @ 3.2 lbs/mmBtu
		B21			165	165		52	52	
7711211 (663020930)	Dairyland Power Coop Genoa Station-Eop	B20	1.8	---	578	**Shut down**	---	253	**Shut down**	NOx: SNCR @ 0.015 lbs/mmBtu by June. 2015* SO_2: FGD @ 0.09 lbs/mmBtu by Jan. 2013 Retired June 2021**
6229211 (246004000)	Wisconsin Electric Power Company D/B/A We Energies-Port Washington	P11	1.3	---	62	62	---	3	3	Nat gas combined-cycle combustion turbines NOx: @ 3.0 ppmv
		P12		---	60	60	---	3	3	
		P21		---	51	51	---	3	3	

EPA FID (WDNR FID)	Facility Name (WDNR Facility Name)	Unit ID	2016 Q/d[a]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
				2018 Target[b]	2016	2028 Projected	2018 Target[b]	2016	2028 Projected	
		P22		---	53	53	---	3	3	SO_2: @ 0.06 lbs/mmBtu (CP #15-RSG-102)
7179611 (436035930)	Manitowoc Public Utilities	B28	1.25	---	27	27	---	68	68	NOx: No Control @ 0.20 lbs/mmBtu during ozone season (NR 428.05) SO_2: DSI @ 0.20 lbs/mmBtu
		B09		---	49	49	---	194	194	NOx: SNCR @ 0.155 lbs/mmBtu (CP #02-RV-147) SO_2: DSI @ 0.30 lbs/mmBtu (NSPS)
6748311 (122003640)	E J Stoneman Station	B21	0	---	Shut down	**Shut Down**	---	Shut down	**Shut Down**	Retired June 2015*
		B22								
Total Emissions				**36,047**	**14,487**	**5,087**	**75,007**	**12,782**	**2,531**	---
Progress from Round 1 2018 Target (% Change)				**---**	**-60%**	**-86%**	**---**	**-83%**	**-97%**	---

DFGD = Dry Flue Gas Desulfurization
DSI = Dry Sorbent Injection
LNB = Low NOx Burner
NG = Natural Gas
OFA = Over-fire Air
ReACT = Regenerative Activated Coke Technology
SCR = Selective Catalytic Reduction
SNCR = Selective Non-catalytic Reduction
TPY = Tons per Year
WFGD = Wet Flue Gas Desulfurization

[a] Q/d values are for the nearest Class I area, and can be found in Table A2-1 of Appendix 2, as well as from LADCO spreadsheets “Q/d spreadsheet” [QoverD_V5.7_2016_scc] and “Process level report of Q/d sources” [Haze_Control_Sheet_V7.3] at LADCO Regional Haze TSD – Second Implementation Period.

[b] 2018 Target emissions were not available for individual power plants or units, therefore only the 2018 Target “total” emissions for EGUs were used.

Table 2 – Wisconsin Point Source Non-EGU Emissions and Control Measures.[a]

Red font indicates emission reductions from 2018 Target to 2028 Projection due to additional control measures.
* Indicates control is beyond the control(s) reflected in Round 1 2018 Target emissions.
** Indicates control is beyond the control(s) reflected in both Round 1 2018 Target emissions and Round 2 LADCO 2028 Modeled emissions.

EPA FID (WDNR FID)	EPA Facility Name (WDNR Fac Name)	2016 Q/d[b]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
			2018 Target	2016	2028 Projected	2018 Target	2016	2028 Projected	
6467811 (445031180)	EXPERA (Ahlstrom-Munksjo NA Specialty Solutions LLC – Kaukauna)	29.8	2,014	1,577	1,577	9,090	6,532	6,532	2010 1-hr SO_2 NAAQS compliance.[c] DSI for HCl control started in 2017 (may achieve some SO_2 control co-benefit). See also Round 2 SIP, Sections 3.5.1 and 3.6.1 for additional information, including that 2028 actual emissions are expected to be lower than 2028 Projected (consistent with demonstrated 2017-2019 emissions).
7048011 (744008100)	EXPERA (Ahlstrom-Munskjo NA Specialty Solutions LLC – Rhinelander)	13.3	1,618	1,168	1,168	2,451	1,596	1,596	Heat input limit of 260 mmBtu/hr and SO_2 emission limit of 2.38 Lb/mmBtu (24-hr basis) for coal boiler B26 effective Dec 31, 2021, per CP # 15-DMM-128-R1.** 4 smaller coal boilers (83.5 mmBtu/hr capacity each) shut down in 2016, representing permanent and enforceable reduction of 326 mmBtu/hr and permitted 1,780 tons/yr SOx.* DSI for HCl control started in 2017 (may achieve some SO_2 control co-benefit). See also Round 2 SIP, Sections 3.5.1 and 3.6.1 for additional information, including: 1) underestimated 2016 and 2028 Projected emissions due to B26 2-month shutdown in 2016; and 2) 2028 actual emissions are expected to be lower than 2028 Projected (consistent with demonstrated 2017-2019 emissions).

EPA FID (WDNR FID)	EPA Facility Name (WDNR Fac Name)	2016 Q/d[b]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
			2018 Target	2016	2028 Projected	2018 Target	2016	2028 Projected	
4193911 (772010030)	WISCONSIN RAPIDS PAPER MILL	13.2	2,147	1,875	1,875	1,239	1,622	1,622	2010 1-hr SO_2 NAAQS compliance.[c] Coal-biomass boilers B20 and B21 have limits of 1.2 lbs/mmBtu SO_2 and 0.80 lbs/mmBtu NOx (OP # 772010030-P12) and use low-sulfur (0.26 %S by wt in 2019) sub-bituminous coal. **Note:** Facility started idling indefinitely Aug. 2020 due to demand drop. 2028 Projected emissions based on 2016 actual emissions to be conservative in the event the facility resumes operation.
4193811 (772009480)	CATALYST PAPER - BIRON MILL (ND Paper Inc-Biron Division)	11.8	2,133	1,436	**968**	5,158	2,506	**565**	B23 switched from coal to natural gas in 2017 (CP #16-POY-131).** Coal-biomass boiler B24 has BACT/NSPS SO_2 limit of 1.2 lbs/mmBtu (24-hr avg) and 0.47 %S by wt, and NOx limit of 0.60 lbs/mmBtu (30-day avg) (OP # 772009480-P20). NOx and SO_2 reductions through 2016 due to lower coal usage in boiler B23 in 2016. **Note:** 2028 Projected emissions based on 2019 actual emissions.
4944011 (405032870)	GEORGIA-PACIFIC [Green Bay]	9.0	1,377	840	**349**	1,980	1,286	**43**	Coal boiler B27 retired in 2015.* Coal boiler B29 retired in 2018 (10% heat input limitation started in 2017).** Replaced coal boiler B26 with 2 natural gas boilers in 2019 (CP #18-MBH-162).**

EPA FID (WDNR FID)	EPA Facility Name (WDNR Fac Name)	2016 Q/d[b]	NOx Annual Tons			SO_2 Annual Tons			Comment on NOx or SO_2 Controls/Limits
			2018 Target	2016	2028 Projected	2018 Target	2016	2028 Projected	
									Replaced coal boiler B28 with natural gas boiler in 2019 – facility NOx PTE of 349 TPY and SO_2 PTE of 43 TPY (CP #19-DMM-030).** Terminated the use of coal by the end of 2020.**
4787911 (737009570)	EXPERA (Ahlstrom-Munksjo Mosinee LLC – Mosinee)	7.6	618	640	640	1,367	1,469	1,469	2010 1-hr SO_2 NAAQS compliance.[c] Coal boiler B20 has SO_2 limit of 3.2 lbs/mmBtu and coal was 0.7 %S by wt in 2019. DSI for HCl control started in 2017 (may achieve some SO_2 control co-benefit likely).
4985511 (816036430)	GRAYMONT (WI) LLC [Superior]	6.6	469	454	**454**	686	454	454	2010 1-hr SO_2 NAAQS compliance.[c] NOx BACT is use of preheater type rotary kiln #4 and good combustion practices, starting 2007 (CP #93-DBY-074). Inherent SO_2 scrubbing in lime kilns for 53-62% control (per 2015 AEI).
4864411 (816009590)	CALUMET SUPERIOR LLC (Superior Refining Company LLC)	5.0	608	365	**365**	882	28	**28**	Consent Decree starting 2010 for NOx and SO_2 reductions from boilers, FCCUs and heaters (CP #11-DCF-138)*
5939211 (617049840)	CARDINAL FG CO [Menominee]	5.0	1,493	1,574	**249**	55	61	61	SCR installed in 2020 – facility NOx PTE of 249 TPY (CP #19-POY-012).** SO_2 is controlled by a semi-dry scrubber.
4943611 (405032100)	GREEN BAY PACKAGING INC MILL DIVISION	4.0	221	203	**125**	981	751	**20**	Coal boiler B26 was replaced w/ two natural gas boilers in 2019 – facility NOx PTE of 125 TPY and SO_2 PTE of 20 TPY (CP #18-DMM-090)**

EPA FID (WDNR FID)	EPA Facility Name (WDNR Fac Name)	2016 Q/d[b]	NOx Annual Tons			SO$_2$ Annual Tons			Comment on NOx or SO$_2$ Controls/Limits
			2018 Target	2016	2028 Projected	2018 Target	2016	2028 Projected	
4208011 (772010690)	DOMTAR A W LLC-NEKOOSA	3.8	1,289	309	**309**	3,278	888	**888**	2010 1-hr SO$_2$ NAAQS compliance.[c] Coal boilers B20, B21 and B24 switched from coal to natural/process gas in 2014 (CP #13-JJW-131).*
7675711 (111071180)	CARDINAL FG [Portage]	3.8	1,423	1,426	**240**	59	62	62	SCR installed in 2019 – facility NOx PTE of 240 TPY (CP #17-DMM-196).** SO$_2$ is controlled by a semi-scrubber.
4782311 (436034390)	CARMEUSE LIME AND STONE - ROCKWELL OPERATION	3.8	223	310	310	824	710	710	NR 428, Wis. Adm. Code, Combustion optimization NOx requirement for kilns.
7049511 (851009390)	FLAMBEAU RIVER PAPERS LLC (Park Falls Industrial Management, LLC)	2.8	294	264	264	182	157	157	2010 1-hr SO$_2$ NAAQS compliance.[c] Coal boiler B24 max capacity < 250 mmBtu/hr.
4943711 (405032210)	PROCTER & GAMBLE PAPER PRODUCTS CO	2.7	821	374	**374**	1,650	0	**0**	Coal boiler B06 shut down in 2015*
4985811 (735008010)	PACKAGING CORPORATION OF AMERICA-TOMAHAWK	2.6	1,557	289	**289**	6,131	53	**53**	Coal boilers B24, B27 and B28 shut down or removed coal in 2015*
6805511 (445031290)	APPLETON COATED LLC (Appleton Property Ventures LLC)	1.6	673	250	**250**	1,093	146	**146**	2010 1-hr SO$_2$ NAAQS compliance.[c] Did not use coal boiler B23 since 2018 (CP #19-POY-093-EXM). **Note:** Publicly announced shutdown by end of Sept. 2021. 2028 Projected emissions based on

EPA FID (WDNR FID)	EPA Facility Name (WDNR Fac Name)	2016 Q/d[b]	NOx Annual Tons			SO$_2$ Annual Tons			Comment on NOx or SO$_2$ Controls/Limits
			2018 Target	2016	2028 Projected	2018 Target	2016	2028 Projected	
									2016 actual emissions to be conservative in the event the facility resumes operation.
9034811 (241870530)	General Mitchell Intern	1.5	443 (est.)	443	443	52 (est.)	52	52	
4943911 (405032650)	EXPERA (Ahlstrom-Munksjo NA Specialty Solutions LLC – De Pere)	1.4	206	98	**98**	700	231	**231**	2010 1-hr SO$_2$ NAAQS compliance.[c] Coal boilers B23 and B24 10% annual heat input limitation started in 2017.**
6480111 (265006830)	USG INTERIORS LLC	1.1	62	47	47	200	359	329	SO$_2$ emissions from the mineral wool production limited to 238 lbs/hr (30-day avg basis) starting in 2017 (Admin Order AM-16-01). **Note:** 2028 Projected SO$_2$ based on 2019 reported SO$_2$ emissions.
14473911 (NA)	POKEGAMA [Railyard]	1.1	152 (est.)	152	152	0	0	0	
Total Emissions			**19,841**	**14,094**	**10,546**	**38,058**	**18,963**	**15,018**	---
Progress from Round 1 2018 Target (% Change)			---	**-29%**	**-47%**	---	**-50%**	**-61%**	---

AEI = WDNR Air Emissions Inventory
CP = Construction Permit
DSI = Dry Sorbent Injection
PTE = Potential to Emit
TPY = Tons per Year

[a] Table A2-2 in Appendix 2 – along with LADCO's spreadsheet "Process level report of Q/d sources" [Haze_Control_Sheet_V7.3] at LADCO Regional Haze TSD – Second Implementation Period – have some additional process- and unit-level information at the facilities (i.e., 2016 NOx and SO$_2$ emissions).

[b] Q/d values are for the nearest Class I area, and can be found in Table A2-1 of Appendix 2, as well as from LADCO spreadsheets "Q/d spreadsheet" [QoverD_V5.7_2016_scc] and "Process level report of Q/d sources" [Haze_Control_Sheet_V7.3] at LADCO Regional Haze TSD – Second Implementation Period.

[c] Subject to required SO$_2$ modeling in air permit during Round 2 timeframe, to demonstrate compliance with 2010 1-hr SO$_2$ NAAQS. Compliance may achieve SO$_2$ reductions beyond 2016 level.

APPENDIX 4

Supplemental Information for WDNR Round 2 Four-Factor Analysis

Background

This appendix provides costing information for sulfur dioxide (SO_2) and nitrogen oxides (NOx) control options at the A-M Kaukauna and A-M Rhinelander mills, based on information WDNR developed in Round 1 as part of implementing Best Available Retrofit Technology (BART) for the Georgia-Pacific – Broadway Street paper mill (G-P) in Green Bay.[1] This information supports the characterization of the four factors in Section 3.4.2 of Wisconsin's Round 2 haze State Implementation Plan (SIP). The coal boilers evaluated for the A-M mills have a similar design and configuration to the G-P mill BART-affected boilers, so the control and cost assessments for G-P BART provide a reasonable basis to estimate the A-M mill boiler costs for the purpose of the required four-factor analysis.

1. SO_2 Control Cost Estimates

Tables 1 through 3 provide the dry sorbent injection (DSI), dry flue gas desulfurization (FGD) and wet FGD SO_2 control cost spreadsheets for the A-M Kaukauna and A-M Rhinelander mills. Each table includes the summary costs for the G-P BART case. Costs were first updated to 2019$ from the G-P BART reference case, using the 2020 Chemical Engineering Plant Cost Index (CEPCI) as recommended by US EPA's Control Cost Manual. WDNR scaled down the capital costs from the G-P BART control equipment costs by boiler size using the "six-tenths" rule of economies of scale. Process operating costs and other costs were also scaled down from the G-P BART control equipment costs, based on total SO_2 emission reduction unless otherwise indicated.

