Appendix B

Re-Calculating CALPOST Visibility Outputs with the New IMPROVE Algorithm

Ivar Tombach, Ph.D.
Environmental Consulting

753 Grada Ave.
Camarillo, CA 93010
805 388-2341
805 445-9424 fax
itombach@aol.com

Instructions: A Postprocessor for Recalculating CALPOST Visibility Outputs with the New IMPROVE Algorithm

Version 2
14 October 2006

Introduction

CALPOST can be used to processes outputs from CALPUFF modeling of a source's emissions to calculate the 24-hr average visibility impairments caused by primary and secondary particulate matter attributable to emissions from the modeled source. Those increments are presented in two tables, both labeled "Ranked Daily Visibility Change", in the CALPOST output (.LST) file. The table of interest to us has the subtitle "Modeled Extinction by Species" and lists the dates and locations of such incremental impacts in light extinction (b_{ext}) in ranked order, starting with the one that represents the largest percentage change in light extinction.[1]

In addition, with a different setup of the control file CALPOST.INP, the CALPOST postprocessor can be used to calculate 24-hr averages of NO_x concentrations. As described below, the outputs from that additional CALPOST run can be used to assess the visibility impact of the NO_2 gas in the source plume.

Visibility effects due to particulate matter are calculated in CALPOST from CALPUFF-modeled particulate matter component concentrations using effectively the "traditional" IMPROVE algorithm. CALPOST allows for choice of the humidity scattering enhancement function (f(RH)) to be used with the IMPROVE algorithm; for modeling in connection with the US EPA's Regional Haze Regulations (RHR), the appropriate form of f(RH) is the one described and tabulated in the EPA's 2003 guidance for tracking progress under the RHR. Visibility effects due to NO_2 are not considered in the CALPOST visibility calculation.

Recently, the IMPROVE Steering Committee developed a new algorithm for estimating light extinction from particulate matter component concentrations. This algorithm (the "new IMPROVE algorithm") provides a better correspondence between the measured visibility and

[1] The other table in the CALPOST visibility output file, with the subtitle "% of Modeled Extinction by Species", provides equivalent results in terms of changes in the haze index, in deciviews. The two tables represent the same results, with identical ranking of events, while just using different (but mathematically related) metrics.

that calculated from particulate matter component concentrations. The new algorithm differs in several substantive ways from the traditional one:

- The extinction efficiencies of sulfates, nitrates, and organics have been changed and are now functions of their concentrations. The extinction efficiencies of sulfate and nitrate are no longer identical, although the new hygroscopic scattering enhancement factors applied to them are the same.
- The concentration of particulate organic matter (POM; variously also labeled OCM or OMC, and sometimes just called "organics") is now taken to be 1.8 times that of the measured organic carbon (OC) concentration. (Confusingly, CALPOST labels the organics concentration as OC.)
- The contribution of fine sea salt to light extinction has been added, and is accompanied by its own hygroscopic scattering enhancement factor, $f_{ss}(RH)$.
- The light scattering by air itself (Rayleigh scattering) now varies with site elevation and mean temperature. It is to be rounded off to the nearest one Mm^{-1} when used with the new algorithm.
- The light absorption by NO_2 gas has been added.

The new IMPROVE algorithm is represented by the following formula:[2]

$$
\begin{aligned}
b_{ext} = \ & 2.2 \bullet f_S(RH) \bullet [small\ sulfate] + 4.8 \bullet f_L(RH) \bullet [large\ sulfate] \\
& + 2.4 \bullet f_S(RH) \bullet [small\ nitrate] + 5.1 \bullet f_L(RH) \bullet [large\ nitrate] \\
& + 2.8 \bullet [small\ organics] + 6.1 \bullet [large\ organics] \\
& + 10 \bullet [elemental\ carbon] \\
& + 1 \bullet [fine\ soil] \\
& + 1.7 \bullet f_{SS}(RH) \bullet [sea\ salt] \\
& + 0.6 \bullet [coarse\ matter] \\
& + Rayleigh\ scattering\ (site\ specific) \\
& + 0.33 \bullet [NO_2(ppb)]
\end{aligned}
\qquad \text{(Eq. 1)}
$$

The concentrations of "large" and "small" sulfate particles are calculated as follows:

$$
\begin{aligned}
&[large\ sulfate] = \{[total\ sulfate]/20\} \bullet [total\ sulfate] \text{ if } [total\ sulfate] < 20\ \mu g^3 \\
&[large\ sulfate] = [total\ sulfate] \text{ if } [total\ sulfate] \geq 20\ \mu g/m^3 \\
&[small\ sulfate] = [total\ sulfate] - [large\ sulfate].
\end{aligned}
\qquad \text{(Eqs. 2)}
$$

Identical formulas, with changes in component names, are used for nitrate and organics. In effect, these formulas conclude that low concentrations of these components are mainly in the form of "small" particles with their own extinction efficiency and $f_S(RH)$, while high

[2] Square brackets denote concentrations.

concentrations (approaching 20 $\mu g/m^3$) are mainly in the form of "large" particles with a different extinction efficiency and $f_L(RH)$. The scaling factor [total sulfate]/20 sets the fraction of total sulfate that is small.

The sea salt concentration is taken to be 1.8•[Cl^-] or, if chloride ion measurements are not available, the chlorine concentration can be used in its place. Site specific Rayleigh scattering values have been calculated for all IMPROVE sites.[3] Nitrogen dioxide concentrations are not measured at IMPROVE sites, but the ambient NO_2 concentrations under natural conditions can be expected to be negligibly small. The higher NO_2 concentration in a source plume may be great enough to cause a change in visibility, however.

In order to enable CALPOST to calculate CALPUFF-modeled source impacts on visibility using the new IMPROVE algorithm, it would have to be extensively reprogrammed. As an alternative, such a calculation could be done "off line" by adding another layer of post processing after CALPOST. To this end, I have developed a processor, in the form of an Excel workbook, that takes the CALPOST "Ranked Daily Visibility Change: Modeled Extinction by Species" output table, referenced against default annual average natural conditions concentrations, and creates an equivalent table of results based on the new algorithm. It can also incorporate the visibility impact due to light absorption by NO_2 in the plume.

The following describes the science behind the processor (which we'll call the CALPOST-IMPROVE Processor) and provides instructions for using it.

Concepts

In addition to the mechanical changes imposed by all the new terms in the new IMPROVE formula, applying the new algorithm also requires some conceptual changes. The biggest of these is that the extinction efficiencies of sulfates, nitrates, and organics now depend on the concentrations of those species. The practical implication of this is that extinction is no longer linearly additive. To calculate total extinction, you cannot take a background level of extinction and add to it CALPOST's calculation of extinction caused by the particulate matter coming from a source, because when the two aerosols mix in the atmosphere their combined mass concentration results in increases in the extinction efficiencies of both the background and the source contribution. This means that combining background particulate matter with the particulate matter from a source gives an extinction result that is greater than the sum of the two separate extinctions.

With the nonlinear behavior resulting from applying the new IMPROVE algorithm, the extinction impact of the source (i.e., the increase in extinction resulting from introducing source emissions into the atmosphere) is the sum of three parts:

1. The source impact calculated by the new IMPROVE algorithm using the CALPOST outputs for a plume in isolation;

---

[3] *Revised IMPROVE Algorithm for estimating Light Extinction from Particle Speciation Data.* Report to IMPROVE Steering Committee, November 2005.

2. An increase in that source impact because the extinction efficiency increases when the source's aerosol combines with the background aerosol; and correspondingly,

3. An increase in the extinction of the background aerosol because of that same mixing.

The total new extinction is the sum of the above three components plus the original background extinction. The original background extinction is just that calculated by the new IMPROVE algorithm from background concentrations of the various components, without any consideration of the effects of the plume. For this application, the background is taken to be that described by EPA's default natural conditions. The difference between the total extinction and the background is the impact of the source.

More details about the calculation are given in the appendix.

Description of Processor

The CALPOST-IMPROVE Processor is a Microsoft Excel workbook that consists of four worksheets. In Version 2 the worksheets are the following.

1. Input & Output – The output table from CALPOST is imported to here and user entries are made for the Rayleigh scattering coefficient and, if desired, for a sea salt concentration at the Class I area of interest. The NO_x concentration on each day attributable to the emissions from the source can also be entered together with an assumption of what fraction of the NO_x is in the form of NO_2. A revised table, with extinction based on the new IMPROVE algorithm is then presented on the same page. This is the only page on which user input takes place, and the results of the calculations appear on this page.

2. Calculations -- The calculations themselves are all done on this worksheet. There is no user input to this page. The variables are explained on the worksheet itself, so the user can find intermediate values if so inclined.

3. F(RH) – This worksheet tabulates the traditional IMPROVE f(RH) against RH, and then also lists values for the three new humidity growth functions, $f_S(RH)$, $f_L(RH)$, and $f_{SS}(RH)$. It serves as a lookup table for the "Calculations" worksheet.

4. Rayleigh & Sea Salt – This page tabulates the IMPROVE-recommended Rayleigh scattering coefficients for all VISTAS Class I areas and for Class I areas in adjacent states. It also lists the average sea salt concentrations for the same locations, as tabulated on the VIEWS web site, based on chloride or chlorine measurements by IMPROVE monitors between 2000 and 2004. This sheet just provides information for the user; it is not linked to the rest of the workbook. The user can obtain Rayleigh and sea salt numbers for the Class I area of interest from this table and then manually enter them in the designated spaces in worksheet 1.

Instructions for Using the CALPOST-IMPROVE Processor

These instructions apply to Version 2 of the processor. Version 2 includes the ability to calculate the light extinction effects of NO_2 resulting from the source's emissions.

Step 1. Begin by opening the output (.LST) file from a CALPOST visibility calculation run in a text editor or word processing program.[4] In the second half of the file, locate the table "Ranked Daily Visibility Change" with the subheading "Modeled Extinction by Species".[5]

Step 2. Copy this table and paste it onto a new page. Save it as a text (.txt) file, not as a formatted (e.g., MS Word .doc or .rtf) file. The final table should contain only the column headings and the data. Delete all other captions, any additional data summaries at the end, and blank lines before or after the table. The processor can handle a maximum of 22 lines of data (i.e., the highest rank in the last, unlabeled, column should be 22) plus a row of column captions. Delete any data that exceed this limit. (Fewer than 22 lines of data are OK.) The result should look like the example in Figure 1, although the line wrapping may differ.

Step 3. Open the CALPOST-IMPROVE Processor in Microsoft Excel. Save the open file under a new name so that the original empty processor will remain available for future use. The front worksheet, labeled "Input & Output" looks like Figure 2. There is a large empty box, surrounded by double lines, into which the table created above will be imported, as described below.[6] On the right is a box into which NO_x concentrations may be entered manually, and a small box below this box is provided for entry of the user's assumption of what fraction of that NO_x is in the form of NO_2. Two smaller boxes provide for user input of the Rayleigh scattering coefficient and, optionally, sea salt concentration for the Class I area, as described below. Results of the new IMPROVE algorithm calculations appear in blue in the lower half of the worksheet and some additional results, that are also useful for quality control, appear in green to the right of the large box. At the moment, many results cells will display nonsensical numbers and error messages, such as shown in Figure 2.