Table 1. DSI Control Cost Estimates for A-M Kaukauna and A-M Rhinelander Mills

Parameter	Reference - G-P BART (2007$)[a]	G-P BART (2019$)[b]	A-M Kaukauna (2019$)[c,d]	A-M Rhinelander (2019$)[c,d]
Boiler(s)	B27	B27	B09&B11	B26
Boiler Size (mmBtu/hr)	615	615	571	300
Baseline Emissions (TPY)	8,715	8,715	6,133	1,915
Maximum Reduction (%)	50	50	40	40
Fraction Reduced	0.5	0.5	0.4	0.4
Emissions Reduction (TPY)	4,358	4,358	2,453	766
Total Installed Cost (TIC)	**23,140,441**	**26,756,410**	**12,795,417**	**8,696,521**
Operating labor	21,900	25,322	25,322	25,322
Supervisor Labor	3,285	3,798	3,798	3,798

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[1] See Wisconsin's Round 1 Regional Haze SIP (pp 24-25), BART TSD for Non-EGUs, and Final BART Determination, available under "Visibility" tab at https://dnr.wisconsin.gov/topic/AirQuality/Particles.html.

Parameter	Reference - G-P BART (2007$)[a]	G-P BART (2019$)[b]	A-M Kaukauna (2019$)[c,d]	A-M Rhinelander (2019$)[c,d]
Maintenance labor & equipment	14,600	16,881	16,881	16,881
Electricity- direct	149,528	172,894	172,894	172,894
Sorbent	6,552,000	7,575,828	3,688,667	1,331,746
Landfill Scrubber system solids	351,120	405,987	197,675	71,368
Total	***7,092,433***	***8,200,710***	***4,105,237***	***1,622,010***
Overhead rate (60% of total labor and material)	23,871	27,601	27,601	27,601
Taxes, insurance, admin. Factor (4% of TIC)	925,618	1,070,256	511,817	347,861
Capital recovery factor (10.98% of TIC)	2,540,696	2,937,854	1,404,937	954,878
Total Annual Operating Cost ($)	**10,582,618**	**12,236,421**	**6,049,592**	**2,952,350**
Cost-effectiveness ($/ton)	**2,428**	**2,808**	**2,466**	**3,854**

TPY = Tons per year

[a] Costs based on BART analysis submitted by G-P in 2009, and includes existing baghouse for particulate matter control.

[b] Cost-effectiveness updated from 2007$ to 2019$ using CEPCI factor of 1.16.

[c] Assume 40% maximum control with existing electrostatic precipitator, based on April 2017 Sargent & Lundy document "IPM Model – Updates to Cost and Performance for APC Technologies. Dry Sorbent Injection for SO2/HCl Control Cost Development Methodology" (p. 3).

[d] Use 50% of "new" cost for TIC, to be conservative for any upgrades needed for existing DSI system and associated operations at facility. The existing DSI and associated operations are currently intended only for minimal sorbent injection for HCl control.

Table 2. Dry FGD Control Cost Estimates for A-M Kaukauna and A-M Rhinelander Mills

Parameter	Reference - G-P BART (2010$)[a]	G-P BART (2019$)[b]	A-M Kaukauna ($2019)	A-M Rhinelander (2019$)
Boiler(s)	B26/B27	B26/B27	B09&B11	B26
Boiler Size (mmBtu/hr)	965	965	571	300
Boiler Size - Total Flue Controlled (mmBtu/hr)	1,200	1,200	571	300
Baseline Emissions (TPY)	10,875	10,875	6,133	1,915
Maximum Reduction (%)	93	93	93	93
Fraction Reduced	0.93	0.93	0.93	0.93
Emissions Reduction (TPY)	10,114	10,114	5,704	1,781

Parameter	Reference - G-P BART (2010$)[a]	G-P BART (2019$)[b]	A-M Kaukauna ($2019)	A-M Rhinelander (2019$)
Total Installed Cost (TIC)	**38,250,000**	**42,187,500**	**27,018,218**	**18,363,176**
Operating labor	131,400	144,926	144,926	144,926
Supervisor Labor	19,710	21,739	21,739	21,739
Maintenance labor & equipment (7.18% of TIC)	2,748,242	3,031,149	1,939,908	1,318,476
Electricity- direct	404,976	446,665	446,665	446,665
Electricity- fan make-up	201,680	222,441	222,441	222,441
Sorbent	4,182,080	4,612,588	2,601,223	812,304
Process water	2,832	3,124	1,761	550
Landfill Scrubber system solids	860,289	948,848	535,094	167,098
Additional Process Steam	0	0	0	0
Total	***8,551,209***	***9,431,481***	***5,913,758***	***3,134,200***
Overhead rate (60% of total labor and material)	1,739,611	1,918,689	1,263,944	891,085
Taxes, insurance, admin. Factor (4% of TIC)	1,530,000	1,687,500	1,080,729	734,527
Capital recovery factor (10.98% of TIC)	4,199,850	4,632,188	2,966,600	2,016,277
Total Annual Operating Cost ($)	**16,020,670**	**17,669,857**	**11,225,031**	**6,776,088**
Cost-effectiveness ($/ton)	**1,584**	**1,747**	**1,968**	**3,804**

TPY = Tons per year

[a] TIC for Turbosorb based on Babcock Power quote received by G-P in 2011. The cost included coal boiler B28, making the cost estimate conservative for the boiler B26/B27 combined flue alone.

[b] Cost-effectiveness updated from 2010$ to 2019$ using CEPCI factor of 1.10.

Table 3. Wet FGD Control Cost Estimates for A-M Kaukauna and A-M Rhinelander Mills

Parameter	Reference - G-P BART (2007$)[a]	G-P BART (2019$)[b]	A-M Kaukauna (2019$)	A-M Rhinelander (2019$)
Boiler(s)	B26/B27	B26/B27	B09&B11	B26
Boiler Size (mmBtu/hr)	965	965	571	300
Boiler Size - Total Flue Controlled (mmBtu/hr)	1,200	1,200	571	300
Baseline Emissions (TPY)	10,875	10,875	6,133	1,915
Maximum Reduction (%)	95	95	95	95

Parameter	**Reference - G-P BART (2007$)[a]**	**G-P BART (2019$)[b]**	**A-M Kaukauna (2019$)**	**A-M Rhinelander (2019$)**
Fraction Reduced	0.95	0.95	0.95	0.95
Emissions Reduction (TPY)	10,331	10,331	5,826	1,819
Total Installed Cost (TIC)	**55,869,465**	**64,599,734**	**41,371,726**	**28,118,667**
Operating labor	43,800	50,644	50,644	50,644
Supervisor Labor	6,570	7,597	7,597	7,597
Maintenance labor & equipment	87,600	101,289	101,289	101,289
Electricity- direct	705,846	816,143	816,143	816,143
Electricity- fan make-up	0	0	0	0
Sorbent	18,833,008	21,775,890	12,280,601	3,834,959
Process water	348,016	402,398	226,934	70,866
Landfill Scrubber system solids	1,256,030	1,452,300	819,030	255,765
Additional Process Steam	2,429,442	2,809,071	1,584,187	494,706
Total	***23,710,312***	***24,606,259***	***15,886,424***	***5,631,970***
Overhead rate (60% of total labor and material)	82,782	95,718	95,718	95,718
Taxes, insurance, admin. Factor (4% of TIC)	2,234,779	2,583,990	1,654,869	1,124,747
Capital recovery factor (10.98% of TIC)	6,134,467	7,093,050	4,542,616	3,087,430
Total Annual Operating Cost ($)	**32,162,340**	**34,379,017**	**22,179,626**	**9,939,864**
Cost-effectiveness ($/ton)	**3,113**	**3,328**	**3,807**	**5,463**

TPY = Tons per year

[a] Costs based on BART analysis submitted by G-P in 2009.

[b] Cost-effectiveness updated from 2007$ to 2019$ using CEPCI factor of 1.16.

2. NOx Control Cost Estimates

Tables 4 through 6 provide the over-fire air (OFA), regenerative selective catalytic reduction (RSCR), and OFA/RSCR NOx control cost spreadsheets for the A-M Kaukauna and A-M Rhinelander mills. Each table includes the summary costs for the G-P BART case. Costs were first updated to 2019$ from the G-P BART reference case, using the 2020 CEPCI cost index as recommended by US EPA's Control Cost Manual. WDNR scaled down the capital costs from the G-P BART costs by boiler size using the "six-tenths" rule of economies of scale. Process operating costs and other costs were also scaled down from the G-P BART control equipment costs, based on total NOx emission reduction.

Table 4. OFA Control Cost Estimates for A-M Kaukauna and A-M Rhinelander

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a]	A-M Kaukauna (2019$)		A-M Rhinelander (2019$)
Boiler	B27	B27	B11	B09	B26
Boiler Size (mmBtu/hr)	615	615	379	192	300
Baseline Emissions (TPY)	2,729	2,729	1,070	239	1,374
Control Efficiency (%)	50	50	50	50	50
Fraction Reduced	0.5	0.5	0.5	0.5	0.5
Emissions Reduction (TPY)	1,365	1,365	535	120	687
Total Direct Cost (TDC)	**693,980**				
Equipment	570,000				
Instrumentation	24,812				
Electrical	99,168				
Indirect Cost (IC)	**536,565**				
Construction Cost	412,585				
Owners Cost (3% TDC)	20,819				
Total Installed Cost (TIC)	**1,230,545**	**1,357,219**	**1,015,099**	**675,003**	**882,262**
Maintenance labor & parts (1.5% TIC)	18,458	20,358	15,226	10,125	13,234
Electricity	52,539	57,947	57,947	57,947	57,947
Overhead rate	0	0	0	0	0
Taxes, insurance, admin. Factor	0	0	0	0	0
Capital recovery factor (9.44% TIC)	116,163	128,121	95,825	63,720	83,286

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a]	A-M Kaukauna (2019$)		A-M Rhinelander (2019$)
Total Annual Operating Cost ($)	**187,161**	**206,427**	**168,999**	**131,793**	**154,467**
Cost-effectiveness ($/ton)	**137**	**151**	**316**	**1,103**	**225**

TPY = Tons per year

[a] Cost-effectiveness updated from 2010$ to 2019$ using CEPCI factor of 1.10.

Table 5. RSCR Control Cost Estimates for A-M Kaukauna and A-M Rhinelander

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a]	A-M Kaukauna (2019$)	A-M Rhinelander (2019$)
Boiler(s)	B27	B27	B09&B11	B26
Boiler Size (mmBtu/hr)	615	615	571	300
Baseline Emissions (TPY)	2,729	2,729	1,309	1,374
Control Efficiency RSCR (%)	70	70	70	70
Fraction Reduced	0.7	0.7	0.7	0.7
Emissions Reduction (TPY)	1,910	1,910	916	962
Total Direct Cost (TDC)	**6,100,000**			
Equipment				
Instrumentation				
Electrical				
Indirect Cost (IC)	**2,013,000**			
Construction Cost (30% TDC)	1,830,000			
Owners Cost (3% TDC)	183,000			
Total Installed Cost (TIC)	**8,113,000**	**8,948,162**	**8,558,357**	**5,816,765**
Additional Operating & Supervisory Labor	0	0	0	0
Maintenance labor & parts (1.5% TIC)	121,695	134,222	128,375	87,251
Electricity	365,574	403,207	403,207	403,207
Ammonia Consumption (5.81 tons/ton NOx)	1,775,815	1,958,619	939,477	986,128
Ammonia Inventory (12,000 gal tank)	7,186	7,926	3,802	3,990
Natural Gas (2.5 mmBtu/hr)	146,292	161,351	77,394	81,237
Catalyst (3-year)	337,245	371,961	178,416	187,276

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a]	A-M Kaukauna (2019$)	A-M Rhinelander (2019$)
Overhead rate	0	0	0	0
Taxes, insurance, admin. Factor	0	0	0	0
Capital recovery factor (9.44% TIC)	765,867	844,706	807,909	549,103
Total Annual Operating Cost ($)	**3,519,674**	**3,881,994**	**2,538,580**	**2,298,192**
Cost-effectiveness ($/ton)	**1,842**	**2,032**	**2,770**	**2,389**

TPY = Tons per year

[a] Cost-effectiveness updated from 2010$ to 2019$ using CEPCI factor of 1.10.

Table 6. OFA/RSCR Control Cost Estimates for A-M Kaukauna and A-M Rhinelander

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a,b]	A-M Kaukauna (2019$)	A-M Rhinelander (2019$)
Boiler(s)	B27	B27	B09&B11	B26
Boiler Size (mmBtu/hr)	615	615	571	300
Baseline Emissions (TPY)	2,729	2,729	1,309	1,374
Existing Control Efficiency (%)	0	0	0	0
Control Efficiency OFA (%)	50	50	50	50
Control Efficiency RSCR (%)	70	70	70	70
Control Efficiency OFA+RSCR (%)	85	85	85	85
Fraction Reduced	0.85	0.85	0.85	0.85
Emissions Reduction (TPY)	2,320	2,320	1,113	1,168
Annual Operating Cost - OFA ($)	**187,161**	**206,427**	**300,792**	**154,467**
Total Direct Cost (TDC) - RSCR	**6,100,000**			
Indirect Cost (IC) - RSCR	**2,013,000**			
Construction Cost (30% TDC)	1,830,000			
Owners Cost (3% TDC)	183,000			
Total Installed Cost (TIC) - RSCR	**8,113,000**	**8,948,162**	**8,558,357**	**5,816,765**
Additional Operating & Supervisory Labor	0	0	0	0
Maintenance labor & parts (1.5% TIC)	121,695	134,222	128,375	87,251

Parameter	Reference - G-P BART (2010$)	G-P BART (2019$)[a,b]	A-M Kaukauna (2019$)	A-M Rhinelander (2019$)
Electricity	365,574	403,207	403,207	403,207
Ammonia Consumption (5.81 tons/ton NOx)	887,908	979,310	469,739	493,064
Ammonia Inventory (12,000 gal tank)	7,186	7,926	3,802	3,990
Natural Gas (2.5 mmBtu/hr)	146,292	161,351	77,394	81,237
Catalyst (3-year)	337,245	371,961	178,416	187,276
Overhead rate	0	0	0	0
Taxes, insurance, admin. Factor	0	0	0	0
Capital recovery factor (9.44% TIC)	765,867	844,706	807,909	549,103
Annual Operating Cost - RSCR	**2,631,767**	**2,902,684**	**2,068,842**	**1,805,128**
Total Annual Operating Cost – OFA+RSCR ($)	**2,818,927**	**3,109,111**	**2,369,633**	**1,959,595**
Cost-effectiveness ($/ton)	**1,215**	**1,340**	**2,130**	**1,678**

TPY = Tons per year

[a] Cost-effectiveness updated from 2010$ to 2019$ using CEPCI factor of 1.10.

[a] Two alternative control technology options to OFA/RSCR presented in WDNR' 2011 BART determination are: 1) OFA/rich reagent injection(RRI)/selective non-catalytic reduction(SNCR), and 2) OFA/SNCR/in-duct SCR(IDSCR). These options may provide a similar NOx control efficiency at lower annual costs.

APPENDIX 5

WDNR Sept 10, 2020 letter to EPA Region 5, “Attainment SIP for the Oneida County 2010 1-hour SO_2 NAAQS Nonattainment Area”

State of Wisconsin
DEPARTMENT OF NATURAL RESOURCES
101 S. Webster Street
Box 7921
Madison WI 53707-7921

Tony Evers, Governor
Preston D. Cole, Secretary
Telephone 608-266-2621
Toll Free 1-888-936-7463
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WISCONSIN
DEPT. OF NATURAL RESOURCES

September 10, 2020

Mr. John Mooney
Acting Director, Air and Radiation Division
U.S. Environmental Protection Agency, Region 5
77 W. Jackson Blvd.
Chicago, IL 60604

Subject: Attainment State Implementation Plan (SIP) for the Oneida County 2010 1-Hour Sulfur Dioxide (SO_2) National Ambient Air Quality Standard (NAAQS) Nonattainment Area

Dear Mr. Mooney:

The Wisconsin Department of Natural Resources (WDNR) is sending this letter to provide you an updated status about the attainment SIP for the Oneida County 2010 1-Hour SO_2 NAAQS nonattainment area.

In July 2013, EPA designated part of Oneida County as nonattainment for the 2010 SO_2 NAAQS based on monitoring data showing SO_2 values that exceeded the standard. The dominant contributor to SO_2 emissions in this area was determined to be the paper mill located in Rhinelander currently owned and operated by Ahlstrom-Munksjo.[1] Following the nonattainment designation, WDNR, EPA and the source worked cooperatively to determine the actions needed to bring this area into attainment. These discussions culminated in the submittal by WDNR of an attainment plan for the area on January 28, 2016. EPA found this submittal to be complete on February 25, 2016.

The submitted attainment plan was based primarily on permanent emissions limitations and stack height changes at the source made enforceable through WDNR Administrative Consent Order AM-15-01 and Air Pollution Control Permit No. 744008100-P21.[2] This order established a good engineering practices (GEP) stack height determination for stack S09, and emissions requirements for boiler B26, based on fluid modeling provided by the company in 2014. At the time of submittal, WDNR, EPA, and the source were in agreement that the actions to be taken by the facility under the terms of the order were sufficient to meet the 2010 SO_2 NAAQS attainment plan requirements. Neither EPA nor any members of the public raised any concerns with this approach during the state's public comment periods for the SIP submittal or permit.

To comply with the terms of the order, by August 2017 the facility had raised stack S09 to the agreed-to GEP height and begun complying with the associated emissions limitations. These actions had the expected air quality impact, with data from the Rhinelander Tower monitor, which was used by EPA to designate the area as nonattainment, immediately dropping well below nonattainment levels. Design values at that monitor have been in attainment since 2018 (see Table 1).

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[1] The former owners of the facility since 2012 were Wausau Paper Mills, LLC and Expera Specialty Solutions, Inc.
[2] Originally incorporated into permit no. 744008100-P20.

Table 1. Rhinelander Tower monitor SO_2 design values

Site ID	Design values			
550850996	2014-2016	2015-2017	2016-2018	2017-2019
	149 ppb	108 ppb	69 ppb	36 ppb

Based on air quality data, this area has therefore been eligible for a clean data determination and redesignation to attainment since 2018.

However, as you are aware, EPA notified WDNR in February 2017 that certain procedural requirements associated with federal stack height regulations were not followed when determining the terms of the order. As such, EPA has not proposed approval of the attainment plan. Although both WDNR and Ahlstrom-Munksjo disagree with EPA's interpretation of the regulations in question, both parties have been working closely with EPA to explore ways to satisfy EPA's concerns while recognizing the investments made by the facility in good faith that have resulted in attainment-level air quality. The source has continued to comply in all aspects with the applicable order and permits as this issue is being resolved.

Earlier this year, WDNR and Ahlstrom-Munksjo proposed a potential pathway to resolve this issue, which was recently deemed inadequate by EPA. As a result, WDNR and the facility are currently developing other alternatives that we believe will satisfy EPA's concerns. These will include either establishing a limit at a lower GEP stack height or conducting additional technical work to support a higher GEP height, both permitted by regulation. Either option will require, at a minimum: additional site-specific modeling; associated emission rate setting; technical, policy and legal review by all parties; the issuance of a new or revised order or permit; and a revised SIP submittal by WDNR to EPA. Cumulatively, and given the statutorily-required administrative processes involved (e.g., public comment periods), this is expected to take until March 31, 2021. This does not include the required EPA rulemaking process that would begin following submittal of the SIP by WDNR.

WDNR believes this is a timeline that realistically can be met, assuming continued close cooperation and engagement by both Ahlstrom-Munksjo and EPA. However, should this deadline not be met, pursuant to its authority under Wis. Stat. §§ 285.11(6) and 285.13(2), WDNR is prepared to issue an order on April 1, 2021, setting an emissions limitation on the facility that fully adheres to federal stack height regulations.[3]

As noted above, the area's air quality has been meeting the 2010 SO_2 NAAQS since 2018 and therefore has been eligible for a clean data determination since that time. However, given limited resources available to both WDNR and EPA, the agencies have determined that efforts are better spent resolving the unique issues associated with the underlying attainment plan, rather than pursuing such a determination.

WDNR remains committed to working closely and constructively with EPA and Ahlstrom-Munksjo to resolve the remaining procedural requirements associated with this attainment plan in the most expedient manner practicable. Please let me know if you have any questions about this letter.

Sincerely,

DocuSigned by:
Gail E. Good
9AA91D46A40C4A3...

Gail E. Good
Director
Air Management Program

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[3] This limitation would be set assuming a 75-meter GEP stack height.

cc: Tom Emond (Ahlstrom-Munksjo)
Peter Tomasi (Foley & Lardner LLP)
Doug Aburano (EPA Region 5)
David Bizot (AM/7)
Phillip Bower (LS/8)

APPENDIX 6

Wisconsin Smoke Management Plan:
Best Management Practices for Prescribed Burns

WISCONSIN SMOKE MANAGEMENT PLAN:
BEST MANAGEMENT PRACTICES FOR PRESCRIBED BURNS

Table of Contents

SMOKE MANAGEMENT BEST MANAGEMENT PRACTICE GUIDELINES:

Appendices

INTRODUCTION

Use of Prescribed Fire for Ecosystem Management in Wisconsin

Many of the vegetation cover types within the state evolved with fire as the natural process for maintaining plant community structure and composition (Curtis, 1959). For thousands of years, vast, sweeping wildfires occurred across the landscape; either through lightning strikes or through Native populations as they prepared settlements and/or attracted game species to the area (Dorney, 1981; Dorney & Dorney, 1989). Because frequent fire played a significant and extensive role in the development of much of Wisconsin's native plant communities, many plant and animal species now depend on fire for their continued existence.

The practice of mimicking fire’s natural ecosystem benefits in a specific area under controlled settings is known as prescribed fire. Prescribed fire is an important tool in Wisconsin for restoring and maintaining fire-dependent ecosystems, providing wildlife habitat, reducing hazardous fuel buildups, and meeting silvicultural and other needs. Vegetation types ranging from grasslands and prairie plantings, to wetlands, savannas, conifer and hardwood forests, brush lands and agricultural fields are all treated with prescribed fire. Prescribed fire, also known as open burning, is often the most cost-effective method for landscape-scale land treatments. Piled slash is also burned throughout the year for cover type conversion, site preparation, and to mitigate insect- and disease-related problems such as oak wilt.

The decline of naturally-occurring fires over the past 100 years has contributed to the loss of acreage and of these ecosystems, and a decrease in the integrity of the remaining acreage. Use of prescribed fire has been intermittent since the post-logging era wildland fires, and lightning-caused fires are often quickly suppressed before they can provide any major benefit to the plant community. The decline in quality of various fire-dependent ecosystems such as savannas, oak and pine barrens, grasslands, and wetlands, are a direct effect of removing this disturbance from the landscape. To restore and maintain the integrity of these systems, it is crucial that prescribed fire be allowed to occur, where and when it is necessary.

In summary, the main reasons to use prescribed fire include:

- Wildlife habitat improvement and maintenance
- Site preparation and seed production
- Ecosystem management and restoration
- Maintenance of biological diversity
- Restoration of fire as a natural process
- Control of insect and disease
- Fuel reduction, including hazardous fuels
- Minimizing the potential for significant air quality impacts from wildfire
- The training of fire personnel resources
- Testing of fire suppression equipment and suppression techniques.

The use of prescribed fire presents the need to weigh the ecological benefit of this practice vs. the impact of increased emissions from current and accelerated prescribed burning programs. To have a successful and sustained prescribed burn program, it involves the careful consideration of and application of smoke management techniques to minimize the impact of emissions, while still meeting the ecological needs during the prescribed burn.

Background

This Smoke Management Plan (SMP) has been developed to minimize those potential air quality impacts while optimizing the opportunity to use prescribed fire as a land management tool. In 2005, several public and private land management agencies and organizations agreed to develop and implement smoke management best management practices to mitigate potential air quality impacts from prescribed fire. In general, agencies and organizations in Wisconsin that conduct prescribed burns prepare site specific individual burn plans. State law and/or local ordinances may require burn permits for "open burning." Currently most prescribed fire plans include provisions that address the effects of smoke to varying degrees. This SMP will begin a formal effort to minimize impacts of smoke produced from prescribed burns in Wisconsin.

The EPA Exceptional Events Rule published on September 30, 2016 states that all wildfires will be considered as natural events and will not be counted in determining an areas attainment or non-attainment status. The impact of prescribed fires may be discounted if the burn was conducted under a certified Smoke Management Plan or the burner was using basic smoke management practices (as defined by the applicable air quality regulatory agency).

The Division of Forestry of the Wisconsin Department of Natural Resources (DNR) serve as the central authority for the State's SMP. The SMP guidelines will become effective when the DNR certifies in writing to the U.S. Environmental Protection Agency (EPA) that a SMP has been adopted and implemented.

Purpose

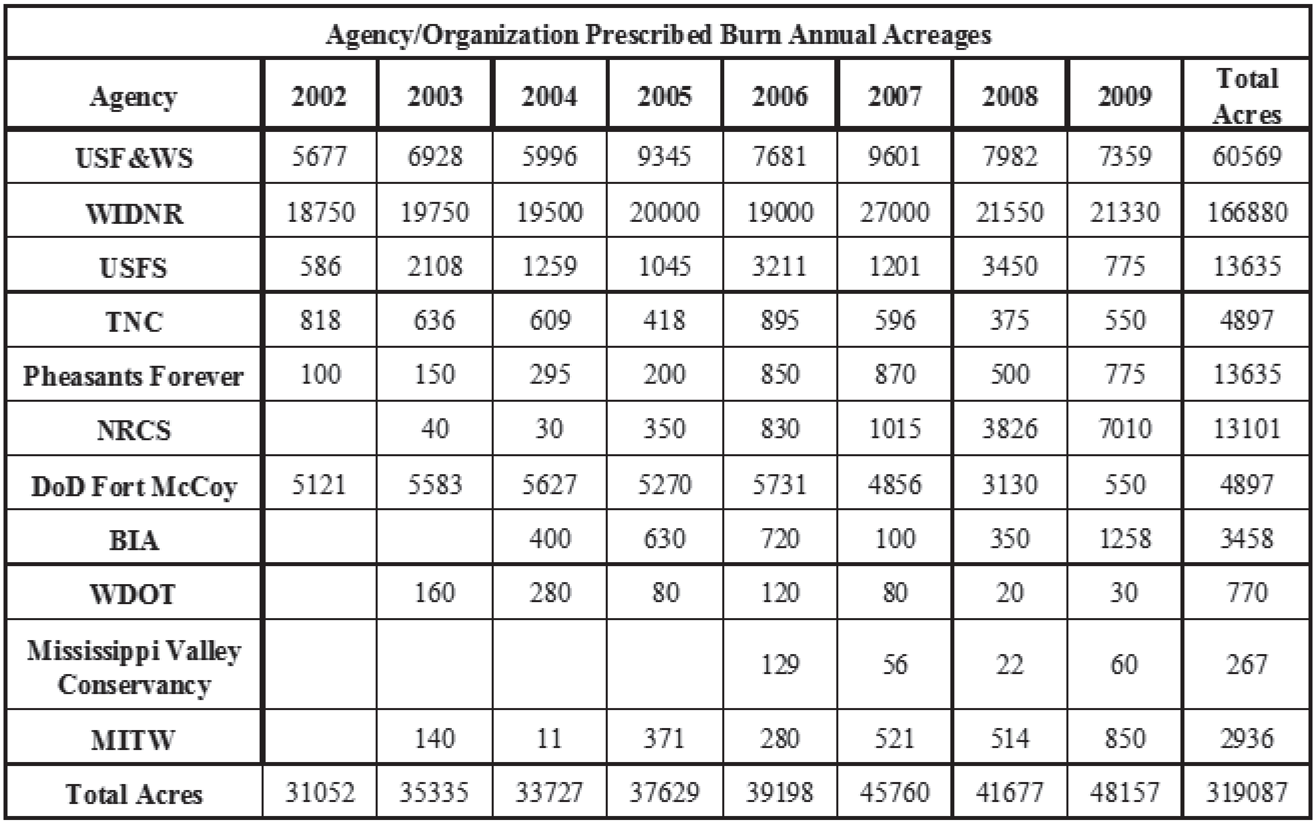
These smoke management best management practices are a set of guidelines and procedures that are followed by signatory organizations to reduce the adverse effects of smoke from prescribed fires. The goal of the Wisconsin SMP is to prevent violations of the federal fine particles standard ($PM_{2.5}$) and minimize adverse effects including:

- Health effects from smoke inhalation
    - Premature death
    - Decreased lung function
    - Increased asthma attacks and chronic bronchitis
    - Acute respiratory symptoms
    - Respiratory- and cardiopulmonary-related hospital admissions
    - Increased work and school absences
- Visibility-related travel hazards
    - Aircraft
    - Highways
    - Rail
- Electric utility hazards
- Violations of an ambient air quality standard
- Decreased visibility in scenic vistas

Organizations that May Wish to Sign on to the Smoke Management Plan

In Wisconsin, a variety of federal, state, county, and non-profit conservation groups, as well as numerous private prescribed burn contractors all use fire to accomplish goals and objectives ranging from ecosystem management to fuels reduction (Table 1). USDA conservation programs (e.g., Conservation Reserve Program, Wildlife Habitat Incentives Program) offered through the Farm Service Agency and Natural Resources Conservation Service (NRCS) place an emphasis on prescribed fire, making the increased use of prescribed fire in the private sector a general trend. Any organization that actively conducts prescribed burns and can adequately encourage and enforce the SMP's Best Management Practices is eligible to become a signatory on the Smoke Management Plan. For further information on the basis for developing the Smoke Management Plan in Wisconsin, please see Appendix B.