Step 4. Select the upper left cell (A7) in the large box. On the Excel menu bar, go to *Data>Get External Data* and click on *Import Text File.*[7] (If the large box is not empty, click on *Edit Text Import* instead.) Select the file that contains the table created in Step 2 and click on the *Get Data* button. Go through the Text Import Wizard steps, checking that all values appear correctly in separate columns. (The label "COORDINATES (km)" will be split over two columns; this is OK.) When everything appears in order, click *Finish.*

[4] The background concentrations that were entered into CALPOST must be the EPA-prescribed default annual average natural conditions concentrations for the East. The processor will not give correct answers if other concentrations were used in CALPOST.
[5] For future reference in Step 7, this may also be a good time to locate the table with the same title but with the subtitle "% of Modeled Extinction by Species", which appears later in the output file.
[6] If the workbook has already been used, the boxes may not be empty. This does not matter.
[7] The exact wording may vary slightly between different versions of Microsoft Excel. The terminology used here is from Excel 2004 for Macintosh.

```
YEAR DAY HR  RECEPTOR    COORDINATES (km)  TYPE BEXT(Model) BEXT(BKG)
BEXT(Total) %CHANGE  F(RH)  bxSO4  bxNO3   bxOC    bxEC  bxPMC  bxPMF
2002 175  0  1027        1479.069    24.683   D       5.495      21.650      27.145
25.38   3.500  5.401  0.045  0.042  0.002  0.001  0.004    1
2002 172  0  1021        1479.244    23.778   D       4.923      21.650      26.573
22.74   3.500  4.475  0.404  0.038  0.001  0.001  0.004    2
2002 284  0  1045        1484.348    27.580   D       3.150      21.470      24.620
14.67   3.300  2.684  0.428  0.033  0.001  0.001  0.003    3
2002 353  0  1026        1482.762    24.457   D       2.594      21.290      23.884
12.18   3.100  2.017  0.557  0.018  0.001  0.000  0.002    4
2002 283  0  1026        1482.762    24.457   D       2.502      21.470      23.972
11.65   3.300  2.269  0.201  0.028  0.001  0.001  0.003    5
2002 195  0  1045        1484.348    27.580   D       2.011      21.830      23.841
9.21   3.700  1.963  0.031  0.015  0.001  0.000  0.001    6
2002  20  0  1117        1486.636    34.592   D       1.872      21.200      23.072
8.83   3.000  1.542  0.320  0.009  0.000  0.000  0.001    7
2002 173  0  1128        1479.259    35.042   D       1.649      21.650      23.299
7.62   3.500  1.625  0.012  0.010  0.000  0.000  0.001    8
2002 234  0  1021        1479.244    23.778   D       1.524      22.190      23.714
6.87   4.100  1.482  0.029  0.011  0.000  0.000  0.001    9
2002 298  0  1021        1479.244    23.778   D       1.459      21.470      22.929
6.80   3.300  1.284  0.160  0.014  0.001  0.000  0.001   10
2002 299  0  1021        1479.244    23.778   D       1.436      21.470      22.906
6.69   3.300  1.281  0.140  0.013  0.000  0.000  0.001   11
2002 275  0  1026        1482.762    24.457   D       1.270      21.470      22.740
5.92   3.300  1.202  0.058  0.009  0.000  0.000  0.001   12
2002 263  0  1045        1484.348    27.580   D       1.237      22.100      23.337
5.60   4.000  1.223  0.008  0.005  0.000  0.000  0.001   13
2002 252  0  1026        1482.762    24.457   D       1.189      22.100      23.289
5.38   4.000  1.166  0.013  0.009  0.000  0.000  0.001   14
2002 285  0  1021        1479.244    23.778   D       0.992      21.470      22.462
4.62   3.300  0.813  0.179  0.001  0.000  0.000  0.000   15
2002 161  0  1026        1482.762    24.457   D       0.873      21.650      22.523
4.03   3.500  0.842  0.020  0.009  0.000  0.000  0.001   16
2002 150  0  1026        1482.762    24.457   D       0.857      21.380      22.237
4.01   3.200  0.822  0.026  0.007  0.000  0.000  0.001   17
2002 340  0  1140        1481.017    37.258   D       0.817      21.290      22.107
3.84   3.100  0.663  0.153  0.001  0.000  0.000  0.000   18
2002 151  0  1117        1486.636    34.592   D       0.745      21.380      22.125
3.49   3.200  0.704  0.033  0.007  0.000  0.000  0.001   19
2002 160  0  1021        1479.244    23.778   D       0.735      21.650      22.385
3.40   3.500  0.710  0.014  0.010  0.000  0.000  0.001   20
2002 346  0  1021        1479.244    23.778   D       0.703      21.290      21.993
3.30   3.100  0.620  0.080  0.002  0.000  0.000  0.000   21
2002 247  0  1021        1479.244    23.778   D       0.661      22.100      22.761
2.99   4.000  0.654  0.004  0.002  0.000  0.000  0.000   22
```

Figure 1. Example of CALPOST Output Table, in Proper Format for Importing into the CALPOST-IMPROVE Processor.

Step 5.[8] The "Import Data" window will appear, with cell A7 indicated as the location at which data will be entered. Click on the *Properties* button. In the window that appears, select "Overwrite existing cells with new data, clear unused cells" and uncheck "Adjust column width", then click on *OK*. Now click on the *OK* button in the "Import Data" window.

Step 6. Assuming that your Excel application is set up to automatically recalculate whenever any entries are changed, you should now have filled the cells in the large box on the first worksheet,

[8] If the processor already had data in it and *Edit Text Import* was clicked in Step 4, then the "Import Data" window will not appear and Step 5 can be skipped.

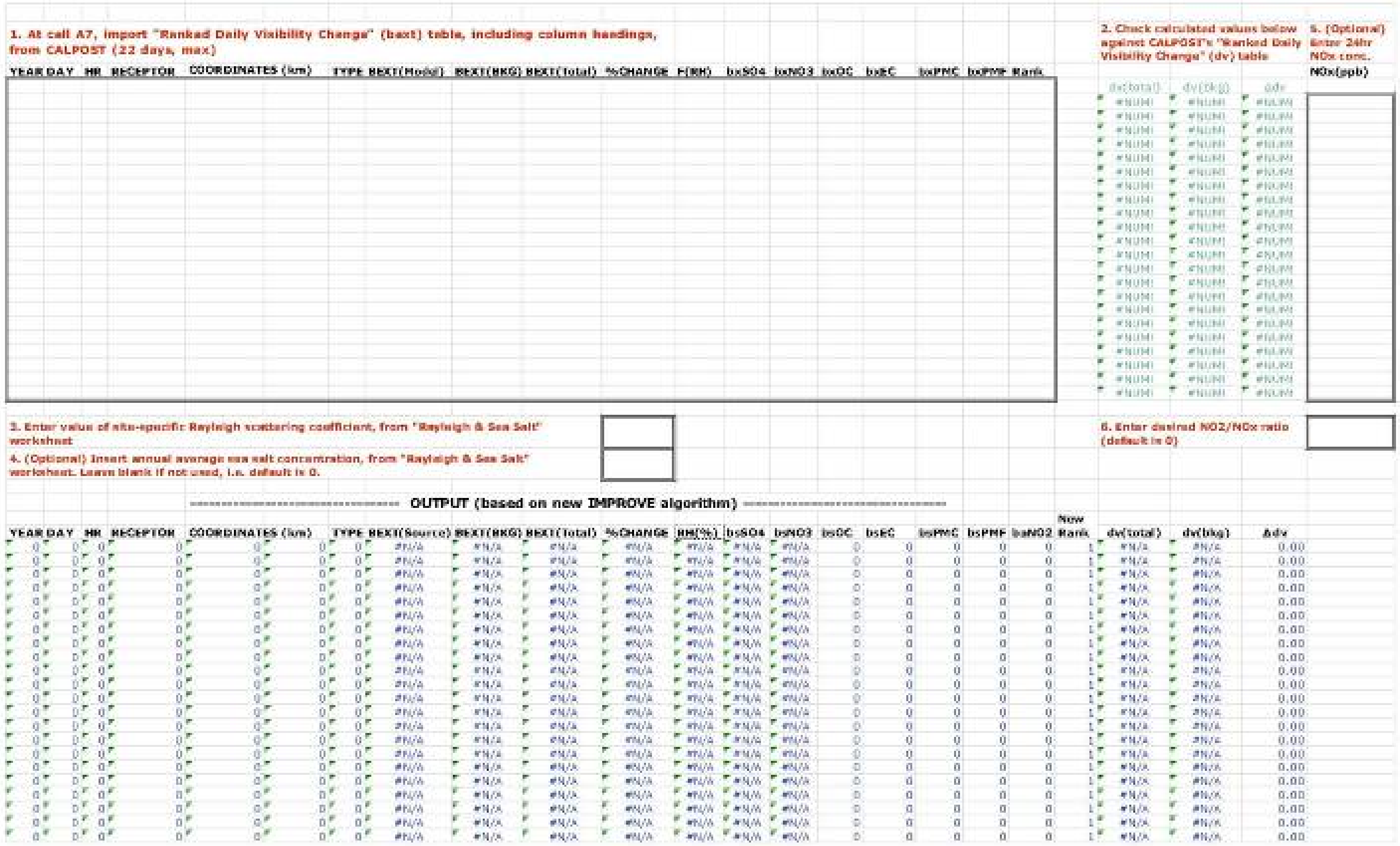

Figure 2. Example of Appearance of Input & Output Worksheet before Data Entry.

numbers should have appeared in the green columns to the right, and some numbers will have appeared in the output table in blue on the lower half of the worksheet. If the data import worked properly, none of the imported data should have spilled out of the large box. Check that all the column captions in bold outside the large box are now duplicated on the first line in the box. (There won't be a caption for Rank.)

Step 7. As a further check on whether everything is correct so far, the dv information in the three columns to the right of the large box should be the same as that in the second CALPOST table "Ranked Daily Visibility Change: % of Modeled Extinction by Species", which was mentioned in Footnote 1.

Step 8. Beneath the large box that was just filled with imported data, enter the Rayleigh scattering coefficient for the Class I area of interest into the top small box after red instruction 3. Also, if you wish, fill in the other small box, the one after red instruction 4, with the annual average sea salt concentration. (The sea salt box may be left blank, but the Rayleigh scattering coefficient box must be filled in.) To help with filling in these two boxes, the fourth worksheet, "Rayleigh & Sea Salt", provides IMPROVE-calculated values of the Rayleigh coefficients for Class I areas in the VISTAS region and in adjacent states. Also, average sea salt concentrations for 2000-2004, calculated in accordance with the new IMPROVE procedures, can be found there.

Step 9.[9] If the impact due to NO_2 is to be considered, a second CALPOST run will be needed to provide the 24-hr average NO_x concentrations estimated by CALPUFF. For this purpose, run CALPOST using the ASPEC = NOX option in Input Group 1 of the CALPOST.INP control file. The NO_x values to insert in the NO_x input box on the Input & Output page of the processor have to be extracted manually from the CALPOST output file for each date and receptor listed in the file that was imported in Steps 1 through 5 above and are displayed in the left hand columns in the large box.