This SMP is an evolving document and will undergo ongoing evaluation using stakeholder input. The SMP document will be reviewed together by the principle contacts of the signatories every five years and amended as necessary to achieve the purpose of the SMP and incorporate changes in regulations, policies and advances in technology.



Agency/Organization Prescribed Burn Annual Acreages

Agency	2002	2003	2004	2005	2006	2007	2008	2009	Total Acres
USF&WS	5677	6928	5996	9345	7681	9601	7982	7359	60569
WIDNR	18750	19750	19500	20000	19000	27000	21550	21330	166880
USFS	586	2108	1259	1045	3211	1201	3450	775	13635
TNC	818	636	609	418	895	596	375	550	4897
Pheasants Forever	100	150	295	200	850	870	500	775	13635
NRCS		40	30	350	830	1015	3826	7010	13101
DoD Fort McCoy	5121	5583	5627	5270	5731	4856	3130	550	4897
BIA			400	630	720	100	350	1258	3458
WDOT		160	280	80	120	80	20	30	770
Mississippi Valley Conservancy					129	56	22	60	267
MITW		140	11	371	280	521	514	850	2936
Total Acres	31052	35335	33727	37629	39198	45760	41677	48157	319087

Table 1: Agency/organization prescribed burn annual acreages

BEST MANAGEMENT PRACTICE GUIDELINES:

BURN PERMITTING

Signing organizations agree to follow the SMP best management practice guidelines below as part of their day-of-burn decision-making.

The DNR Division of Forestry is responsible for issuing permits for open burning in organized protection areas, outside of incorporated cities or villages in Wisconsin (Figure 1), for forest fire protection purposes. In cooperative protection areas, town chairpersons are responsible for issuing permits for open burning for forest fire protection purposes. This authority is stated in Wisconsin State Statute Chapter 26 and associated administrative rules.

The DNR issues written permits for open burning of vegetation (see Figure 1 below). A permit is not required when the ground is covered with snow. Permitting of open burning is also administered locally when municipalities or townships have local ordinances more restrictive than the state rules.

Wisconsin Administrative Code, NR 429.04(1) prohibits open burning with certain exceptions. One of those exceptions is backfires to control forest fires or fires set for forest or wildlife habitat management with the approval of the DNR where no reasonable alternative is available. Factors in considering the reasonableness of alternatives may include: 1) costs of other alternatives, 2) availability of other alternatives, or 3) effectiveness of each of the other alternatives in comparison to a prescribed burn in achieving the land management objectives. In addition, NR 429.04(2) specifies that all allowed open burning shall be conducted in a safe, pollution-free manner, when wind and weather conditions will minimize adverse effects and in conformance with local and state fire protection regulations.

Historically, federal agencies in Wisconsin have complied with state burning regulations. The SMP is a formal agreement among signatory agencies for following state burning regulations for the purposes of future smoke-related emission and impact reduction.

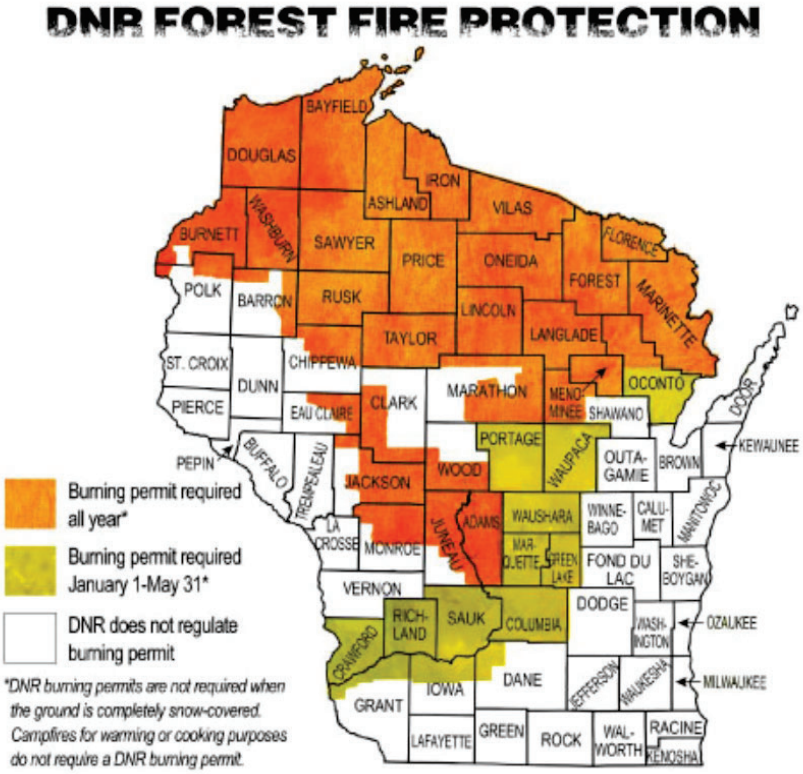


Figure 1: Forest fire protection and co-op areas in Wisconsin

BEST MANAGEMENT PRACTICE GUIDELINES:

BURN PLANNING

Signing organizations agree to follow the SMP best management practice guidelines below as part of their burn plan content.

Burn Plan Elements

All signatories to this SMP agree to have burn plans that incorporate the elements listed below. They should be on file at agency or organization offices and are available upon request. Prescribed burn plans will include the following elements at a minimum:

- Location and legal description (Town, Range, Section and quarter-quarter section) of the area to be treated, including ownership
- Personnel and/or certified prescribed Burn Boss responsible for managing the fire
- Type of vegetation or fuel model (utilizing the National Fire Behavior Prediction System) to be burned
- Area in acres to be burned
- Amount of fuel to be consumed*
- Fire prescription including smoke management components and ventilation index limits
- Criteria the fire manager will use for making go/no-go burn decisions
- Safety and contingency plans

**As an example, if burning in a Fuel Model 6 (brush fuel type), and the objective is to reduce 75% of the woody vegetation, this can be calculated by multiplying average fuel present (6 tons/acre) by 75%. This results in amount of fuel to be consumed equaling 4-1/2 tons/acre. Fuel loading assumptions for the standard 13 fuel models can be found within the Aids to Determining Fuel Models for Estimating Fire Behavior (Anderson, 1982).*

Evaluating Smoke Dispersion and Sensitive Receptor Sites

Prescribed burn plans should identify and evaluate potential smoke impacts on sensitive receptors. Fires should be timed to minimize exposure of sensitive populations (those that smoke may present particular health risks). For more information on smoke production and dispersion, please see Appendix C.

There are 5 steps to address sensitive receptor sites and smoke dispersion:

- Identify and list sensitive receptor sites
- Specify the requirements for smoke dispersal at sensitive receptor sites
- Check for Air Quality Advisories and elevated AQI levels
- Notify affected populations and authorities
- Identify monitoring plans for sensitive receptor sites

These steps are further described below.

1. Identify and list sensitive receptor sites

   Sensitive receptor sites are usually defined as locations where human populations tend to concentrate and where smoke could impact the health of those populations or significantly impact visibility that may be detrimental to health or the enjoyment of scenic qualities of the landscape. These may be residential concentrations in the form of towns or cities, or locations where people tend to gather in groups such as parks and schools. Areas where citizens can be especially sensitive to smoke include hospitals, schools, and retirement facilities. Travel routes such as highways may be labeled as sensitive receptor sites where smoke can be a factor in potential motor vehicle accidents. Particular areas along highways or other locations may be more prone to being declared sensitive receptor sites because of topographic and microclimate features.

2. Specify the requirements for smoke dispersal at sensitive receptor sites

   The plan should identify the distance and direction from the burn site to local sensitive receptor areas where appropriate. Fire prescriptions will specify minimum requirements for the atmospheric capacity for smoke dispersal such as minimum surface and upper level wind speeds, desired wind direction, minimum mixing height, and dispersion index. Utilize the Ventilation Index explained in Appendix D for minimum requirements.

3. Check for Air Quality Advisories

   The Burn Boss or prescribed fire manager responsible for a proposed prescribed burn has the responsibility to ensure that there is no air quality advisory in effect for the county or counties affected by smoke dispersal on the day that the prescribed burn occurs. Check the Air Quality Index (AQI) for the area of the burn and downwind impact zone on the DNR website or the AirNow website (both post air quality advisories). When AQI values are orange (unhealthy for sensitive groups) or above in the area where the burn unit is located, or in the downwind smoke impact zone, further evaluation and consideration should be exercised. Air Quality Advisory information can also be delivered by email alerts, which staff can sign up for, In the event of an air quality advisory, signatories to this SMP agree to cancel all open burning related to prescribed fire use for the applicable county or counties while the advisory remains in effect.

4. Notify affected populations and authorities

   The burn plan should identify actions that will be taken to notify populations and authorities at sensitive receptors, including those in adjacent jurisdictions, prior to the fire. The plan should also identify contingency recommendations that should be taken during a fire to reduce the exposure of people at sensitive receptors if smoke intrusions occur.

   Recommendations below are from the National Wildfire Coordinating Group's Smoke Management Techniques Course (RX-410):

   - Notify sensitive receptors and the DNR Air Management Program as soon as possible when conditions change
   - Place field observers at sensitive receptors to monitor smoke conditions
   - Work with local health agencies and DNR Air Management Program (issues air quality health advisories)
   - Relocate smoke-sensitive people
   - Terminate project
   - Accelerate completion of project

5. Identify monitoring plans for sensitive receptor sites

   The plan should identify how the effects of the fire on air quality at sensitive receptor areas should be monitored. The extent of the monitoring plan should match the size of the fire, fuel loading and consider the proximity to smoke sensitive areas. For small, or short duration fires (such as those in grass or leaf litter), visual monitoring of the directions of the smoke plume and monitoring nuisance complaints by the public may be sufficient. Other monitoring techniques include posting personnel at sensitive receptors to identify smoke intrusions and continued tracking of meteorological conditions during the fire. For fires in fuels with longer duration burning (such as timber litter or slash), and which are expected to last more than one day, locating real-time PM monitors at sensitive receptors may be warranted to facilitate timely response to smoke impacts.

Smoke Dispersion Forecasts

The National Weather Service (NWS) forecast offices in Green Bay, Sullivan, LaCrosse, Duluth, MN, and Minneapolis, MN provide twice daily fire weather forecasts every day during the fire season (generally April 1st to November 1st). The fire weather forecasts issued by the respective NWS offices, at 0700 and again by 1500, include projected smoke management information. The Fire Weather Annual Operating Plan (FWAOP), available at the forecast offices or most agency dispatch or coordination centers, provides extensive forecast information.

To ensure optimum dispersal of smoke emissions during prescribed burns, the mixing height should be deep enough and have sufficient transport wind speed to ensure the dilution and dispersal of emission concentrations. The ventilation index multiplies mixing height (measured in feet) and transport wind speed (measured in knots per hour) to produce an index that expresses the ability of the atmosphere to disperse emissions. This dispersion information is included as part of the daily fire weather forecast. It describes the mixing height, transport wind speed and ventilation index for the peak or low conditions during the forecast period. State and federal agency prescribed fire managers who plan ignitions at other than the time listed on the forecast may request dispersion/ventilation criteria as part of a spot weather forecast from the NWS. At this time, a spot weather forecast from the NWS is not available to the private sector. For more information on the ventilation index, refer to Appendix D.

Actions to Minimize Fire Emissions

The burn plan should document the steps to be taken prior to, during, and after the burn to reduce air emissions. This could include, but may not be limited to, any of the following measures stated in the Smoke Management Guide for Prescribed Fire (NWCG, 2018):

- Minimize the area burned; reduce the acreage burned per burning period or use non-fire treatments.
- Reduce the fuel loading in the area to be burned by mechanical means, or by using frequent, low intensity burns to gradually reduce fuels.
- Reduce the amount of fuel consumed by the fire by burning when large non-target fuel moistures and duff moistures are higher.
- Minimize emissions per ton of fuel consumed, by using mass ignition techniques, using backing fires, increasing combustion efficiency and performing rapid and complete mop-up.
- Pre-treat heavy fuels or use firing techniques that exclude them from the burn.
- Minimize potential smoke impacts on sensitive receptors

SMOKE MANAGEMENT BEST MANAGEMENT PRACTICE GUIDELINES:
TRANSPORTATION & UTILITIES

Signing organizations agree to follow the SMP best management practice guidelines below as part of their mitigation strategy for transportation and utility infrastructure.

Road Impacts

The Wisconsin Department of Transportation (WDOT) is responsible for maintaining the state and federal highways within Wisconsin. If a prescribed burn is being planned within a WDOT right-of-way (ROW) by another state or federal land management agency, organization or private landowner, a DOT permit may be required. Planning for smoke management adjacent to state and federal highways begins with contacting the local WDOT Regional Office to determine if a DOT permit is required. Each WDOT Regional Office has an individual contact for obtaining right-of-way permits.

The following documents will be submitted to the WDOT Regional Right of Way permit contact:

1. Application/Permit to Work on Highway Right-Of-Way (WDOT Form DT 1812)

2. The approved burn plan

Processing time for permit approval is up to 30 days and is intended for non-emergency activities. The approval of an annual permit rather than an individual permit may be desirable to accommodate flexibility in the time range to complete multiple burns adjacent to highways planned by state and federal land managers.

The thresholds for pre-planning the distance of a burn from travel routes should be determined on a site-by-site basis. Property ownership, rural vs. urban environment, average daily traffic (ADT) and the justification for burning within the vegetated ROW should be evaluated and addressed within the burn plan.

Participation in the WDOT ROW permit process as described above should assure that the Burn Boss/Fire Manager receives specific information on the required signage and its proper placement within the ROW. The WDOT brochure *Work Zone Safety: Guidelines for Construction, Maintenance, & Utility Operations* is an excellent reference. The use of electronically programmable signs for smoke warning and speed reduction is an option. The responsibility for providing standard signs or renting the programmable signs lies with the agency or organization conducting the prescribed burn. Traffic control devices placed and maintained by the state, county, city or other local officials are required by Wisconsin law to conform to the *Wisconsin Manual on Uniform Traffic Control Devices*.

For emergency situations, Burn Bosses should immediately call 911 or local law enforcement or contact the local Region WDOT Emergency Coordinator for the fastest response. The use of signage, the decision to temporarily close a state or federal highway and to reroute traffic must be coordinated with WDOT in cooperation with fire officials and law enforcement.

Responsibility for county, city, or town roads is under the jurisdiction of the local unit of government. Prescribed fire managers/Burn Bosses should contact local highway officials for the permitting process. Contact information for each County Highway Commissioner in Wisconsin is available on the WDOT website. Detailed information about all roads within the state of Wisconsin including State and Federal Routes, County roads, Town roads or others can be found at the WDOT maps website.

Authority to control traffic must be coordinated with state, county, or local units of government having jurisdiction over the road. The best practice would be not to burn when it is apparent that smoke would be placed over a roadway.

Railway Impacts

Contact the emergency management representative for the specific railroad effected. These representatives should have firsthand knowledge of their internal processes for emergency response to smoke and the timing of rail activity along the rail line.

The *Official Rail Map* and directory of railroads is available from the WDOT public website. The *Wisconsin Rail Map*, *Emergency Railroad Phone Numbers* and *Required Clearances near Railroad Tracks* are just a few of the documents available to assist in planning for smoke management along railroad corridors.

Air Traffic Impacts

The coordinating agency should contact any private and/or public airport within 10 miles of the closest burn perimeter so that air traffic control is aware of the situation. Prescribed burning within 5 miles of an airport perimeter should be closely coordinated with the airport manager/owner so that the burn does not conflict with airport usage (e.g. new pilot training). The WDOT airport website can provide detailed information on airport locations and contact information on locations.

Utility Impacts

The safety of fireline personnel in relation to fire use near overhead transmission lines, where smoke, ash and incidental mist from fireline operations may contaminate the insulators on transmission structures is a consideration. Standard utility recommendations are to maintain a minimum radial distance of 35 feet between firefighters, vehicles, and transmission structures to protect firefighting personnel from this electrical hazard. Further recommendations would be to place containment lines no closer than 100 feet of and parallel to the edge of the outer most conductor.

Planning to address the direction and dispersion of smoke in these situations is critical as a heavy smoke plume on power lines may cause a conductor to ground short. Consider including any utility owner or operator that maybe impacted in the planning process. Qualified company representatives are responsible for safely adhering to all other rules pertaining to this subject matter.

SMOKE MANAGEMENT BEST MANAGEMENT PRACTICE GUIDELINES:
OUTREACH, ENFORCEMENT, & EVALUATION

Signing organizations agree to follow the SMP best management practice guidelines as part of their outreach, enforcement, and evaluation strategies.

Public Education and Awareness

Agencies and organizations that conduct prescribed burns should work to establish and maintain programs to stress the use and importance of fire for ecosystem and related land management goals. Public health and safety are critical to this effort.

Record-keeping and Enforcement

Prescribed Burn Bosses should follow a pre-burn Go/No-go procedure to ensure that the burn day parameters meet the burn plan prescription, including the smoke management best management practices. Failing to follow the burn plan prescription, Burn Bosses would be subject to that organization's specific review protocols and possible disciplinary action. Agencies are encouraged to include prescribed burn personnel from other signatory agencies in any prescribed fire review. Should legal action be taken for a prescribed burn that may trigger a review, the review may be delayed or pre-empted by necessary legal considerations.

Signatory agencies should also maintain records necessary to demonstrate an Exceptional Event, per Environmental Protection Agency Exceptional Event Rules. This allows the DNR to petition EPA to exclude historic exceptional event data. In 2017, the allowable time period to exclude historic data was 4 years. In addition, the DNR air monitoring contact should review data from the existing $PM_{2.5}$ and ozone monitors in Wisconsin. Any correlations of National Ambient Air Quality Standards (NAAQS) with prescribed burns should be assessed. In the event an exceedance (PM_{10}, $PM_{2.5}$, or ozone) is recorded, DNR will notify the principal contacts listed in the MOA to ensure the documentation necessary to demonstrate an Exceptional Event is collated and available.

Optional Air Quality Protection

Agencies should consider opportunities to establish specific, stringent protection for those special areas requiring additional regulation in the interest of public health and safety. Recognition of these areas should be documented in site-specific burn unit plans, along with the steps to minimize impacts.

Program Evaluation

To evaluate the effectiveness of the SMP, the DNR Prescribed Fire Specialist will annually review information on acres burned by fuel type with prescribed fire. Reports of nuisance complaints or smoke intrusions should be noted and used to measure the effectiveness of this plan. Upon implementation of this plan, by January 31st of each year signatories should annually submit electronically to DNR Prescribed Fire Specialist the following:

1. Acres prescribed burned by fuel model for the previous calendar year.
2. Amount of fuel consumed, based on fuel model
3. Date of burns
4. Moisture content (if available)
5. Location and legal description of burns conducted.
6. Nuisance complaints or smoke intrusions. DNR will estimate emissions based upon stakeholder inputs for inclusion in the annual emissions report for the previous calendar year to EPA. The annual emissions report will be shared with contacts listed in this agreement.

GLOSSARY

air quality – The characteristics of the ambient air (all locations accessible to the general public) as indicated by concentrations of the six air pollutants for which national standards have been established [i.e., particulate matter (PM), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3), carbon monoxide (CO) and lead], and by measurement of visibility in mandatory Federal Class I areas.

Air Quality Advisory – An air quality advisory is issued when the ambient air quality in an area is unhealthy for sensitive individuals or when the air quality is expected to degrade to that level within a few hours.

ambient air – That portion of the atmosphere, external to buildings, to which the general public has access.

attainment area – A geographic area in which levels of a criteria air pollutant meet the national ambient air quality standard (NAAQS) for the pollutant. An area may have on acceptable level for one criteria air pollutant, but may have unacceptable levels for others. Thus, an area could be both attainment and non-attainment at the same time. Attainment areas are designated by EPA.

Burn Boss – Person responsible for supervising a prescribed burn from ignition through mop-up.

Class I Area – An area set aside under the Clean Air Act (CAA) to receive the most stringent protection from air quality degradation. Mandatory Class I Federal areas are (1) international parks, (2) national wilderness areas which exceed 5,000 acres in size, (3) national memorial parks which exceed 5,000 acres in size, and (4) national parks which exceed 6,000 acres and were in existence prior to the 1977 CAA Amendments. The extent of a mandatory Class I Federal area includes subsequent changes in boundaries, such as park expansions.

combustion – Burning. Many important pollutants, such as sulfur dioxide, nitrogen oxides, and particulates (PM_{10}) are combustion products, often products of the burning of fuels such as coal, oil, gas and wood

criteria air pollutants – A group of air pollutants regulated by EPA on the basis of criteria (information on health and/or environmental effects of pollution) and for which NAAQS have been established. In general, criteria air pollutants are widely distributed all over the country. They are: particulate matter (PM), carbon monoxide (CO), sulfur dioxide (SO_2), ozone (0_3), Nitrogen Oxide (NOx) and lead (Pb).

emission – Release of pollutants into the air from a mobile source (e.g. vehicle), stationary source (e.g. industry), or area sources (e.g. gas stations, chimneys, vegetative burning). We say sources emit pollutants

fuel – Includes combustible vegetative matter such as grass, trees, shrubs, limbs, branches, duff, and stumps.

haze – Particles in the air that scatter light and degrade visibility.

***monitoring (monitor*)** – Measurement of air pollution is referred to as monitoring. EPA, state and local agencies measure the types and amounts of pollutants in the ambient in air.

National Ambient Air Quality Standards (NAAQS) – National standards for maximum acceptable concentrations of “criteria” pollutants in the ambient air. Designed to protect public health with an adequate margin of safety (primary standard), and to protect public welfare from any known or anticipated adverse effects of such pollutants (e.g., visibility impairment, soiling, materials damage, etc.) in the ambient air (secondary standard).

non-attainment area – A geographic area in which the level of a criteria air pollutant is higher than the level allowed by the federal standards. A single geographic area may have levels that are acceptable of one criteria air pollutant but unacceptable levels of one or more other criteria air pollutants; thus, an area can be both attainment and non-attainment at the same time.

nuisance smoke – Amounts of smoke in the ambient air, that interfere with a right or privilege common to members of the public, including the use or enjoyment of public or private resources.

ozone – A highly reactive gas consisting of three oxygen atoms.

particulate matter (PM) – Any airborne finely divided material mixture of very small particles that are suspended in the atmosphere, except uncombined water, which exists as a solid or liquid at standard conditions (e.g., dust, smoke, mist, fumes, or smog).

PM_{10} – Particles with an aerodynamic diameter less than or equal to a nominal 10 micrometers (including $PM_{2.5}$). Concentrations in the air are measured as micrograms per cubic meter of air ($\mu g/m^3$).

$PM_{2.5}$ – Particles with an aerodynamic diameter less than or equal to a nominal 2.5 micrometers. Concentrations in the air are measured as micrograms per cubic meter of air ($\mu g/m^3$).

prescription – Measurable criteria that guide selection of appropriate management response and actions. Prescription criteria may include the meteorological conditions affecting the area under prescription, as well as factors related to the state of the area to be burned such as the fuel moisture condition and other physical parameters. Other criteria which may be considered include safety, economic, public health, environmental, geographic, administrative, social or legal considerations, and ecological and land use objectives.

Prevention of Significant Deterioration (PSD) -- A requirement in the Clean Air Act, which establishes the maximum allowable increases in ambient air concentrations of selected air pollutants above baseline concentrations in areas designated as Class I, Class II, or Class III.

prescribed fire – Any fire ignited by management actions to meet specific objectives. For federal agencies a written, approved prescribed fire plan must exist, and NEPA requirements (where applicable) must be met, prior to ignition.

sensitive populations – Those populations to which smoke emissions may present particular health risks.

sensitive receptors – Locations where human population tend to concentrate and where smoke could impact the health of those populations or significantly impact visibility that may be detrimental to either health or the enjoyment of scenic qualities of the landscape. These may be residential concentrations in the form of towns or cities, or locations where people tend gather in groups such as parks. Travel routes such as highways may be labeled as sensitive receptor sites where smoke can be a factor in potential motor vehicle accidents. Particular areas along highways or other locations may be more prone to being declared sensitive receptor sites because of topographic and microclimate features. *(i.e., Population centers such as towns and villages, camp grounds and trails, hospitals, nursing homes, schools, roads, airports, mandatory Class I Federal areas, etc. where smoke and air pollutants can adversely affect public health, safety and welfare.)*

smoke management best management practices – Establish a basic framework of procedures and requirements for managing smoke from fires that are managed for resource benefits. The purpose of these best management practices are to mitigate the health, nuisance and public safety hazards (e.g., on roadways and at airports) posed by smoke intrusions into populated areas; to prevent deterioration of air quality and NAAQS violations; and to address visibility impacts in mandatory Class I Federal areas in accordance with the regional haze rules.

source – Any place or object from which pollutants are released, such as power plants, factories, dry cleaners, gas stations, farms, motor and consumer products.

State Implementation Plan **(SIP)** – State implementation plans are collections of the regulations and emission reduction measures used by a state to reduce air *pollution* in order to attain and maintain NAAQS or to meet other requirements of the Clean Air Act. The Clean Air Act requires that EPA approve each state implementation plan.

Violation of the PM NAAQS – As revised in 2006, the daily PM_{10} standard is violated when the 99th percentile of the distribution of 24-hour concentrations for a period of 1 year (averaged over 3 calendar years) exceeds 150 $\mu g/m^3$ at any monitor within an area. $PM_{2.5}$ are set at a daily concentration less than or equal to 35 $\mu g/m^3$, and an annual mean concentration of less than or equal to 15 $\mu g/m^3$. For $PM_{2.5}$ the daily standard is violated when the 98th percentile of the distribution of the 24-hour concentrations for a period of 1 year (averaged over 3 calendar years) exceed 35 $\mu g/m^3$ at any monitor within an area. The annual standard is violated when the annual arithmetic mean of the 24-hour concentrations from a network of one or more population-oriented monitors (averaged over 3 calendar years) exceeds 15 $\mu g/m^3$.

wildfire – An unplanned and unwanted wildland fire including unauthorized human-caused fire, escaped prescribed fire, and all other wildland fires where the objective is to put the fire out.

wildland fire – Any non-structural fire that occurs in the wildland. Two distinct types of wildland fire have been defined in Wisconsin and include wildfire and prescribed fire.

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Appendix A
Principle Contacts for Wisconsin Smoke Management Plan

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Appendix B
Basis for Developing Smoke Management Best Management Practices

The purposes of the Smoke Management Plan (SMP) and its accompanying best management practices are directly related to the mitigation of any public health, nuisance and safety hazards posed by smoke intrusions into populated areas and roadways. The goals are to prevent deterioration of air quality and National Ambient Air Quality Standards (NAAQS) violations, and address visibility impacts on mandatory Class 1 Federal areas. The NAAQS referred to here are for particulate matter (PM) less than 2.5 microns ($PM_{2.5}$) and PM less than 10 microns (PM_{10}) in diameter.

The reasons the SMP is being developed for Wisconsin are:

1. <u>There has been an increase in the use of prescribed fire in Wisconsin.</u>

   Table A1 identifies a trend of increased use of prescribed fire in Wisconsin. This follows a nationwide trend identified by federal and state land managers. This increase of prescribed fire has strong ecosystem and landscape management implications to increase biodiversity and productivity.

2. <u>To utilize a voluntary program to prevent PM NAAQS violations related to emissions from prescribed fire managed for resource benefits.</u>

   Implementation of the smoke management best management practices by land management agencies, should reduce potential emissions and smoke impacts from prescribed fires so that emissions do not result in "non-attainment" status with NAAQS and state air quality standards. The EPA Interim Guidance document explains that states which implement a certified SMP and do violate the PM_{10} or $PM_{2.5}$ standards will not have areas designed as "non-attainment", if the State demonstrates that prescribed and/or wildland fire significantly contributed to the concentration of pollutants that exceeded the standards. This incentive by the EPA for implementation of a Smoke Management Plan is important if an area of the state were to violate the air quality standards due to smoke produced by prescribed burning.

3. <u>The EPA Regional Haze Rule, which aims to protect and improve visibility in mandatory Class I areas</u>.

   Section 169A of the Clean Air Act Amendments (CAAA) of 1977 sets forth "the national goal of preventing any future, and remedying any existing, impairment of visibility in mandatory Class I Federal areas which impairment results from man-made air pollution." The EPA rules issued in 1980 included language directed at those sources "reasonably attributable" to visibility impairment. With the addition of section 169B of the CAAA of 1990, congress addressed "regional haze" visibility impairment in the nation's national parks and wilderness areas. The EPA determined that all 156 listed mandatory Class I areas across the nation demonstrate impaired visibility based on monitoring data from the Interagency Monitoring of Protected Visual Environments (IMPROVE). Within Wisconsin this includes Forest County Potawatomi Community; neighboring Class 1 areas include Seney National Wildlife Refuge and Isle Royale National Park in Michigan, and Voyageurs National Park and Boundary Waters Canoe Area Wilderness in Minnesota. For the Class I areas, in Minnesota and Michigan, smoke from Wisconsin prescribed fires have not been shown to be a significant contributor to visibility impairment.