Step 10. Select a value between 0 and 1 to represent what fraction of NO_x is in the form of NO_2. Enter this value into the small box at red instruction 6 below the column where the NO_x concentrations were entered.[10]

Step 11. The blue data table at the bottom of the page represents the new IMPROVE algorithm outputs. An example is shown in Figure 3. This table can be compared with the original CALPOST table at the top of the page. All of the columns in both tables show exactly the same variables, except that the F(RH) column in the top table is replaced by just the RH in the lower table (since the new procedure has three different f(RH) functions) and a new $baNO_2$ column has been added to the bottom table to show the light absorption due to NO_2 (in Mm^{-1}). Although the events are listed in the same order in both tables, note that their rankings may have changed, as is the case for many of the lines in the blue output table in Figure 3.

[9] Steps 8 and 9 are optional. If the impact due to NO_2 is not of interest, just leave the entry fields mentioned in these steps blank.

[10] An easy way to see the effect of the NO_2 on the source's impact in the output table in the lower half of the page is to toggle this NO_2/NO_x value between the selected value and zero.

For those who are interested in more detail concerning the calculations that take place, values of the three f(RH) functions appear in columns M through O on the second, "Calculations" spreadsheet. The extinction impact of the source, including enhancement of the extinction efficiencies for sulfates, nitrates, and organics because of greater total mass concentrations, appears in columns V through AC. Extinction due to the annual average natural background appears in Columns AJ through AN; natural background extinctions for those components that are enhanced by greater total mass concentrations appear in columns AU through AX.

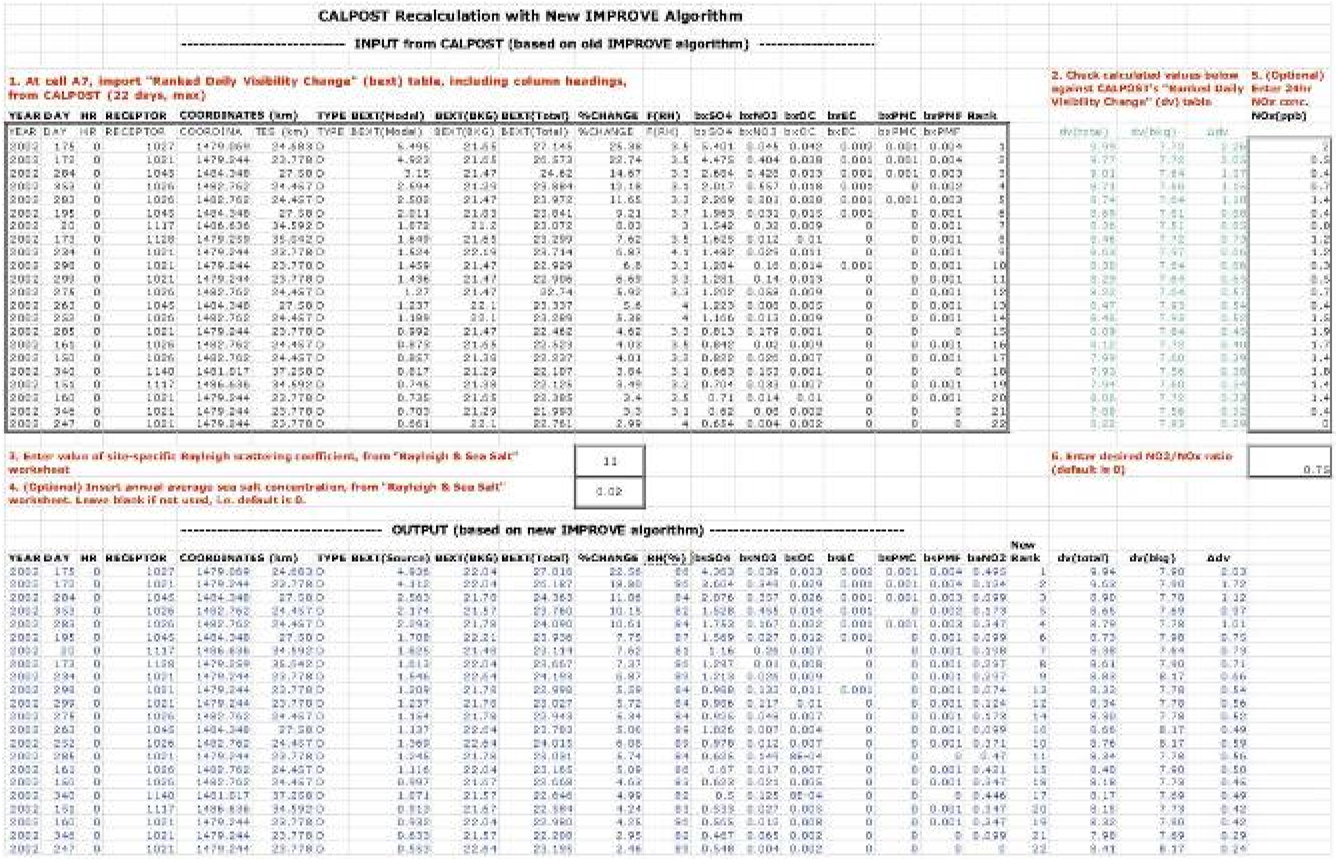

Figure 3. Example of Appearance of Finished Input & Output Worksheet.

Appendix
Details of Calculation Approach

As an example of the calculation steps, assume that the sulfate concentration resulting from emissions from a source is $[S_E]$ and the sulfate in the undisturbed natural background is $[S_N]$, for a total ambient sulfate concentration of $[S_T]$. According to Equations 1 and 2 in the main body of this document, the total extinction due to sulfate for this combination is

$$b_{ext}(sulfate) = 2.2 \cdot f_S(RH) \cdot [small\ sulfate] + 4.8 \cdot f_L(RH) \cdot [large\ sulfate], \qquad \text{(Eq. A-1)}$$

where

$$[large\ sulfate_T] = \{[S_T]/20\} \cdot [S_T] \text{ if } [S_T] < 20\ \mu g^3$$

$$[large\ sulfate_T] = [S_T] \text{ if } [S_T] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. A-2)}$$

$$[small\ sulfate_T] = [S_T] - [large\ sulfate_T],$$

and the subscript T denotes total sulfate

For the original background, where there is no source impact, the corresponding formulas for the terms in Equations A-2 are

$$[large\ sulfate_N] = \{[S_N]/20\} \cdot [S_N] \text{ if } [S_N] < 20\ \mu g^3$$

$$[large\ sulfate_N] = [S_N] \text{ if } [S_N] \geq 20\ \mu g/m^3 \qquad \text{(Eqs. A-3)}$$

$$[small\ sulfate_N] = [S_N] - [large\ sulfate_N],$$

where the subscript N denotes natural sulfate.

Similar calculations need to be carried out for nitrates. Contributions of the other particulate components are linear and can just be calculated according to Equation 1.

If the impact due to NO_2 is also to be considered, then the source impact due to this component is, according to Equation 1,

$$b_{ext}(NO_2) = 0.33 \cdot [NO_2], \qquad \text{(Eq. A-4)}$$

where $[NO_2]$ is in ppb. It is reasonable to assume that the ambient NO_2 concentrations under natural conditions would be so small as to cause negligible light absorption, so the corresponding term is not needed in the natural conditions calculation.

The contributions due to the various components are summed together as in Equation 1 to obtain the total extinction $b_{ext,T}$ and the natural background extinction $b_{ext,N}$. The fractional change in extinction is then calculated as the difference, normalized by the natural background extinction

$$(b_{ext,T} - b_{ext,N})/b_{ext,N}, \qquad \text{(Eq. A-5)}$$

a result that can also be expressed in deciviews.

These formulas are used in the CALPOST-IMPROVE Processor. Similar formulas apply for nitrates and organics. There is no nonlinearity in the remaining terms in Equation 1.

This page intentionally left blank.

Appendix E

US Steel Four-Factor Analysis Submittal

This page intentionally left blank.

United States Steel Corporation
Gary Works
One North Broadway
Gary, IN 46402-3199

September 30, 2020

Via Electronic Mail
Jean Boling
Indiana Department of Environmental Management
Office of Air Quality, Programs Branch
JBoling@idem.in.gov

Subject: U. S. Steel - Gary Works Four-Factor Analysis
Re: Regional Haze State Implementation Plan – Second Planning Period – Request for Four-Factor Analysis

Dear Ms. Boling:

On June 18, 2020, the Indiana Department of Environmental Management (IDEM) notified U. S. Steel – Gary Works that it was a selected source for the second implementation period four-factor analysis for the Regional Haze State Implementation Plan (SIP) and requested U. S. Steel – Gary Works to submit a Four-Factor Analysis. The request included evaluations of the No. 3 Sinter Plant sinter strands (NOx and SO2), the No. 14 Blast Furnace (NOx and SO2), and the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers (NOx). The requested Four-Factor Analysis report is attached for your review.

Any questions regarding this notification can be directed to Marrissa Taylor at (219) 888-7938.

Sincerely,

Alexis Piscitelli
Senior Director, Environmental Control
United States Steel Corporation

Regional Haze Four-Factor Analyses for NO_X and SO_2 Emission Controls

- ***No. 3 Sinter Plant Sinter Strands***
- ***No. 14 Blast Furnace Stoves and Casthouse***
- ***84” Hot Strip Mill Reheat Furnaces No. 1 through No. 4 and Waste Heat Boilers No. 1 and No. 2***

Prepared for
United States Steel Corporation
Gary Works Facility

September 25, 2020

325 South Lake Avenue, Suite 700
Duluth, MN 55802
218.529.8200
www.barr.com

Regional Haze Four-Factor Analyses for NO_X and SO_2 Emission Controls

September 25, 2020

Contents

List of Tables

List of Figures

List of Appendices

Abbreviations

2010 Nucor BACT	Nucor Steel Louisiana Best Available Control Technology Analyses, March 1, 2010
2019 RH SIP Guidance	EPA Guidance on Regional Haze State Implementation Plans for the Second Implementation Period, August 20, 2019
BACT	best available control technology
BART	best available retrofit technology
CEPCI	Chemical Engineering Plant Cost Index
dv	deciview
EGU	Electric Generating Unit
EPA	U.S. Environmental Protection Agency
Gary Works	U. S. Steel Gary Works
IDEM	Indiana Department of Environmental Management
IMPROVE	Interagency Monitoring of Protected Visual Environments
km	kilometer
LAER	lowest achievable emission rate
lb	pounds
LNB	Low-NO_X Burners
Mammoth Cave	Mammoth Cave National Park
Mingo	Mingo National Wildlife Refuge
MMBtu	million British Thermal Units
MMscf	million standard cubic feet
NO_X	nitrogen oxides
O&M	operating and maintenance
PM	particulate matter
PSD	Prevention of Significant Deterioration
RACT	reasonably available control technology
RBLC	RACT/BACT/LAER Clearinghouse
RFI	Request for Information
RHR	Regional Haze Rule
SCR	Selective Catalytic Reduction
Seney	Seney National Wildlife Refuge
SIP	State Implementation Plan
SO_2	sulfur dioxide
tpy	tons per year
URP	Universal Rate of Progress
VOC	volatile organic compound

1 Executive Summary

In accordance with the Indiana Department of Environmental Management's (IDEM's) June 18, 2020 Request for Information (RFI) Letter,[1] U. S. Steel Gary Works (Gary Works) evaluated potential emission control measures for nitrogen oxides (NO_X) and sulfur dioxide (SO_2) for the No. 3 Sinter Plant Sinter Strands (ISS10379 and ISS30381) and No. 14 Blast Furnace (IDST0359 and IDBF0369), and for NO_X emissions from the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers (RB1B0508, RB2B0509, RMF10500, RMF20501, RMF30502, and RMF40503). This report addresses the four statutory factors, laid out in 40 CFR 51.308(f)(2)(i), for the reasonable set of emission control measures pursuant to the final U.S. Environmental Protection Agency (EPA) RHR State Implementation Plan (SIP) guidance[2] on August 20, 2019 (2019 RH SIP Guidance). The four statutory factors are as follows:

1. cost of compliance
2. time necessary for compliance
3. energy and non-air quality environmental impacts of compliance
4. remaining useful life of the source

This report, commonly referred to as a four-factor analysis, describes the background and analysis for identifying the reasonable set of emission control measures, evaluating effective emission control measures, and conducting the review of the four statutory factors. Additionally, this analysis evaluates the visibility benefits at the associated Class I areas from the installation of potential emission control measures, consistent with the 2019 RH SIP Guidance.