   EPA published their final Regional Haze Rule on July 1, 1999 (64FR35714). This rule is directed at man-made air pollution sources that have the potential to cause or contribute to visibility impairment including: 1) stationary sources (industry), 2) mobile sources (vehicles), 3) area sources (gas stations, dry cleaners, etc.), and 4) the use of managed fire. Of the pollutants most responsible for haze (nitrates, sulfates, soil material, organic carbon, and elemental carbon), nitrates, organic carbon and elemental carbon are produced by vegetative burning. The regional haze program goal is to show continued improvement in monitored visibility in Class 1 areas and restore natural background conditions by 2064.

Appendix C
Smoke Production and Dispersion

Overview and Definition of Smoke Dispersion

Information pertaining to smoke dispersion is an important element of a prescribed burn plan. Mixing height is defined as the upper limit of an unstable mixed layer, in which upward and downward exchange of air occurs. In theory, the mixing height represents the level that smoke will rise to before spreading out horizontally. Transport wind is defined as the arithmetic average of the wind speed and direction within the mixed layer. Transport wind should provide a basic estimate of the movement of the smoke column as it travels out of the source region.

Climate Factors that Influence Smoke Dispersion in Wisconsin

Wisconsin resides in the humid continental climate region, due to its interior location in the mid-latitudes of North America. The state lies in the boundary zone between many different air masses, including those of polar and tropical origin. As a result, Wisconsin experiences highly variable weather conditions and large seasonal changes in temperature. Weather conditions are most variable during the spring and fall months, when the jet stream migrates across the Great Lakes, resulting in strong storm systems tracking through the region. Lake Superior and Lake Michigan strongly influence local weather conditions near their respective shorelines in northwest and eastern Wisconsin.

Here are some more detailed explanations of the various factors that influence smoke dispersion potential in Wisconsin:

Air Masses and Frontal Systems are the main factors that influence day-to-day variations in smoke dispersion. There are five different types of air masses that affect the United States, including continental polar, continental arctic, continental tropical, maritime polar and maritime tropical. Wisconsin can be affected by all of these air masses during the course of a fire season, but is most commonly affected by continental polar, maritime polar and maritime tropical air masses. Continental polar air masses, which arrive from northern Canada, are usually cool, dry and stable, and sometimes result in low mixing heights and poor smoke dispersion due to the presence of a subsidence inversion. Maritime polar air masses form over the northern Pacific Ocean region, where they take on their typical cool, moist and unstable characteristics. However, these air masses usually lose most of their moisture as they ascend the west slopes of the Rocky Mountains, and warm as they descend the east slopes. By the time they arrive in Wisconsin, they are usually dry, mild and unstable. As a result, mixing heights are typically quite high in air masses of Pacific origin. Maritime tropical air masses, which originate from the Gulf of Mexico, are usually warm, moist and unstable.

Frontal systems can also have a significant effect on smoke dispersion. Cold fronts are usually accompanied by windy and unstable conditions, which provide for excellent smoke dispersion. Conditions are quite variable with warm fronts, with stable conditions and poor smoke dispersion expected north of the front, and unstable and windy conditions to the south.

Latitude, which controls the sun angle and length of the day, is responsible for seasonal temperature contrasts. Mid-latitude locations such as Wisconsin experience sharp changes in seasonal temperatures due to widely varying sun angle and day length. These temperature changes can significantly impact smoke dispersion. For example, mixing heights are typically lowest during the winter months, since daytime heating is limited due to low sun angle, short day length and snow-covered ground. During the spring and summer, increased solar heating due to a high sun angle and longer day length is usually sufficient to mix out low level inversions, resulting in higher mixing heights and more effective smoke dispersion.

Lake Superior and Lake Michigan have a significant impact on smoke dispersion, especially during the spring and summer months. Lake breezes, which frequently develop in northwest and eastern Wisconsin from April through August, often result in poor smoke dispersion near the lakeshore. Lake breezes typically form during the late morning or early afternoon, become strongest during the mid to late afternoon, then weaken by early evening. On most days, the lake breeze front will only push inland 5 to 10 miles, but in extreme cases, may move inland 50 miles or more. Stable conditions develop as the cooler marine air penetrates inland, forcing warmer air aloft. In addition to smoke dispersion concerns, shifting winds associated with a lake breeze front can occasionally cause fire control problems.

Upper Level Disturbances, also known as upper level troughs of low pressure, often result in improved smoke dispersion as they pass through the western Great Lakes region. These disturbances, which are usually accompanied by pockets of cold air aloft, often produce windy and unstable conditions, and help to generate large scale rising motion in the atmosphere.

Weather Patterns that Affect Smoke Dispersion in Wisconsin

Wisconsin usually receives good ventilation throughout most of the fire season. During the months of April through October, solar radiation is usually strong enough to either mix out or lift inversions that are near the surface. However, there are some typical seasonal weather patterns that cause smoke dispersion problems.

- During the early spring and late fall, strong Canadian high pressure systems often sag into the northern Great Lakes region and persist for several days. These Canadian highs typically have strong subsidence inversions, which gradually lower toward the surface, leading to poor smoke dispersal. Ventilation is especially poor when widespread low clouds (stratus) are present. The low clouds typically form in two ways; either due to low level east winds affecting marine moisture off of Lake Michigan, or due to the presence of a warm front over Iowa

  and northern Illinois, which lifts warm, moist air from the Gulf of Mexico over the top of the cooler Canadian air mass. The poor smoke dispersal is the net result of low mixing heights (generally 1,000-2,000 feet) and light winds.
- Persistent (lasting up to a week or more) summertime high pressure systems accompanied by a large blocking ridge of high pressure aloft can produce significant smoke dispersion problems. Although daytime mixing heights are often sufficiently high, transport winds are typically too light to support efficient smoke dispersion. The stagnant conditions eventually lead to reduced visibility and poor air quality, especially during the nighttime and early morning hours, when smoke particles aloft fall back to the surface.
- Radiation inversions (also known as nocturnal inversions), which develop as the earth's surface cools at night, can trap smoke near the ground during the nighttime and morning hours. Radiation inversions can occur throughout the year, and typically form on nights when skies are clear and winds are light. Summertime radiation inversions tend to be shallower, and usually mix out earlier in the morning, than those that develop during the spring and fall.
- Inland intrusions of cool, stable marine air associated with lake breeze fronts (or persistent onshore winds) can significantly hinder smoke dispersion during the spring and summer months. Lake breeze fronts are most common on days when winds at the surface and aloft are light. Lake breezes that develop near Lake Superior in northwest Wisconsin typically have a northerly component to their wind direction, while those that develop near Lake Michigan (and the bay of Green Bay) have an easterly component. Although a lake breeze front will typically remain within 5 to 10 miles of the lake during the early to mid-afternoon, they can occasionally penetrate well inland (50 miles or more) before weakening during the late afternoon or early evening hours.

Appendix D
Guidance for Use of the Ventilation Index and Dispersion Tables

Smoke dispersion is directly related to ventilation, which is the process within the atmosphere that mixes and transports smoke away from its source. Ventilation is a function of atmospheric stability, mixing height and transport winds.

Just as various indices are used to estimate fire behavior, a ventilation index has been developed to estimate the lower atmosphere's ability to diffuse and disperse smoke. The Ventilation Index (also known as the Dispersion Index) is calculated by multiplying the mixing height (feet) by the transport wind (knots). A high Ventilation Index usually means that smoke will disperse in an efficient manner. A low Ventilation Index usually means that the dispersion of smoke in the lower atmosphere will be hindered. Caution should be used when interpreting the Ventilation Index, as the values can sometimes be misleading. For instance, a high Ventilation Index can be produced with either a high transport wind and low mixing height or a low transport wind and high mixing height. In both situations, smoke dispersion may still be hindered.

Dispersion Rate	Dispersion Index
<13,000	Poor
13,000 - 29,999	Fair
30,000 - 59,999	Good
60,000 or greater	Excellent

Table D1 – Ventilation (Dispersion) Index

Smoke dispersion information is available on the Fire Weather Planning Forecast (FWF), which is issued twice daily during the fire season at 7 am and 3 pm. Average mixing height and transport wind for the noon to 6 pm period are provided for the daytime periods (through day 2) in the Fire Weather Planning Forecast. The Ventilation Index, which is labeled as *smoke dispersal* in the FWF, is also averaged between noon and 6 pm, and is provided for the daytime periods of the forecast through day 2. Average values are used in order to provide a more representative estimate for prescribed burn projects, which may be started at varying times of the day (depending on the agency, type and size of the project). Fire Weather Planning Forecasts are posted on all local National Weather Service (NWS) websites. Smoke dispersion forecasts are also available as part of a spot forecast request.

When utilizing the ventilation index it is important to consider the total fuel load being burned, both in terms of the fuel loading (tons of fuel per acre) and the total area to be treated. The proximity of downwind smoke sensitive areas to the burn unit should also be considered, so that in general the lower the expected total fuel consumption and the farther away from smoke sensitive receptors, the lower the ventilation index can be. Additionally, practices that reduce the total fuel load available for consumption can lower the acceptable dispersion category either by reduction of fuel, or acres to be treated.

Identifying the Closest Smoke-sensitive Receptors

1. Locate on a map the prescribed fire and all potential smoke sensitive targets, plus areas known to already have air pollution problems.
2. Determine the wind direction that should have the least impact on smoke sensitive targets.
3. Draw a line representing the centerline of the path of the smoke plume using the wind direction chosen in the previous step.
4. Determine the distance from the edge of the prescribed fire to the nearest smoke-sensitive target.

5. To allow for horizontal dispersion of the smoke, as well as shifts in wind direction, draw two other lines from the burn at an angle of 30 degrees from the centerline.

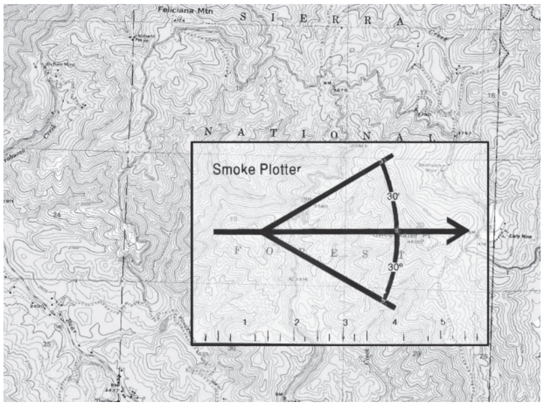

Figure D1 – Smoke Plotter (NWCG RX 410)

Once smoke-sensitive receptors have been identified, there are two methods that can be utilized for mitigation of smoke impacts during the burn planning process:

Method A: This method may be used as a general guide to use the Ventilation Index in combination with a smoke screening map to screen for sensitive downwind receptors. It is recommended for those burn units with low to moderate potential for smoke impacts.

1. From the Daily Burn Unit Size chart (Table D2) select the size of the planned burn unit* in acres.

2. Determine the general fuel category which best represents the majority of the burn unit.

3. On a map of the area locate the sensitive downwind receptors that could be impacted by smoke produced by the burn unit.

4. Use the Dispersion Category charts (Table D3) and determine the minimum distance which a burn should take place upwind of a sensitive receptor on a certain Dispersion Category day.

*Note: These are voluntary guidelines which may vary based on the local unit's definition of smoke sensitive receptor and the ability to mitigate potential smoke problems by instituting traffic controls when smoke could impact major roads or by burning under fuel moisture conditions which limit consumption of heavier fuels.

Method B: This is recommended for complex prescribed burns with is high potential for smoke impacts.

1. Estimate the fuel loading for the area to be burned. This may be done formally, utilizing site-specific survey data if available or by consulting the fuel model information found in: *Aids in Determining Fuel Models for Estimating Fire Behavior*, or *Standard Fire Behavior: A Comprehensive Set for Use with Rothermel's Surface Spread Model* or the Natural Fuels Photo Series.
2. Determine the acreage to be burned in one day.
3. Estimate the expected fuel consumption using hand calculations or computer models such as FOFEM or CONSUME. Selection of higher fuel moistures (such as higher 100- and 1,000-hour fuel moisture), which should reduce the fuel available for consumption, should be factored into the calculations.
4. Determine the total PM_{10} and $PM_{2.5}$ emissions per day based on outputs from #3.
5. Locate downwind sensitive receptors that could be impacted from your smoke.
6. Utilize a dispersion computer program to screen for the potential to exceed ambient air quality

standards.

Daily Burn Unit Sizes	
Small	<50 acres
Medium	50 - 150 acres
Large	151 - 500 acres
Landscape	501 + acres

Table D2 – Daily Burn Unit Sizes

DISPERSION CATEGORY	PROXIMITY OF CLOSEST DOWNWIND SMOKE-SENSITIVE AREAS	DESCRIPTION OF UNIT SIZE AND AVAILABLE FUEL LOAD
EXCELLENT	<0.25 mile	Small – Large burns in grass or leaf litter
	<0.25 mile	Small – Med burns in timber, slash, or piled fuels
	>0.25 mile	Landscape burns in grass or leaf litter
	>0.25 mile	Large burns in timber, slash, or piled fuels
	>0.5 mile	Landscape burns in timber, slash, or piled fuels
GOOD	<0.25 mile	Small – Large burns in grass or leaf litter
	<0.25 mile	Small – Med burns in timber, slash, or piled fuels
	>0.5 mile	Landscape burns in grass or leaf litter
	>0.5 mile	Large burns in timber, slash, or piled fuels
	>0.75 miles	Landscape burns in timber, slash or piled fuels
FAIR	<0.25 mile	Small – Med burns in grass or leaf litter
	>0.25 mile	Large burns in grass or leaf litter
	>.5 mile	Small – Med burns in timber, slash, or piled fuels
	>0.75 mile	Landscape burns in grass or leaf litter
	>0.75 miles	Large burns in timber, slash or piled fuels
	>1.0 mile	Landscape burns in timber, slash, or piled fuels
POOR*	< 0.25 mile	No burns
	>0.50 mile	Small burns of primarily grass fuels.
	>1.00 mile	Single large pile or scattered small piled debris

Table D3 – Distances to Smoke-sensitive Areas

*On Poor Category days no burning is suggested within ¼ mile of any downwind smoke sensitive area and is not recommended in general. As an example, for a 500 acre burn in grass fuels, a minimum distance that a burn should occur upwind of a sensitive receptor would be: greater than 0.25 miles with Excellent Dispersion, greater than 0.5 mile with Good Dispersion, greater than 0.75 miles with Fair Dispersion and there should be no burn under Poor Dispersion.

APPENDIX 7

WDNR Responses to Federal Land Manager Consultation Comments

Background

The Wisconsin Department of Natural Resources (WDNR) shared the February 2021 draft of Wisconsin's regional haze State Implementation Plan (SIP) revision for the second planning period (or "Round 2 haze SIP") with the U.S. Forest Service (FS), the National Park Service (NPS), and the U.S. Fish and Wildlife Service (FWS) on February 22, 2021. The Federal Land Managers (FLMs) and representatives of the WDNR held a conference call on March 23, 2021, as required in 40 CFR § 51.308 (i)(2). Written comments received from the FLMs are available at https://dnr.wisconsin.gov/topic/AirQuality/Particles.html. This appendix contains WDNR's responses to the written comments received from the FS and NPS and the FWS's verbal comments[1] on the February 2021 draft of the Round 2 haze SIP.

Emissions Inventory and Visibility Modeling

1. The FS and NPS acknowledge the significant trends in Wisconsin's emissions reductions and the achievements in visibility improvement (i.e., current and projected visibility conditions for Round 2 are below the LADCO Class I areas' glidepaths) that are shown in Wisconsin's draft Round 2 haze SIP.

   Response: These are significant trends and factors to be considered in the Round 2 haze SIP. For example, the most recent complete year (2019) of emissions data show that Wisconsin point source emissions of nitrogen oxides (NOx) and sulfur dioxide (SO_2) have decreased by 51% and 83%, respectively, relative to Wisconsin's Round 1 2018 emissions targets (Table 10 of Round 2 regional haze SIP). Please see below for additional responses related to this topic.

2. The FS notes that Wisconsin is the second largest contributing state on the most visibly impaired days at the Boundary Waters Canoe Area Wilderness (BWCAW). Additionally, the FS notes that the Lake Michigan Air Directors Consortium's (LADCO) technical analyses indicate that emission sources to the south contribute the most to poor visibility at BWCAW.[2]

   Response: The WDNR confirms that the FS's statement is supported by LADCO's source apportionment analysis based on the 2011 inventory base year (Table 2 of Wisconsin's February 2021 draft Round 2 haze SIP).[3] The 2011 base year results are placeholders, as WDNR noted in the February 2021 draft Round 2 haze SIP. It is important to note that the final source apportionment results will correspond to LADCO's

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[1] This appendix contains WDNR's responses to the FWS's verbal comments from the March 23, 2021 conference call. The WDNR did not receive written comments from the FWS on Wisconsin's Round 2 haze SIP.

[2] LADCO, DRAFT Technical Support Document, Modeling and Analysis for Demonstrating Reasonable Progress for the Regional Haze Rule 2018-2028 Planning Period, January 27, 2021, https://www.ladco.org/wp-content/uploads/Projects/Regional-Haze/Round2/LADCO_RegionalHaze_Round2_TSD_27Jan2021.docx.

[3] LADCO, 2011-based 2028 glidepaths and PSAT tracer contributions, https://www.ladco.org/wp-content/uploads/Projects/Regional-Haze/Round2/LADCO_RegionalHaze_2011_28_PSAT_Charts_23July2020.xlsx.

2016 base year inventory modeling which were not available during the FLM consultation period.

Source Selection

3. The FWS recommends considering the cumulative Q/d (Q = emissions / d = distance) impact at all Class I areas, including those outside of the Lake Michigan Air Directors Consortium (LADCO) Class I areas.

   Response: As noted in Section 3.1 of the draft Round 2 haze SIP, the LADCO Regional Haze Workgroup developed nationwide inventories of process-level point source emissions that were ranked by Q/d relative to the nearest Class I area.[4] The WDNR is utilizing the Q/d ranking system described in the Round 2 haze SIP to maintain consistency with the LADCO Regional Haze Workgroup's approach for source ranking. The WDNR notes that LADCO's source apportionment modeling did consider LADCO states' impacts on all Class I areas, not just those within the LADCO region.[2,3]

4. The FS and NPS recommended that Wisconsin evaluate six to seven additional Wisconsin sources by using a Q/d threshold of 4. The FS and NPS stated that other LADCO states selected sources over a Q/d threshold of 4, and that Wisconsin's selection of sources (which have Q/d values above 10) leads to an inconsistency across the LADCO region. FS further stated that in EPA's draft Haze guidance, 80% of each state's overall impact was suggested as appropriate.

   Response: WDNR is utilizing the most updated Haze Rule[5] and EPA Guidance[6] in its approach for selecting sources. This is addressed in Section 3.4.1 of Wisconsin's draft Round 2 haze SIP. There are dozens of non-Wisconsin LADCO units with greater Q/d impacts than Wisconsin's highest emission units at the LADCO Class I areas. These non-Wisconsin units would need to be assessed for necessary emissions reductions before it would be appropriate to select additional Wisconsin sources for analysis. Wisconsin sources also contribute significantly less than other LADCO states to total Q/d impact, which makes selecting only the highest contributing Wisconsin sources appropriate. Finally, the 80% threshold suggested by the commenters is not included in EPA's final guidance.

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[4] LADCO, Process level report of Q/d sources, https://drive.google.com/file/d/17LOuUXLS5-bZU1eegR6t5dVZyfRQbxgR/view?usp=sharing

[5] The revised Regional Haze Rule, effective January 10, 2017 (82 FR 3078).

[6] "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period", US EPA, August 2019. https://www.epa.gov/sites/production/files/2019-08/documents/8-20-2019_-_regional_haze_guidance_final_guidance.pdf.

Characterization of Factors

5. The NPS states that WDNR's four-factor analyses relied on the 2015 LADCO report which provides "outdated" cost data.

   Response: WDNR used its Georgia-Pacific BART analysis from Round 1 as a control cost reference. As WDNR notes in the draft Round 2 haze SIP (p. 37), the EPA Guidance allows for BART analyses from Round 1 to be used for estimating control costs in Round 2, and WDNR found these BART analyses to provide a reasonable basis (after adjusting for inflation) for estimating control costs for the selected sources.

Reasonable Progress Goals

6. The FS and NPS recommended that the four-factor analysis be considered exclusively for determining what is needed for reasonable progress and for requiring cost-effective controls, rather than also considering the other required elements of the haze SIPs, such as the five additional required factors. The FS referenced the preamble of the revised Haze Rule to support this recommendation.

   Response: The WDNR used the flexibility given in the Haze Rule and EPA Guidance to consider the five additional factors and other factors relative to the four-factor analysis, as laid out in the draft Round 2 haze SIP (see Sections 3.4 – 3.6). The EPA Guidance – which FS does not reference in its comments – allows states to consider these "5 additional factors" at any step of SIP development (selecting sources, evaluating control requirements, etc.).

7. The FS and NPS recommended that WDNR require cost-effective NOx and SO_2 controls for selected sources.

   Response: As described in Section 3.6.1 of the draft Round 2 haze SIP, WDNR determined that no additional controls are required to meet the Round 2 haze SIP requirements.

8. The FS stated that it is unclear if the recent emission reductions in actual emissions at the Kaukauna and Rhinelander mills can be expected to continue in the future due to enforceable requirements. The FS and NPS stated concerns about whether SO_2 NAAQS requirements for point sources achieved any meaningful benefit to downwind Class I areas.

   Response: As explained in Sections 3.5.1 and 3.6.1 of the draft Round 2 haze SIP, the Kaukauna and Rhinelander mills have demonstrated reduced SO_2 emissions from both the Round 1 2018 Target emissions and the Round 2 2016 Base emissions. These reductions were in part a response to SO_2 NAAQS actions and are therefore expected to continue into the future. The Rhinelander mill had permit 15-DMM-128-R1 issued in March 2021 with 2010 SO_2 NAAQS emission requirements, and the Kaukauna mill is undergoing a permit revision process which will address 2010 SO_2 NAAQS emission requirements.

Smoke Management Plan

9. The FS noted the inclusion of Wisconsin's Smoke Management Plan (SMP) and looks forward to future discussion regarding its implementation.

   Response: No response necessary. The WDNR has signed the most recent version of the Wisconsin SMP included in Appendix 6 and is implementing the SMP in the state. The WDNR also looks forward to discussing the SMP with the FS following their review.

Monitoring Strategy

10. The FS questioned why the former WDNR acid rain site located in Spooner, WI that is now supported by the FS was not included in the map of Wisconsin air monitoring sites (Figure 7 of the Round 2 haze SIP).

    Response: The WDNR updated Figure 7 of the Round 2 haze SIP to include the FS-operated Spooner acid rain site.

APPENDIX 8

WDNR Responses to Public Comments

Background

On April 28, 2021, the Wisconsin Department of Natural Resources (WDNR) posted the April 2021 draft of Wisconsin's regional haze State Implementation Plan (SIP) revision for the second planning period (or "Round 2 haze SIP") for public review through June 2, 2021. The WDNR received no verbal comments at the public hearing held on June 1, 2021. This appendix contains WDNR's responses to the written comments received from the US Environmental Protection Agency (EPA), the National Park Service (NPS), and the Ahlstrom-Munksjö (A-M) paper mill in Rhinelander, WI, on the April 2021 draft of the Round 2 haze SIP.

General Comments

1. The EPA commented that the Round 2 haze SIP should address the provisions of Section 110(l) of the Clean Air Act (CAA). [EPA General Comment]

   Response: The WDNR included a Section 110(l) noninterference justification in the cover letter of the submittal package for Wisconsin's Round 2 haze SIP**.**

2. The EPA requested that any referenced material necessary for EPA to determine the technical soundness of WDNR's determinations or compliance with the Haze Rule that were made accessible via a web link in the April 2021 version of the Round 2 haze SIP be included in the official SIP submission, as web addresses can be moved or deleted. The EPA made this comment in reference to the Lake Michigan Air Directors Consortium's technical support document (LADCO TSD), "Modeling and Analysis for Demonstrating Reasonable Progress for the Regional Haze Rule 2018 – 2028 Planning Period" and to LADCO's spreadsheet of process-level emissions units and related technical information. [EPA Comments #1, 9, 32]

   Response: The WDNR has addressed EPA's comments by ensuring all referenced information and analyses necessary for EPA to determine the technical soundness of WDNR's determinations or compliance with the Haze Rule are included in the official SIP submission. Specifically, instead of web links, WDNR is including the entire LADCO TSD in Appendix 2 [EPA Comment #1, 32], along with a table excerpted from the LADCO spreadsheet, "Process level Report of Q/d sources" (Haze_Control_Sheet_6.9.xlsx) [EPA Comment #9].

3. The EPA commented that WDNR should provide excerpts from LADCO Regional Haze Workgroup meeting notes, if the meeting notes contain key information, as part of the final SIP submission. This comment was in reference to the web link WDNR provided in Section 3.1 of the SIP to the Workgroup meeting notes housed on LADCO's website. [EPA Comment 3]

   Response: Because the Round 2 haze SIP already describes key decisions made during LADCO Regional Haze Workgroup calls, excerpts of the Workgroup notes are not necessary to support the SIP. The WDNR revised Section 3.1 in response to EPA's comment.

Visibility Modeling

4. The EPA acknowledged that WDNR was still awaiting the results of LADCO's 2016 base year speciated source region apportionment modeling during Wisconsin's Round 2 haze SIP comment period. In the final SIP, EPA requested that WDNR address Wisconsin's potential impacts on visibility impairment in Class I areas outside of the LADCO states and explain how WDNR's approach for determining whether Wisconsin impacts a Class I Area is consistent with the requirements of the Regional Haze Rule. [EPA Comments #2, 29]

   Response: The WDNR revised Section 2 of the Round 2 haze SIP to provide a summary of Wisconsin's negligible impact on visibility in Class I areas outside of the LADCO region (i.e., Wisconsin contributions do not meet contribution criteria). Section 2 has also been revised to explain how WDNR's approach for determining its potential visibility impairment at Class I areas is consistent with EPA Guidance for preparation of SIP revisions for the second implementation period. The Haze Rule does not provide criteria for determining if a state's emissions contribute to visibility impairment at out-of-state Class I areas.

Emissions Inventory

5. The EPA commented that if Wisconsin relies on any of the "*significant emission reductions from…unit shutdowns and committed controls in Wisconsin that are not included in LADCO's 2028 Modeled emissions*" to demonstrate reasonable progress, the measures need to be federally enforceable, either in the Round 2 haze SIP or elsewhere. [EPA Comment #5]

   Response: The WDNR has addressed this item for facilities where measures are enforceable under the facilities' permitting actions. Several EGUs have publicly announced shutdown by 2025. Since the shutdowns have not yet occurred, WDNR will provide retired unit exemptions or other available enforceable actions to EPA when available. See also Responses #13 and #20 related to this comment.

Uniform Rate of Progress

6. In response to a WDNR statement about current and projected visibility conditions at Northern LADCO Class I Areas being below their respective Uniform Rate of Progress (URP) lines (Section 3.2.4), EPA commented that long-term strategies for making reasonable progress should be based on the four statutory factors, which does not include visibility relative to the URP line. The URP was established by extrapolating the rate of

visibility improvement achieved in the mid-1990's to ~2005 in the eastern U.S. into the future. The EPA determined that if the past rate of improvement were sustained moving forward, those Class I areas would reach the national goal in 60 years. [EPA Comment #4]

Response: As EPA acknowledges in its comment, WDNR noted the progress in visibility improvement achieved since the Round 1 period and expected over the remainder of the Round 2 period at the Northern Class I Areas. The WDNR made no change to the SIP in response to this comment because WDNR did not rely solely on the URP line to develop Wisconsin's long-term strategy for the Round 2 period.

Selection of Sources for Analysis

7. The EPA requested that the Q/d threshold WDNR chooses for the source selection screening process be plainly stated. The EPA also requested additional justification for the use of a Q/d threshold of 10. The EPA also commented that WDNR should base its source selection criteria on characteristics of Wisconsin's contribution to visibility impairment, include LADCO's sector, state, and pollutant apportionment modeling, and identify and explain why units above a Q/d threshold of 4 were not captured in screening. [EPA Comments #6, 7, 8]

   The NPS commented that WDNR should select and evaluate additional sources for emission reduction opportunities that would reduce haze across the region and in NPS Class I areas. [NPS Comment #1]

   Response: The WDNR updated Section 3.4.1 of the Round 2 haze SIP to plainly state the unit-level Q/d threshold chosen (i.e., 10) for the source selection screening process, and added information on EPA and LADCO's state and pollutant apportionment modeling in Sections 3.3 and 3.4.1 of the SIP. (See also Response #12 related to this comment.) This Q/d is appropriate based on emission reductions achieved from Wisconsin sources prior to 2016 as well as the other factors presented in Section 3.4.1 of the SIP. The Q/d of 10 appropriately recognizes the significant point source emission reductions in Wisconsin and is consistent with EPA requirements. Also, most of the Wisconsin units and emissions between Q/d of 4 and 10 are already well-controlled/retired or will be by 2025, and WDNR has already added one of the units (A-M Kaukauna coal boiler B09) to the selection for further analysis (see Response #14).

   Lastly, WDNR is utilizing the most updated Haze Rule and EPA Guidance in its approach for selecting sources. This is addressed in Section 3.4.1 of Wisconsin's Round 2 haze SIP. The list of additional sources recommended by NPS is associated with EPA's draft Haze Guidance, where 80% of each state's overall impact was suggested as appropriate. That 80% threshold is not included in the final EPA Guidance or in the Haze Rule.