The NO_X and SO_2 four-factor analyses with visibility benefits evaluations conclusions are summarized in Table 1-1 and Table 1-2, respectively.

As described in Section 3 and Section 4, the No. 3 Sinter Plant Sinter Strands and No. 14 Blast Furnace (Stoves and Casthouse) four-factor analyses with visibility benefits evaluations concluded that:

- There is no reasonable set of NO_X and SO_2 emission control measures beyond what is currently installed and operated for these emission units (see Sections 3.1.1, 3.2.1, 4.1.1, and 4.2.1).
- The existing emission control measures are equivalent to those determined to be the Best Available Control Technology (BACT) in a recent BACT analysis and, therefore, are considered effective emission controls (see Sections 3.1.1, 3.2.1, 4.1.1, and 4.2.1).

[1] June 18, 2020 letter from Mathew Stuckey of IDEM to Marrissa Taylor of U. S. Steel Gary Works.

[2] US EPA, "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period," August 20, 2019, EPA-457/B-19-003.

- Additional NO_X and SO_2 emission reductions are not appropriate and are unnecessary for these sources because:
  - o The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave National Park (Mammoth Cave) and Seney National Wildlife Refuge (Seney)), or trending towards (Mingo National Wildlife Refuge (Mingo)), the 2028 uniform rate of progress (URP) (see Section 6.1),
  - o The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors and, therefore, any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).
- Therefore, the No. 3 Sinter Plant Sinter Strands and No. 14 Blast Furnace (Stoves and Casthouse) existing NO_X and SO_2 emission performance are appropriate and sufficient for the IDEM's regional haze reasonable progress goal (see Sections 3.1.8, 3.2.8, 4.1.8, and 4.2.8).

As described in Section 5, the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers NO_X four-factor analysis with visibility benefits evaluation concluded that:

- The reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units consists of Low-NO_X Burners (LNB) (see Section 5.1.1).
- LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers are not cost-effective, based on the associated cost-effectiveness values ($ per ton of emissions reduction). Furthermore, the additional capital and operating costs may negatively impact Gary Works' ability to compete in the economic market (see Section 5.1.3).
- Independent of the cost-effectiveness evaluation, which alone indicates that no additional emission control measures are necessary and appropriate, the additional NO_X emission control measures and their associated NO_X emission reductions are also not necessary and appropriate for Gary Works because:
  - o The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
  - o The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
  - o Thus, the NO_x emission reduction associated with LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers does not justify the associated cost, as described in Section 5.1.3, because the emission control measure will not appreciably improve visibility in these Class I areas (see Section 5.1.7).
- Therefore, the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers existing NO_X emission performance are appropriate and sufficient for the IDEM's regional haze reasonable progress goal (see Section 5.1.8).

In addition to the four statutory factors, this analysis also considers the current visibility and the potential visibility benefits from installing additional emission control measures on the associated sources at the facility. An analysis of current visibility conditions was completed at the three Class I areas closest to Gary Work's facility (~500-570 km away): Mammoth Cave in Kentucky, Seney in northern Michigan and Mingo in Missouri. The analysis compared the current visibility conditions to the natural visibility goal, the 2028 URP, and to the possible reasonable progress goals for the SIP. As shown in Section 6.1, the 5-year average visibility impairment on the most impaired days is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP. Thus, it is not necessary for Gary Works to install additional emission control measures to make reasonable progress at these distant Class I areas and, as shown below, any reductions in emissions at Gary Works will not appreciably improve visibility in these Class I areas.

Furthermore, a reverse particle trajectory analysis was completed from these same Class I areas (Mammoth Cave, Mingo, and Seney) to determine how emissions from Gary Works could impact visibility in Class I areas on the 20% most impaired days. As shown in Section 6.1, the majority (97.5%) of the most impaired trajectories are not traveling from the general direction of Gary Works. Furthermore, most of the 48-hour reverse trajectories end before reaching the Gary Works facility location, indicating that the nearest Class I areas are at a distance far enough away from the facility, and therefore Gary Works is not reasonably expected to contribute to visibility impairment at the Class I areas. This information generally demonstrates sources from other regions, and not Gary Works, are contributing to the visibility impairment on the most impaired days at the monitors. For example, the emissions are likely coming from other metropolitan areas such as Louisville, St. Louis, Indianapolis, Columbus, Cincinnati, and Nashville. As such, the installation of additional emission control measures at Gary Works would not improve visibility in these Class I areas on the most impaired days.

Lastly, additional emission control measures could impact the economic viability of the company to continue to operate in competitive economic markets. Gary Works, as well as the entire integrated iron and steel mill industry, is highly sensitive to incremental capital and operating costs due to substantial fluctuation in global economic markets. Considering the current visibility progress and that Gary Works does not appreciably contribute to the associated visibility impairment at the pertinent Class I areas, any additional emission control measures that would be a substantial barrier for the facility to continue to operate would be unreasonable and inappropriate.

Table 1-1 Summary of NO_X Four-Factor Analyses with Visibility Benefits Evaluations

Reasonable Set of Emission Control Measures	Factor #1 – Cost of Compliance	Factor #2 – Time Necessary for Compliance	Factor #3 – Energy and Non-Air Quality Environmental Impacts of Compliance	Factor #4 – Remaining Useful Life of the Source	Visibility Benefits	Does this Analysis Support the Installation of this Emission Control Measure?
No. 3 Sinter Plant Sinter Stands						
No reasonable set of NO_X emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of NO_X emission control measures beyond what is currently installed and operated.
No. 14 Blast Furnace Stoves						
No reasonable set of NO_X emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of NO_X emission control measures beyond what is currently installed and operated.
No. 14 Blast Furnace Casthouse						
No reasonable set of NO_X emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of NO_X emission control measures beyond what is currently installed and operated.
84" Strip Mill Reheat Furnaces No. 1 through No. 4						
Low-NO_X Burners (LNB)	$14,100 per ton of NO_X removed	2-3 years after SIP promulgation.	Negligible energy and non-air quality environmental impacts	20-year control equipment life	Emissions reductions at Gary Works would not improve visibility at Class I areas of interest on the most impaired days.	No – LNB are not cost-effective and would not improve the visibility at the associated Class I areas of interest on the most impaired days.

Reasonable Set of Emission Control Measures	Factor #1 – Cost of Compliance	Factor #2 – Time Necessary for Compliance	Factor #3 – Energy and Non-Air Quality Environmental Impacts of Compliance	Factor #4 – Remaining Useful Life of the Source	Visibility Benefits	Does this Analysis Support the Installation of this Emission Control Measure?
Waste Heat Boiler No. 1						
Low-NO_X Burners (LNB)	$6,100 per ton of NO_X removed	2-3 years after SIP promulgation.	Negligible energy and non-air quality environmental impacts	20-year control equipment life	Emissions reductions at Gary Works would not improve visibility at Class I areas of interest on the most impaired days.	No – LNB are not cost-effective and would not improve the visibility at the associated Class I areas of interest on the most impaired days.
Waste Heat Boiler No. 2						
Low-NO_X Burners (LNB)	$6,300 per ton of NO_X removed	2-3 years after SIP promulgation.	Negligible energy and non-air quality environmental impacts	20-year control equipment life	Emissions reductions at Gary Works would not improve visibility at Class I areas of interest on the most impaired days.	No – LNB are not cost-effective and would not improve the visibility at the associated Class I areas of interest on the most impaired days.

Table 1-2 Summary of SO_2 Four-Factor Analyses with Visibility Benefits Evaluations

Reasonable Set of Emission Control Measures	Factor #1 – Cost of Compliance	Factor #2 – Time Necessary for Compliance	Factor #3 – Energy and Non-Air Quality Environmental Impacts of Compliance	Factor #4 – Remaining Useful Life of the Source	Visibility Benefits	Does this Analysis Support the Installation of this Emission Control Measure?
No. 3 Sinter Plant Sinter Stands						
No reasonable set of SO_2 emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of SO_2 emission control measures beyond what is currently installed and operated.
No. 14 Blast Furnace Stoves						
No reasonable set of SO_2 emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of SO_2 emission control measures beyond what is currently installed and operated.
No. 14 Blast Furnace Casthouse						
No reasonable set of SO_2 emission control measures beyond what is currently installed and operated.	Not Applicable	Not Applicable	Not Applicable	Not Applicable	Not Applicable	No – There is no reasonable set of SO_2 emission control measures beyond what is currently installed and operated.

2 Introduction

Section 2.1 discusses the RFI provided to Gary Works by IDEM, pertinent regulatory background and relevant information from the 2019 RH SIP Guidance. Section 2.2 provides a description of the emission units which IDEM identified in the RFI, and Section 2.3 presents the 20-year facility-wide NO_X and SO_2 emissions data trends.

2.1 Four-Factor Analysis Regulatory Background

The RHR requires state regulatory agencies to submit a series of SIPs in ten-year increments to protect visibility in certain national parks and wilderness areas, known as mandatory Federal Class I areas. The original State SIPs were due on December 17, 2007 and included milestones for establishing reasonable progress towards the visibility improvement goals, with the ultimate goal to achieve natural background visibility by 2064. The initial SIP included best available retrofit technology (BART) analyses for all BART-subject sources. The second RHR implementation period ends in 2028 and requires development and submittal of a comprehensive SIP update by July 31, 2021.

As part of the SIP development process, IDEM sent an RFI to Gary Works on June 18, 2020. The RFI stated that data from the Interagency Monitoring of Protected Visual Environments (IMPROVE) monitoring site at Bondville, Illinois indicates that sulfates and nitrates continue to be the largest contributors to visibility impairment in Indiana. The primary precursors of sulfates and nitrates are emissions of SO_2 and NO_X that react with available ammonia. The RFI stated that IDEM's source selection rankings identified iron and steel mills as one of the source categories for analysis of emission control measures based on rudimentary estimates of Q/d, or emissions divided by distance from the parks which do not account for meteorological conditions or other site-specific data. Based upon the rudimentary Q/d criterion that does not account for many factors, including meteorological data, IDEM requested that Gary Works submit a four-factor analysis evaluating potential emission control measures, pursuant to 40 CFR 51.308(f)(2)(i),[3] by September 30, 2020 for the emission units identified in Table 2-1.