Characterization of Factors for Emission Control Measures

8. A-M Rhinelander provided a few technical corrections for Table 13B of the Round 2 haze SIP.

   Response: The WDNR updated Table 13B of the SIP with the correct information from A-M Rhinelander.

9. A-M Rhinelander commented that many of the technologies identified in Section 3.4.2, including FGD, could exceed the profit margin(s) of the facilities and, therefore, have the potential to force facility closures. A-M Rhinelander also commented that FGD provides technical challenges with installation, as well as additional costs, that are not addressed in the four-factor analyses.

   Response: The WDNR added a footnote in Section 3.4.2 of the Round 2 haze SIP to reflect these concerns. The EPA has indicated that guidance to states is forthcoming on the use of "affordability" when considering whether additional controls on selected units are necessary for reasonable progress.

10. The EPA commented that WDNR should either explain how all the sources screened above the threshold, are effectively controlled, i.e., are controlled in a manner analogous to the examples provided on pages 23-25 of the Guidance such that it is reasonable to assume that no additional controls would be reasonable, or provide a four-factor analysis. [EPA Comment #10]

    Response: The WDNR did not make any updates to the draft Round 2 haze SIP or appendices based on this comment as the SIP contains this information.

11. EPA commented that for the sources in Table 12 of the Round 2 haze SIP, WDNR needs to provide additional information about the units and their controls. [EPA Comment #11] EPA added that in Table 12, Table 1 of Appendix 3, or in some other section, WDNR needs to include the limits and indicate the type of enforceable mechanism for units or sources above the chosen Q/d threshold. [EPA Comment #33]

    Response: The WDNR added the current permitted emissions rates for the selected units for the relevant pollutants, and otherwise provided sufficient information for this area in the Round 2 haze SIP as well as Appendix 3.

12. The EPA commented that WDNR should discuss why control options for other pollutants besides NOx and SO_2 are not considered at this point. The EPA also commented that expanding the "Determination of Pollutants to Consider" section to explain the relative impacts of each pollutant on visibility in the region would also help justify the Q/d threshold by showing that most of the most impactful emissions are being captured by the threshold, and that WDNR should indicate what percentage of each of the main pollutants (SO_2, NOx, PM, NH_3, VOC) that the threshold captures. [EPA Comment #12]

Response: The WDNR updated Section 3.3.1 of the Round 2 haze SIP to describe that Wisconsin pollutant contributions to visibility impairment in Northern LADCO Class I Areas continue to be dominated by NOx, and to a lesser extent, SO_2 emissions. Section 3.3.3 explains that only NOx and SO_2 controls were considered for this reason. The updated text references Figure 8-22 and Table 8.6 of the LADCO TSD (Appendix 2), which provides a speciated particulate tracer analysis partitioned by state/region contributions to visibility impairment at the Northern LACO Class I Areas.

13. The EPA commented that if Wisconsin relies on these shutdowns [WPL – Edgewater Generating Station coal boilers B24 and B25] to demonstrate reasonable progress, the measures should be made federally enforceable and permanent, either in the Round 2 haze SIP or elsewhere [EPA Comment #13]

    Response: See Response #5 which also addresses this comment.

14. The EPA commented that some additional explanation as to why only [A-M Kaukauna] B11 is considered under the four-factor analysis should be included in the Round 2 haze SIP, especially since B09 and B11 share a common exhaust stack, and that WDNR should provide current enforceable and/or permitted emissions rates for these units. [EPA Comment #14]

    Response: The WDNR added A-M Kaukauna B09 to the SIP for further evaluation, as well as the current permitted emissions rates for these units for the relevant pollutants.

15. The EPA commented that WDNR should note in Appendix 4 (Supplemental Information for WDNR Round 2 Four-Factor Analysis) if the costing information follows EPA's Control Cost Manual, and referred WDNR to previous communication from EPA to the LADCO Workgroup regarding considerations for interest rates, retrofit factors, and equipment lifespan. The EPA also commented that it appears that A-M Kaukauna is already making emission reductions through voluntary operational constraints and fuel switching and that A-M Rhinelander recently established a revised emission rate, so WDNR might wish to consider evaluating these as additional control measures in the four-factor analyses. [EPA Comment #34]

    Response: The WDNR did not make any updates to the Round 2 haze SIP or appendices as the SIP and appendices contains this information. The WDNR used its Georgia-Pacific BART analysis from Round 1 as a control cost reference. As WDNR notes in the Round 2 haze SIP, the EPA Guidance allows for BART analyses from Round 1 to be used for estimating control costs in Round 2, and WDNR found these BART analyses to provide a reasonable basis (after adjusting for inflation) for estimating control costs for the selected sources. See also Responses #16 and #21, related to the comment on A-M Kaukauna emission reductions and A-M Rhinelander revised emission rate.

Emission Reductions Due to Ongoing Air Pollution Control Programs

16. The EPA commented that WDNR should note the finalized SO_2 emission limits and the expected reductions from the 2010 SO2 NAAQS emission requirements for A-M Rhinelander. The EPA also commented that since WDNR noted that the A-M Kaukauna mill has not fired high-sulfur petroleum coke since 2016, and that the Title V operation permit renewal scheduled for 2021 will require SO_2 NAAQS attainment modeling along with associated permit emission limitations, WDNR should identify this as an on-the-way control and predict reductions that will be associated with permit revisions from potential new limits and operational restrictions on fuel sources. [EPA Comments #18, 19]

    Response: The WDNR added information at Section 3.5.1 of the Round 2 haze SIP to address this comment. As explained in Sections 3.5.1 and 3.6.1 of the SIP, the A-M Kaukauna and A-M Rhinelander mills have demonstrated reduced SO_2 emissions from both the Round 1 2018 Target emissions and the Round 2 2016 Base emissions. These reductions were in part a response to SO_2 NAAQS actions and are therefore expected to continue into the future. The Rhinelander mill had permit 15-DMM-128-R1 issued in March 2021 with 2010 SO_2 NAAQS emission requirements, and the Kaukauna mill is undergoing a permit revision process which will address 2010 SO_2 NAAQS emission requirements. See also Responses #11 and #21 which also relates to this comment.

17. The EPA commented that WDNR should include reference to the CSAPR Update Rule and details of budgets for 2015 and 2016. The EPA also commented that for the Wisconsin NOx RACT and NOx RACM rules, WDNR should list the applicable NOx emission limits and name the southeast counties where they apply, and indicate if the rules are included in the Round 2 haze SIP such that they would be considered already federally enforceable and permanent. Finally, EPA commented that WDNR should elaborate in the SIP on the details of specific permitting actions, sources, and quantity of emission reductions (i.e., from Boiler MACT and Title V permitting actions), especially as they relate to the Regional Haze 2nd Implementation Period. [EPA Comments #15, 16, 17]

    Response: The WDNR updated Section 3.5.1 of the Round 2 haze SIP to provide additional detail of the NOx RACT and NOx RACM rules. The SIP includes relevant information on the CSAPR Update Rule, Boiler MACT and Title V permitting actions regarding the affected sources and associated emission reductions.

18. The EPA commented that it is not clear if WDNR is relying on the listed measures in Appendix 3 to make reasonable progress, or if the measures are for informational purposes only, so WDNR might consider some revisions to Appendix 3 for clarity. [EPA Comment #33]

    Response: No updates to the Round 2 haze SIP or appendices were made as this information is already available in Appendix 3. Measures with a “*” or “**” in Appendix 3 Tables 1 and 2 should be credited towards reasonable progress for Round 2.

19. A-M Rhinelander provided additional information regarding the decommission of four coal boilers at the facility, as well as the proposed SO_2 NAAQS SIP and associated recent permit revision.

    Response: The WDNR updated Section 3.5.1 of the Round 2 haze SIP and Appendix 3 to reflect this information.

Anticipated Net Effect on Visibility

20. The EPA commented that WDNR should clarify in Section 3.5.5 if on-the books and on-the-way controls, as well as scheduled EGU shutdowns, are considered in LADCO's 2028 visibility projections, as is indicated in Section 3.7 of the SIP. The EPA also commented that WDNR should state if the listed EGU shutdowns are federally enforceable and permanent and provide a narrative of the anticipated shutdown retirement schedule and associated emissions reductions. [EPA Comments #21, 22]

    Response: Section 3.5.5 has been updated to clarify that LADCO's 2028 visibility projections account for on-the books and on-the-way controls, which include scheduled EGU shutdowns that have been publicly announced as of September 2020. See also Response #5 which relates to this comment.

Decisions on Control Measures Necessary to Make Reasonable Progress

21. The EPA commented that to the extent WDNR determined that the emission reductions (i.e., A-M Kaukauna and A-M Rhinelander recent demonstrated emission reductions) are necessary for the two sources to make reasonable progress, the Round 2 haze SIP must explain how the SIP contains the "*enforceable emission limitations, compliance schedules, and other measures that are necessary to make reasonable progress.*" 40 CFR 51.308(f)(2) [EPA Comment #25]

    Response: The WDNR updated Section 3.5.1 of the Round 2 haze SIP with additional information about the A-M Kaukauna and A-M Rhinelander mills related to the 2017-2019 demonstrated lower emissions. See also Responses #11 and #16 which also relate to this comment.

22. The EPA commented that based on WDNR's four-factor analysis, clearly there appear to be reasonable control options for the A-M Kaukauna and A-M Rhinelander mills [even beyond control measures associated with recent demonstrated emission reductions] to reduce both NOx and SO_2. The EPA further commented that states cannot reject reasonable controls on the basis that the affected Class I area is under the URP, and that the Haze Rule does not allow a state to reject a control measure on the basis that emission reductions from other sources will provide an amount of overall progress that the state considers 'reasonable.' [EPA Comments #23, 24, 34]

The NPS encouraged WDNR to require all technically feasible and cost-effective emission controls identified, specifically post-combustion NOx and SO2 controls for the A-M Kaukauna and A-M Rhinelander mills. [NPS Comment #2]

Response: The WDNR made two updates to Section 3.4.2 of the Round 2 haze SIP to further support the SIP's justification that additional controls are not reasonable, while also addressing EPA's and NPS' comments here. First, under the four-factor analyses, WDNR added information under the optional 5th factor of visibility improvement to demonstrate that additional controls on Wisconsin's selected units is estimated to result in insignificant visibility improvement. Second, WDNR integrated a comment from A-M Rhinelander that the cost of adding control technologies could potentially exceed the mill's profit margin(s) of the facilities (see Response #9, including that EPA is considering providing guidance to states on how the factor of affordability of controls may be included for decisions on controls in SIPs).

As described in Section 3.6.1 of the Round 2 haze SIP, WDNR determined that no additional controls are required to meet the SIP requirements. The EPA and NPS comments could be interpreted to suggest that the four-factor analysis be considered *exclusively* for determining what is needed for reasonable progress and for requiring cost-effective controls, rather than also considering the other required elements of the haze SIPs, such as the five additional required factors. The WDNR used the flexibility given in the Haze Rule and EPA Guidance to consider the five additional factors and other factors relative to the four-factor analysis, as laid out in the Round 2 haze SIP (see Sections 3.4 – 3.6). The EPA Guidance (which both EPA and NPS do not reference in their comments) allows states to consider these "5 additional factors" at any step of SIP development (selecting sources, evaluating control requirements, etc.). The "under URP" and "significant Wisconsin point source emission reduction trends" factors hold significant weight especially in the Decisions on Controls step.

Consideration of Other Factors

23. The EPA commented that it would be helpful to reiterate in Section 3.6.2 of the Round 2 haze SIP how Wisconsin coordinated with the other states, including through LADCO, regarding the necessary emission reductions or to refer to Section 3.1. [EPA Comment #26]

Response: Section 3.6.2 of the SIP has been updated to describe how WDNR coordinated with other LADCO states about the sources it brought forward for, as well as the results of, the four-factor analysis. As is now noted in Section 3.6.2, WDNR also notified LADCO and its member states when the proposed SIP revision was posted for public comment, but did not receive any formal comments or "asks" from LADCO member states.

Conclusion and Long-Term Strategy Requirements

24. The EPA commented that The LTS – and Section 3.6.3 of the Round 2 haze SIP – should clearly identify the measures relied upon to achieve reasonable progress, including the specific sources to which they apply, and what enforceable mechanisms are in place for each measure. [EPA Comment #27]

    Response: The WDNR did not make any updates to the Round 2 haze SIP or appendices based on this comment as the SIP contains this information.

25. Although WDNR mentioned that they did not receive any "asks," EPA requested that WDNR indicate if consultation occurred as required by the Haze Rule. [EPA Comment #28]

    Response: Section 3.6.2 has been updated to describe how WDNR consulted with other LADCO states with respect to Wisconsin's Round 2 haze SIP.

26. A-M Rhinelander commented that given Wisconsin's relatively small contribution to visibility impairment and the glidepath of reductions that the state is on, no additional controls of emissions at Wisconsin sources are necessary to meet regional haze progress for the second planning period.

    Response: No updates to the Round 2 haze SIP were necessary.

Reasonable Progress Goals

27. The EPA commented that more specifics should be provided to support WDNR's statement that "*Emissions reductions are expected to result from permanent and enforceable control measures implemented within the state to meet nonattainment area requirements under the SO2 NAAQS*," including source commitments and upcoming permit revisions and how those measures will be made federally enforceable and permanent. [EPA Comment #30]

    Response: The WDNR did not make any updates to the Round 2 haze SIP or appendices based on this comment as the SIP contains this information. The WDNR can provide the specific enforceable actions to EPA when they are available in the 2021-2022 timeframe.

Procedural Requirements

28. The EPA commented that WDNR should include information regarding its efforts to consult with tribes during the Round 2 haze SIP preparation process. The EPA also commented that WDNR should clarify its statement in Section 3.2.4 that there are no Class I areas in Wisconsin. [EPA Comment #31]

Response: The WDNR has updated Section 2 of the Round 2 haze SIP to identify Wisconsin's two Class I areas and describe why they are not covered by the Haze Rule. This updated section also describes WDNR outreach to its tribal partners associated with Wisconsin's nonfederal Class I area. Section 3.2.4 has also been updated to clarify that there are no mandatory Class I Federal areas within Wisconsin that are covered by the Haze Rule.

Reasonably Attributable Visibility Impairment (RAVI)

29. The EPA commented that RAVI provisions in 40 CFR § 51.302 describe how a federal land manager (FLM) may provide a state with a certification regarding a particular Class I area and an associated source responsible for visibility impairment. The EPA commented that WDNR should identify if Wisconsin has such a certification for a source in the state. [EPA Comment #20]

    Response: The WDNR has updated Section 4.1 of the Round 2 haze SIP to clarify that FLMs have not provided Wisconsin a RAVI certification for a source responsible for visibility impairment at a particular Class I area.