[3] The four statutory factors are 1) cost of compliance, 2) time necessary for compliance, 3) energy and non-air quality environmental impacts of compliance, and 4) remaining useful life of the source.

Table 2-1 Identified Emission Units

Unit	Unit ID	Applicable Pollutants
No. 3 Sinter Plant Sinter Strands	ISS10379	NO_X, SO_2
	ISS30381	
No. 14 Blast Furnace Stoves	IDST0359	NO_X, SO_2
No. 14 Blast Furnace Casthouse	IDBF0369	NO_X, SO_2
Waste Heat Boiler No. 1	RB1B0508	NO_X
Waste Heat Boiler No. 2	RB2B0509	NO_X
Reheat Furnace No. 1 (84" Hot Strip Mill Furnace)	RMF10500	NO_X
Reheat Furnace No. 2 (84" Hot Strip Mill Furnace)	RMF20501	NO_X
Reheat Furnace No. 3 (84" Hot Strip Mill Furnace)	RMF30502	NO_X
Reheat Furnace No. 4 (84" Hot Strip Mill Furnace)	RMF40503	NO_X

This analysis addresses the four statutory factors which are laid out in 40 CFR 51.308(f)(2)(i) and explained in the 2019 RH SIP Guidance:

1. cost of compliance
2. time necessary for compliance
3. energy and non-air quality environmental impacts of compliance
4. remaining useful life of the source

Additionally, this analysis evaluates the visibility benefits at the associated Class I areas from the installation of potential emission control measures, consistent with the 2019 RH SIP Guidance.

2.1.1 Four-Factor Analysis Overview

The following sections describe the approach that was used to determine the reasonable set of emission control measures and summarize the approach for the evaluation factors as detailed in the 2019 RH SIP guidance.

2.1.1.1 Identifying Available Emission Control Measures

The identification of emission control measures for NO_X and SO_2 are discussed in Sections 3.1, 3.2, 4.1, 4.2, and 5.1. The approach that was used to identify the emission control measures is described in Section 2.1.1.1.1 and Section 2.1.1.1.2.

2.1.1.1.1 Evaluating the Reasonable Set of Emission Control Measures

The 2019 RH SIP Guidance states that the first step of the analysis is to identify the technically feasible control options.[4] However, EPA recognizes that "there is no statutory or regulatory requirement to consider all technically feasible measures or any particular measures,"[5] and states that "a range of technically feasible measures available to reduce emissions would be one way to justify a reasonable set."[6] Emission control measures may include both physical and operational changes. Once all technically feasible emission control measures are identified, Gary Works justifies which emission control measures were considered against the four factors (reasonable set).

In order to be considered technically feasible, an emission control measure must have been previously installed and operated successfully on a similar source under similar physical and operating conditions. Novel emission control measures that have not been demonstrated on full-scale industrial operations are not considered as part of this analysis. Instead, this evaluation focuses on commercially demonstrated control options on similar sources in iron and steel mills.

For purposes of this analysis, Gary Works evaluated only those emission control measures that have the potential to achieve an overall pollutant reduction greater than the performance of the existing systems, including optimizations.

The following tasks were completed to develop the reasonable set of emission control measures to be considered against the evaluation factors:

1. Review the EPA's Reasonably Available Control Technology (RACT), Best Available Control Technology (BACT), and Lowest Achievable Emission Rate (LAER) Clearinghouse (RBLC), which contains "case-specific information on the 'Best Available' air pollution technologies that have been required to reduce the emission of air pollutants from stationary sources." The RBLC provided limited and dated information; the most recent pertinent information was provided in the BACT evaluation for Nucor Steel Louisiana[7] (2010 Nucor BACT). A summary of the RBLC data reviewed is provided in Appendix A.
2. Review air permits for similar sources to identify emission control measures and emission limits, which are being used in practice; a comparison of air permits from similar facilities is provided in Appendix B.

---

[4] US EPA, "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period," August 20, 2019, EPA-457/B-19-003., Page 28.

[5] Ibid, Page 29.

[6] Ibid.

[7] Consolidated Environmental Management Inc – Nucor Steel Louisiana, Best Available Control Technology Analyses, March 1, 2010, PSD-LA-740.

3. Review the 2010 Nucor BACT[8] analysis, which provides additional detail regarding specific control technologies that were considered technically feasible and descriptions of why certain technologies were not considered technically feasible.
4. Select the reasonable set of emission control measures, by process operation and by pollutant, that are most likely to be considered technically feasible; the reasonable set was selected based on the frequency of installation as identified in the RBLC, the air permits that were reviewed, and the technical discussion provided in the 2010 Nucor BACT.

In addition to the literature review, Barr interviewed process engineers from the affected areas of the Gary Works facility (i.e., sinter plant, blast furnace, and hot strip mill) to review potential emission control measures, discuss technical feasibility, and compare the physical configuration of existing equipment to that required for additional emission control measures.

This approach to establish the reasonable set of emission control measures is appropriate and justified because:

1. It is consistent with the 2019 RH guidance (see the discussion above), and
2. The current visibility status does not warrant a more stringent emission control measure selection approach because:
    a. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
    b. The trajectory analysis demonstrates that sources from other regions, and not Gary Works, are contributing to the visibility on the most impaired days at the monitors (see Section 6.2), and
    c. Because Gary Works does not appreciably contribute to visibility impairment of the Class I areas, the installation of additional emission control measures at Gary Works will not appreciably improve visibility in the associated Class I areas on the most impaired days (see Section 6.2).

2.1.1.1.2 Evaluating Effective Emission Control Technology

The 2019 RH SIP Guidance identified eight example scenarios and described the associated rationale for when sources should be considered to already have effective emission control technology in place and, therefore, states could exclude these sources from needing to complete a four-factor analysis.[9] The Guidance includes a list of eight potential scenarios for which EPA believes the source could be

[8] On page 23 of the 2019 RH SIP Guidance, EPA recognized that the "statutory considerations for selection of BACT and LAER are also similar to, if not more stringent than, the four statutory factors for reasonable progress."

[9] US EPA, "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period," August 20, 2019, EPA-457/B-19-003., Page 22.

considered effectively controlled. In addition, EPA clarified that the associated scenarios are not an exhaustive list; they are merely to illustrate examples for the state to consider.[10]

One of the example scenarios of a source which has effective emission control technology is for sources that underwent a BACT or Lowest Achievable Emission Rate (LAER) analysis for visibility impairing pollutants (SO_2 and NO_X) after July 31, 2013. EPA notes that the BACT and LAER control equipment review methodologies are "similar to, if not more stringent than, the four statutory factors for reasonable progress."[11]

Barr assumes that states could justify that a source has effective controls with a BACT or LAER determination from before July 31, 2013, if the current control measures are equivalent or sufficiently similar to the control measures for similar sources that did undergo a BACT or LAER review.

2.1.1.2 Factor 1 – Cost of Compliance

Factor #1 considers and estimates, as needed, the capital and annual operating and maintenance (O&M) costs of the emission control measure. As directed by the 2019 RH SIP Guidance at page 31, costs of emission control measures follow the accounting principles and generic factors from the EPA Air Pollution Control Cost Manual (EPA Control Cost Manual) [12] unless more refined site-specific estimates are available. Under this step, the annualized cost of installation and operation on a dollars per ton of pollutant removed ($/ton) of the emission control measure, referred to as "average cost effectiveness," is compared to a cost-effectiveness threshold that is relative to the expected visibility improvements. As stated in the 2019 RH SIP Guidance, the "balance between the cost of compliance and the visibility benefits will be an important consideration in a state's decisions."[13]

Generally, if the average cost-effectiveness is greater than the threshold and/or there is no expected visibility improvement, the cost is considered to not be reasonable, pending an evaluation of other factors. Conversely, if the average cost-effectiveness is less than the threshold and visibility improvements are expected, then the cost is considered reasonable *for purposes of Factor #1,* pending an evaluation of whether the absolute cost of control (i.e., costs in absolute dollars, not normalized to $/ton) is unreasonable. This situation is particularly applicable to a source with existing emission control measures

---

[10] Ibid, Page 23.

[11] Ibid.

[12] US EPA, "EPA Air Pollution Control Cost Manual, Sixth Edition," January 2002, EPA/452/B-02-001. The EPA has updated certain sections and chapters of the manual since January 2002. These individual sections and chapters may be accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution as of the date of this report.

[13] US EPA, "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period," August 20, 2019, Page 37.

with an intermediate or high degree of effectiveness, as is the case for the No. 3 Sinter Plant Sinter Strands due to their existing SO_2 emission control measures (see Section 2.2.1 for additional information).

The cost of an emission control measure is derived using capital and annual O&M costs. Capital costs generally refer to the money required to design and build the system. This includes direct costs, such as equipment purchases and installation costs. Indirect costs, such as engineering and construction field expenses and lost revenue due to additional unit downtime in order to install the additional emission control measure(s), are considered as part of the capital calculation. Annual O&M costs include labor, supplies, utilities, etc., as used to determine the annualized cost in the numerator of the cost-effectiveness value. The denominator of the cost-effectiveness value (tons of pollutant removed) is derived as the difference in: 1) projected emissions using the current emission control measures (baseline emissions), in tons per year (tpy), and 2) expected annual emissions performance through the installation of the additional emission control measure (controlled emissions), also in tpy.

There is not an applicable and appropriate cost-effectiveness threshold because installation of additional emission control measures at Gary Works would not improve visibility at the associated Class I areas (as described in Section 6).

2.1.1.3 Factor 2 – Time Necessary for Compliance

Factor #2 considers the time needed for Gary Works to comply with potential emission control measures. This includes the planning, designing, installing, and commissioning of the selected control based on experiences with similar sources and source-specific factors.

For purposes of this analysis and if a given NO_X or SO_2 emission control measure requires a unit outage as part of its installation, Gary Works considers the forecasted outage schedule for the associated units in conjunction with the expected timeframe for engineering and equipment procurement following any necessary permitting through IDEM and EPA for the given emission control measure.

2.1.1.4 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Factor #3 considers the energy and non-air environmental impacts of each emission control measure. Energy impacts to be considered are the direct energy consumed at the source, in terms of kilowatt-hours or mass of fuels used. Non-air quality impacts may include solid or hazardous waste generation, wastewater discharges from a control device, increased water consumption, and land use. The analysis is conducted based on the consideration of site-specific circumstances.

2.1.1.5 Factor 4 – Remaining Useful Life of the Source

Factor #4 considers the remaining useful life of the source, which is the difference between the date that additional emission control measures will be put in place and the date that the facility permanently ceases operation. Generally, the remaining useful life of the source is assumed to be longer than the useful life of the emission control measure unless the source is under an enforceable requirement to cease operation. In the presence of an enforceable end date, the cost calculation can use a shorter period to amortize the capital cost.

For the purpose of this evaluation, the remaining useful life for the units is assumed to be longer than the useful life of the additional emission control measures. Therefore, the expected useful life of the emission control measure is used to calculate the emissions reductions, amortized costs, and the resulting cost per ton removed.

2.1.1.6 Visibility Benefits

In addition to the four statutory factors, this analysis considers the potential visibility benefits from installing additional emission reduction measures at the source. The 2019 RH SIP Guidance states that "visibility benefits may again be considered in that control analysis to inform the determination of whether it is reasonable to require a certain measure."[14]

For the purpose of this evaluation, additional emission control measures would be inappropriate and unnecessary to make reasonable progress at the associated Class I areas if any of the following conditions are satisfied:

1. The current visibility conditions are already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP,
2. The facility is shown not to appreciably impact the associated Class I areas on the most impaired days at the associated Class I areas, or
3. The additional emission control measure does not provide sufficient incremental visibility benefits to justify the other four factors (cost, time to implement, energy and non-air quality environmental impacts, and remaining useful life).

2.2 Affected Emission Unit Description and Existing Emission Control Measures

Gary Works is an integrated iron and steel mill located in Gary, Indiana. Operations include raw material handling, sintering, ironmaking, steelmaking, and manufacturing of steel slabs, hot rolled, cold rolled, and tin mill products, as well as on-site utility generation. The three emission unit groups addressed in IDEM's RFI are described below.

2.2.1 No. 3 Sinter Plant Sinter Strands

The No. 3 Sinter Plant agglomerates iron bearing and other materials from various sources to create a raw material feedstock for the blast furnaces that supplements iron ore pellets. The sinter feedstock is thoroughly blended and combusted on each sinter strand by drawing air through the sintered material and into the windboxes. The windboxes exhaust fumes through the two existing control trains which control particulate matter (PM) and SO_2 emissions. Each train consists of reheat burners, cyclones, a

[14] US EPA, "Guidance on Regional Haze State Implementation Plans for the Second Implementation Period," August 20, 2019, Page 34.

quench reactor, a dry venturi scrubber, and a baghouse. Sintered material is then cooled, sized, and screened, so that on-spec material is sent to the blast furnaces.

Along the traveling grate, the iron ore fines, coke breeze, and other materials are ignited with natural gas burners. The NOx emissions are generated from the associated combustion of the coke and natural gas and the combustion of natural gas at the reheat burners. The No. 3 Sinter Plant Sinter Strands follow good combustion practices.

The No. 3 Sinter Plant Sinter Strands generate SO_2 emissions through oxidation of sulfur compounds present in the raw materials (iron ore, coke, etc.) and natural gas fuel. Figure 2-1 presents a simplified version of the existing emission control measures for the No. 3 Sinter Plant windbox exhaust. The exhaust treatment reduces PM and SO_2 emissions.

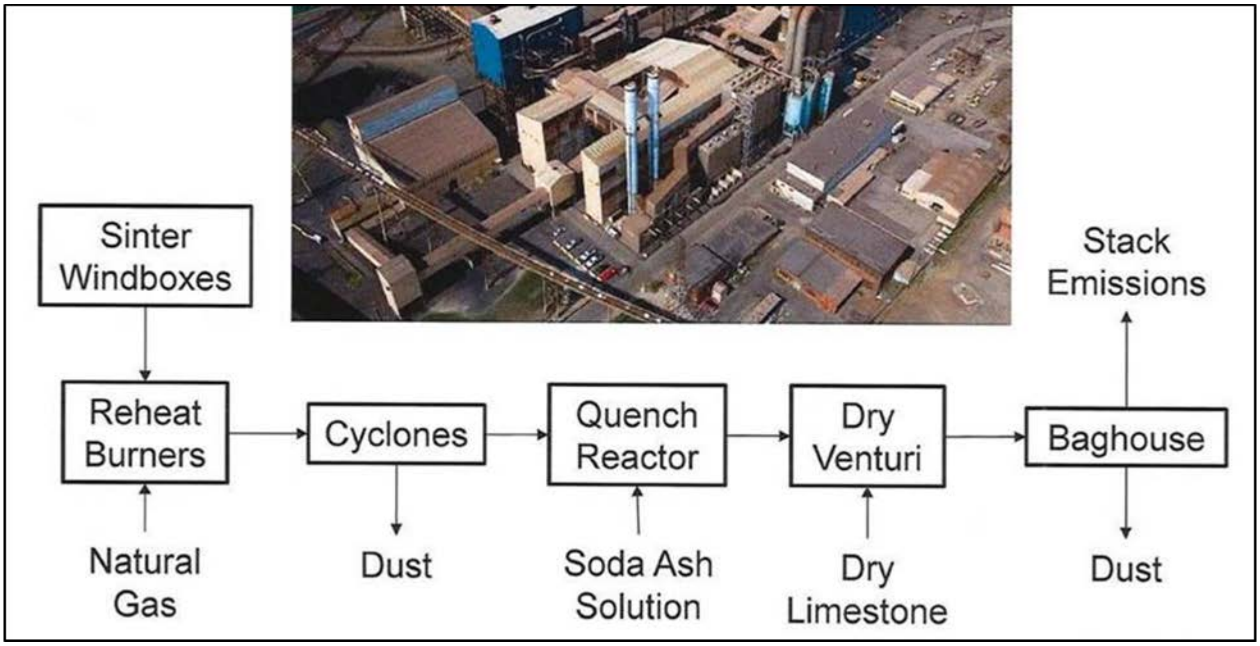

Figure 2-1 No. 3 Sinter Plant Windbox Exhaust Treatment

The exhaust gas from the sinter windbox is processed through five main stages before exiting the stack. First, the exhaust gas passes through reheat burners ensure that the temperature remains above the acid dew point to help prevent corrosion in downstream control equipment and to prepare the gas for downstream contact with the soda ash solution. The cyclones remove fine PM from the exhaust gas stream. The quench reactor sprays a soda ash solution to cool the hot exhaust gas stream and to react with and absorb SO_2. The dry venturi scrubber with dry limestone addition allows for further removal of the SO_2 through reaction with the limestone. Finally, the exhaust gas (also containing any excess dry limestone as well as dry reaction products) is processed through a baghouse to reduce PM before ultimately being discharged to the atmosphere from the stack.

The original control system, an electrodynamic venturi scrubber, was replaced in 1996. After startup, the facility worked to optimize the design and performance of the system through 2003 in order to achieve significant emission reductions over the previous technology.

2.2.2 No. 14 Blast Furnace (Stoves and Casthouse)

The blast furnace combines coke, limestone, sinter, iron ore pellets, and other iron sources with high heat to produce pig iron and slag. To produce this high amount of heat, hot air must be injected into the blast furnace to ignite the added coke. This hot air is produced in the blast furnace stoves, which fire blast furnace gas and supplemental natural gas to heat fresh air for injection. The blast furnace is also able to inject pulverized coal and natural gas. Blast furnace gas is the partially combusted, CO-rich gas that is produced within the blast furnace itself. This gas has a low but beneficial heating value and is cleaned for PM via the integrated scrubbing system prior to combustion as a fuel source to reduce consumption of natural resources and improve energy efficiency.

Once the pig iron and slag are produced in the No. 14 Blast Furnace, they flow through a series of troughs which empty the molten iron into a submarine car for transfer and empty the slag into the adjacent slag pit or slag granulation facility.

The No. 14 Blast Furnace Stoves resulting NO_X emissions are generated from primarily firing BFG and supplemental natural gas (to maintain flame temperature) to heat fresh air for injection. BFG is considered a low-NO_X fuel because it generates less than half of the NO_X per unit of energy as natural gas. BFG burns at a cooler temperature, which prevents the majority of thermal NO_X formation when compared to natural gas combustion. Therefore, the use of BFG in the No. 14 Blast Furnace Stoves is an existing NO_X emission control measure.

The NOx emissions from the No. 14 Blast Furnace Casthouse are not significant (28.98 ton NO_X per year in 2019). The NO_X emissions may be released during the casting process and are fugitive in nature (i.e., not emitted from a stack).

The No. 14 Blast Furnace Stoves generate SO_2 emissions through oxidation of sulfur compounds present in the fuel (blast furnace gas and natural gas). Blast furnace gas and natural gas are considered low sulfur fuels compared to other solid and liquid fuels and are utilized as SO_2 emission control measures.

The No. 14 Blast Furnace Casthouse's molten iron and slag streams contain sulfur and sulfur compounds that form SO_2 upon contacting air during the casting process and are fugitive in nature (i.e., not emitted from a stack).

2.2.3 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers

The 84" Hot Strip Mill Reheat Furnaces are used to heat incoming steel slabs to working temperatures to be rolled into steel coils. These reheat furnaces fire natural gas and route their exhausts towards the waste boilers to recoup thermal energy.

The No. 1 and No. 2 Waste Heat Boilers produce utility steam for use throughout the Gary Works facility. The boilers are natural gas-fired, but also make use of hot exhaust from the stacks of the 84" Hot Strip Mill Reheat Furnaces to reduce heating input requirements. These boilers increase efficiency by using recouped heat from the reheat furnaces.

The 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers generate NO_X emissions from natural gas combustion. The units implement good combustion practices as a NO_X emission control measure. In addition, the 84" Hot Strip Mill Reheat Furnaces operate John Zink Hamworthy's ZoloSCAN technology, which is a laser-based combustion diagnostic system, that allows for better process control (temperature, O_2, CO and water) and results in actual NO_X emission reductions from fuel savings and minimizing excess air.[15]

2.3 20-year Facility-wide NO_X and SO_2 Emission Trends

The goal of the RHR is to improve the visibility at Class I areas of interest through visibility-impairing pollutant emission reductions. Independent of any RHR requirements, Gary Works has achieved substantial facility-wide NO_X and SO_2 emission reductions in the last twenty years as a result of extensive projects, including the installation of SO_2 emission control measures on the No. 3 Sinter Plant Sinter Strand and shutting down three Coke Battery units. Figure 2-2 presents the facility-wide NO_X and SO_2 emissions from 2000 to 2019. Since Gary Works has already reduced facility-wide NO_X and SO_2 emissions by 58% from 2000 (2000 = 11,557 tons/year NO_X and SO_2, 2019 = 4,887 tons/year NO_X and SO_2), additional emission control measures are imprudent and unnecessary to achieve the Regional Haze goal when considered in conjunction with the current visibility trends (see Section 6.1) and the visibility impacts at the associated Class I areas from Gary Works (see Section 6.2).

[15] https://www.johnzinkhamworthy.com/wp-content/uploads/steel-reheat-combustion-monitoring.pdf

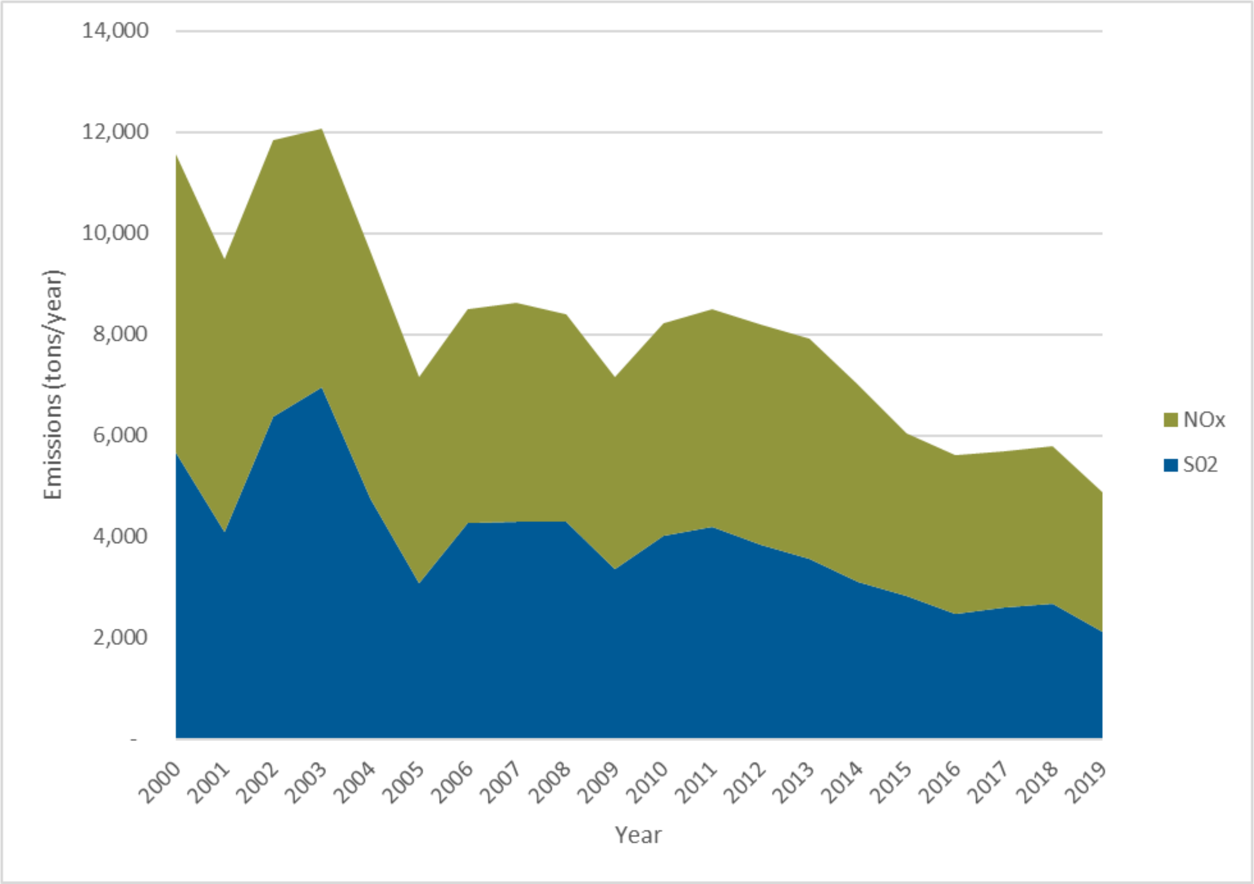

Figure 2-2 Facility-wide NO_X and SO_2 Emissions from 2000 to 2019

3 No. 3 Sinter Plant Sinter Strands

The following sections describe the analysis for NO_X and SO_2 emission control measures for the No. 3 Sinter Plant Sinter Strands.

3.1 Four-Factor Analysis – NO_X

The following sections describe the four-factor analysis with visibility benefits evaluation for determining the reasonable set of NO_X emission control measures (Section 3.1.1), the evaluation factors (Sections 3.1.3 through 3.1.7), and the proposed emission control measures (Section 3.1.8) for No. 3 Sinter Plant Sinter Strands.

3.1.1 NO_X Emission Control Measures

Table 3-1 presents NO_X emission control measures for sinter plants at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 3-1 Sinter Plant NO_X Emission Control Measures at Similar Sources

Facility	Emission Unit Description	NO_X Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	Sinter Plant	None
ArcelorMittal Indiana Harbor West(1)	Sinter Plant	None
ArcelorMittal Burns Harbor	Continuous Sintering Process Plant	None
Nucor St. James(2) (2010 Nucor BACT)	Sinter Plant	None

(1) The sinter plant at ArcelorMittal Indiana Harbor West is no longer included in the facility's most recently issued Title V permit.
(2) The sinter plant at Nucor St. James has not been constructed.

There are no additional NO_X emission control measures based on the 2010 Nucor BACT and emission control measures described in the RBLC (Appendix A) and air permits for similar sources (Appendix B). As such, the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units. Furthermore, the existing NO_X emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT and, therefore, are considered effective emission controls.

3.1.2 Baseline Emission Rates

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not necessary to represent a projected 2028 emissions scenario.

3.1.3 Factor 1 – Cost of Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to estimate the cost of compliance for additional NO_X emission control measures. Even in the circumstance where there was an emission control measure identified as part of the reasonable set, the associated emission control measure's cost-effectiveness would not be reasonable because the emission reduction technology would not impact visibility at the associated Class I areas (see Section 6).

3.1.4 Factor 2 – Time Necessary for Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the time that is necessary to achieve compliance for additional NO_X emission control measures.

3.1.5 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the energy and non-air quality environmental impacts for additional NO_X emission control measures.

3.1.6 Factor 4 – Remaining Useful Life of the Source

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the remaining useful life of the source.

3.1.7 Visibility Benefits

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the potential visibility benefits for additional NO_X emission control measures. However, as described in Section 6, additional NO_X emission reductions are not appropriate and are unnecessary for Gary Works because:

1. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
2. The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
3. Any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).

3.1.8 Proposed NO_X Emission Control Measures

The four-factor analysis with visibility benefits evaluation concluded that additional NO_X emission control measures at the No. 3 Sinter Plant Sinter Strands beyond those described in Section 2.2.1 are not required to make reasonable progress in reducing NO_X emissions. As such, Gary Works proposes to maintain the existing NO_X emission control measures.

3.2 Four-Factor Analysis – SO_2

The following sections describe the four-factor analysis with visibility benefits evaluation for determining the reasonable set of SO_2 emission control measures (Section 3.2.1), the evaluation factors (Sections 3.2.3 through 3.2.7), and the proposed emission control measures (Section 3.2.8) for No. 3 Sinter Plant Sinter Strands.

3.2.1 SO_2 Emission Control Measures

As described in Section 2.2.1, the No. 3 Sinter Plant Sinter Strand already utilizes a windbox exhaust treatment system, including a quench reactor and dry lime scrubber, as post-combustion SO_2 emission control measures. Table 3-2 presents SO_2 emission control measures for sinter plants at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 3-2 Sinter Plant SO_2 Emission Control Measures at Similar Sources

Facility	Emission Unit Description	SO_2 Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	Sinter Plant	None
ArcelorMittal Indiana Harbor West(1)	Sinter Plant	Wet venturi scrubbers
ArcelorMittal Burns Harbor	Continuous Sintering Process Plant	Venturi scrubber
Nucor St. James(2) (2010 Nucor BACT)	Sinter Plant	Lime spray dry scrubber Dry sorbent injection(3)

(1) The sinter plant at ArcelorMittal Indiana Harbor West is no longer included in the facility's most recently issued Title V permit.
(2) The sinter plant at Nucor St. James has not been constructed.
(3) The 2010 Nucor BACT identified dry sorbent injection as technically feasible but was listed as a lower control efficiency than a lime spray dry scrubber.

A wet scrubber system has functionally equivalent SO_2 control performance compared to the existing quench reactor with dry-lime scrubber at Gary Works' sinter plant; therefore, a wet scrubber system does not represent additional SO_2 emission reduction potential compared to the existing system. A wet scrubber system is not evaluated further.

There are no additional SO_2 emission control measures because the existing SO_2 emission control measures represent the best SO_2 emission reduction potential based on the 2010 Nucor BACT and emission control measures described in the RBLC (Appendix A) and air permits for similar sources

(Appendix B). As such, the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures. Furthermore, the existing SO_2 emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT and, therefore, are considered effective emission controls.

3.2.2 Baseline Emission Rates

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not necessary to represent a projected 2028 emissions scenario.

3.2.3 Factor 1 – Cost of Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to estimate the cost of compliance for additional SO_2 emission control measures. Even in the circumstance where there was an emission control measure identified as part of the reasonable set, the associated emission control measure's cost-effectiveness would not be reasonable because the emission reduction technology would not impact visibility at the associated Class I areas (see Section 6).

3.2.4 Factor 2 – Time Necessary for Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the time that is necessary to achieve compliance for additional SO_2 emission control measures.

3.2.5 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the energy and non-air quality environmental impacts for additional SO_2 emission control measures.

3.2.6 Factor 4 – Remaining Useful Life of the Source

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the remaining useful life of the source.

3.2.7 Visibility Benefits

Since the four-factor analysis concluded the No. 3 Sinter Plant Sinter Strands have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the potential visibility benefits for additional SO_2 emission control measures. However, as described in Section 6, additional SO_2 emission reductions are not appropriate and are unnecessary for Gary Works because:

1. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
2. The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
3. Any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).

3.2.8 Proposed SO_2 Emission Control Measures

The four-factor analysis with visibility benefits evaluation concluded that additional SO_2 emission control measures at the No. 3 Sinter Plant Sinter Strands beyond those described in Section 2.2.1 are not required to make reasonable progress in reducing SO_2 emissions. As such, Gary Works proposes to maintain the existing SO_2 emission control measures.

4 No. 14 Blast Furnace (Stoves and Casthouse)

The following sections describe the analysis for NO_X and SO_2 emission control measures for the No. 14 Blast Furnace Stoves and Casthouse.

4.1 Four-Factor Analysis – NO_X

The following sections describe the four-factor analysis with visibility benefits evaluation for determining the reasonable set of NO_X emission control measures (Section 4.1.1), the evaluation factors (Sections 4.1.3 through 4.1.7), and the proposed emission control measures (Section 4.1.8) for the No. 14 Blast Furnace Stoves and Casthouse.

4.1.1 NO_X Emission Control Measures

4.1.1.1 No. 14 Blast Furnace Stoves

As described in Section 2.2.2, the No. 14 Blast Furnace Stoves already utilize low-NO_X fuel combustion (blast furnace gas) as a NO_X emission control measure. Table 4-1 presents NO_X emission control measures for blast furnace stoves at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 4-1 Blast Furnace Stoves NO_X Emission Control Measures at Similar Sources

Facility	Emission Unit Description	Allowed Fuels	NO_X Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	No. 7 Blast Furnace Stoves	Pulverized Coal Natural Gas Blast Furnace Gas	None
ArcelorMittal Indiana Harbor West	No. 3 Blast Furnace Stoves	Not listed	None
	No. 4 Blast Furnace Stoves		
ArcelorMittal Burns Harbor	C Blast Furnace	Not listed	None
	D Blast Furnace		
AK Steel Dearborn	EUBFURNACE, group of four stoves	Natural gas Blast furnace gas	LNB
	EUCFURNACE, group of four stoves		
AK Steel Middletown	No. 3 Blast Furnace	Not listed	None
ArcelorMittal Cleveland	Blast Furnace C5	Not listed	None
	Blast Furnace C6		
U. S. Steel Edgar Thompson	Blast Furnace No. 1 Stoves	Blast furnace gas Coke oven gas Natural gas	None
	Blast Furnace No. 3 Stoves		
Nucor St. James[(1)] (2010 Nucor BACT)	Blast Furnace 1	Natural gas Blast furnace gas	Low-NO_X fuel combustion[(2)]
	Blast Furnace 2		

(1) The emission units at Nucor St. James have not been constructed.

(2) Nucor St. James identified BACT as low-NO_X fuel combustion through firing blast furnace gas and thus it is explicitly referenced in their permit. However, their operations are not materially different from others in the industry; it is standard operating practice to fire low-NO_X fuel (blast furnace gas) in blast furnace stoves.

The AK Dearborn B and C Furnaces have LNB installed as part of a 2014 Prevention of Significant Deterioration (PSD) Permit. Although LNB are technically feasible to install on blast furnace stoves, it is not clear whether LNB offer any additional emission reduction potential compared to the existing NO_X emission control measures (blast furnace gas – low-NO_X fuel). EPA stated the following in a document titled "Alternative Control Techniques Document -- NO_X Emissions From Iron and Steel Mills" (EPA's Alternative Control Techniques Document)[16]:

> "[…] *the primary fuel is BFG, which is largely CO, has a low heating value, and contains inerts, factors that reduce flame temperature. Thus, the NO_X concentration in blast furnace stove flue gas tends to be low and the potential for NOx reduction is considered to be small.*"

It is important to note that Gary Works historically represented the actual NO_X emissions generated from the supplement natural gas combustion at the Blast Furnace Stoves based on a conservatively high AP-42

[16] EPA, "Alternative Control Techniques Document – NO_X Emissions from Iron and Steel Mills" (EPA-453/R-94-065), 1994, Page 5-22

uncontrolled pre-New Source Performance Standard (NSPS) natural gas boiler emission factor (280 lb/MMscf or 0.275 lb/MMBtu).[17] Since the natural gas is fired as a supplement to the blast furnace gas to meet operating temperatures, the associated AP-42 natural gas emission factor value over-represents thermal NO_X formation because the flame temperatures are less than what would be achieved when firing natural gas exclusively (i.e., basis for the AP-42 emission factor). In Table 4-4 of EPA's Alternative Control Techniques Document, EPA represented the average uncontrolled blast furnace NO_X emission factor as 0.021 lb/MMBtu with a range from 0.002 lb/MMBtu to 0.057 lb/MMBtu. The associated NO_X emission performance is consistent with the range that would be expected from LNB and corroborates EPA's conclusion that the "potential for NO_X reduction is considered to be small."

Additionally, the Briefing Sheet accompanying the 2010 Nucor Permit to Construct (PSD-LA-740) stated that LNB was eliminated as technically infeasible for the following rationale:

> *"Low NO_X burners limit the formation of NO_X by staging the addition of air to create a longer, cooler flame. The combustion of BFG in the hot blast stoves requires the supplement of a small amount of natural gas in order to maintain flame stability and prevent flame-outs of the burners. The use of low NO_X burners would attempt to stage fuel gas at the limits of combustibility and would prevent the operation of the hot blast stoves. Thus, low NO_X burners are not a feasible control technology for the hot blast stoves."*[18]

Since LNB represent a negligible or potentially small emission reduction potential, compared to the current NO_X emission control measures, and have the potential operational challenges, LNB are not considered as part of the reasonable set of NO_X emission control measures for the No. 14 Blast Furnace Stoves and are not evaluated further in this analysis.

The No. 14 Blast Furnace Stoves have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units based on the 2010 Nucor BACT, emission control measures described in the RBLC (Appendix A) and air permits for similar sources (Appendix B). Furthermore, the existing NO_X emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT evaluation and determination; and, therefore, are considered effective emission controls.

4.1.1.2 No. 14 Blast Furnace Casthouse

Table 4-2 presents NO_X emission control measures for blast furnace casthouses at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

[17] AP-42 Section 1.4 "Natural Gas Combustion" Table 1.4-1, U. S. Environmental Protection Agency, 1998.

[18] Louisiana Department of Environmental Quality, Nucor Steel Permit to Construct (PSD-LA-740) Briefing Sheet, 2010, Page 23.

Table 4-2 Blast Furnace Casthouse NO_X Emission Control Measures at Similar Sources

Facility	Emission Unit Description	NO_X Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	No. 7 Blast Furnace Casthouse	None
ArcelorMittal Indiana Harbor West	No. 3 Blast Furnace Casthouse	None
	No. 4 Blast Furnace Casthouse	
ArcelorMittal Burns Harbor	C Blast Furnace East and West Casthouses	None
	D Blast Furnace East and West Casthouses	
AK Steel Dearborn	EUBFURNACE Casthouses	None
	EUCFURNACE Casthouses	
AK Steel Middletown	No. 3 Blast Furnace Casthouse	None
ArcelorMittal Cleveland	Blast Furnace C5 Casthouse	None
	Blast Furnace C6 Casthouse	
U. S. Steel Edgar Thompson	Blast Furnace No. 1 Casthouse	None
	Blast Furnace No. 3 Casthouse	

The 2010 Nucor BACT analysis did not evaluate NO_X emission control measures because Nucor Steel Louisiana did not estimate NO_X emissions for the casthouse in the associated permit application. However, the 2010 Nucor BACT stated that there are no feasible SO_2 emission control measures because of the corresponding low SO_2 concentration (~4 ppm SO_2) and high exhaust flow rate. Gary Works' NO_X emissions estimates are significantly less than the SO_2 emissions estimates (28.98 tpy NO_X vs. 579.64 tpy SO_2 in 2019); therefore, the corresponding NO_X concentrations would be comparatively lower and outside the effective range for any add-on NO_X emission control measures.

There are no additional NO_X emission control measures based on the 2010 Nucor BACT, emission control measures described in the RBLC (Appendix A) and air permits for similar sources (Appendix B). As such, the No. 14 Blast Furnace Casthouse has no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units. Furthermore, the existing NO_X emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT and, therefore, are considered effective emission controls.

4.1.2 Baseline Emission Rates

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not necessary to represent a projected 2028 emissions scenario.

4.1.3 Factor 1 – Cost of Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to estimate the cost of compliance for additional NO_X emission control measures. Even in the circumstance where there was an emission control measure identified as part of the reasonable set, the associated emission control measure's cost-effectiveness would not be reasonable because the emission reduction technology would not impact visibility at the associated Class I areas (see Section 6).

4.1.4 Factor 2 – Time Necessary for Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the time that is necessary to achieve compliance for additional NO_X emission control measures.

4.1.5 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the energy and non-air quality environmental impacts for additional NO_X emission control measures.

4.1.6 Factor 4 – Remaining Useful Life of the Source

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the remaining useful life of the source.

4.1.7 Visibility Benefits

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of NO_X emission control measures beyond what is currently installed and operated, it is not appropriate to describe the potential visibility benefits for additional NO_X emission control measures. However, as described in Section 6, additional NO_X emission reductions are not appropriate and are unnecessary for Gary Works because:

1. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
2. The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
3. Any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).
4. The No. 14 Blast Furnace Casthouse's emissions are fugitive in nature and would not impair visibility at the associated Class I areas (greater than 500 km away from Gary Works).

4.1.8 Proposed NO_X Emission Control Measures

The four-factor analysis with visibility benefits evaluation concluded that additional NO_X emission control measures at the No. 14 Blast Furnace Stoves and Casthouse beyond those described in Section 2.2.1 are not required to make reasonable progress in reducing NO_X emissions. As such, Gary Works proposes to maintain the existing NO_X emission control measures.

4.2 Four-Factor Analysis – SO_2

The following sections describe the four-factor analysis with visibility benefits evaluation for determining the reasonable set of SO_2 emission control measures (Section 4.2.1), the evaluation factors (Sections 4.2.3 through 4.2.7), and the proposed emission control measures (Section 4.2.8) for the No. 14 Blast Furnace Stoves and Casthouse.

4.2.1 SO_2 Emission Control Measures

4.2.1.1 No. 14 Blast Furnace Stoves

As described in Section 2.2.2, the No. 14 Blast Furnace Stoves routinely fires low-sulfur fuels (blast furnace gas and pipeline-grade natural gas) as an existing SO_2 emission control measure. Table 4-3 presents SO_2 emission control measures for blast furnace stoves at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 4-3 Blast Furnace Stoves SO_2 Emission Control Measures at Similar Sources

Facility	Emission Unit Description	Allowed Fuels	SO_2 Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	No. 7 Blast Furnace Stoves	Natural Gas Blast Furnace Gas	None
ArcelorMittal Indiana Harbor West	No. 3 Blast Furnace Stoves No. 4 Blast Furnace Stoves	Natural gas Blast furnace gas	None
ArcelorMittal Burns Harbor	C Blast Furnace D Blast Furnace	Blast furnace gas Coke oven gas Natural gas	None
AK Steel Dearborn(1)	EUBFURNACE, group of four stoves EUCFURNACE, group of four stoves	Natural gas Blast furnace gas	None
AK Steel Middletown	No. 3 Blast Furnace	Not listed	None
ArcelorMittal Cleveland	Blast Furnace C5 Blast Furnace C6	Natural gas Blast furnace gas	None
U. S. Steel Edgar Thompson	Blast Furnace No. 1 Stoves Blast Furnace No. 3 Stoves	Blast furnace gas Coke oven gas Natural gas	None
Nucor St. James(2) (2010 Nucor BACT)	Blast Furnace 1 Blast Furnace 2	Natural gas Blast furnace gas	Low sulfur fuels

(1) AK Steel Dearborn (RBLCID = MI-0413) underwent SO_2 BACT in 2014 and concluded that BACT did not require additional SO_2 emission control measures.
(2) The emission units at Nucor St. James have not been constructed.

The 2010 Nucor BACT determined that other than the low-sulfur fuels (blast furnace gas and natural gas), no additional add-on SO_2 emission control measures are technically feasible.

There are no additional SO_2 emission control measures based on the 2010 Nucor BACT, emission control measures described in the RBLC (Appendix A) and air permits for similar sources (Appendix B). As such, the No. 14 Blast Furnace Stoves have no reasonable set of SO_2 emission control measures. Furthermore, the existing SO_2 emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT and, therefore, are considered effective emission controls.

4.2.1.2 No. 14 Blast Furnace Casthouse

As described in Section 2.2.2, there are no existing SO_2 emission control measures associated with the No. 14 Blast Furnace Casthouse. Table 4-4 presents SO_2 emission control measures for blast furnace casthouses at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 4-4 Blast Furnace Casthouse SO_2 Emission Control Measures at Similar Sources

Facility	Emission Unit Description	SO_2 Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	No. 7 Blast Furnace Casthouse	None
ArcelorMittal Indiana Harbor West	No. 3 Blast Furnace Casthouse	None
	No. 4 Blast Furnace Casthouse	
ArcelorMittal Burns Harbor	C Blast Furnace East and West Casthouses	None
	D Blast Furnace East and West Casthouses	
AK Steel Dearborn	EUBFURNACE Casthouses	None
	EUCFURNACE Casthouses	
AK Steel Middletown	No. 3 Blast Furnace Casthouse	None
ArcelorMittal Cleveland	Blast Furnace C5 Casthouse	None
	Blast Furnace C6 Casthouse	
U. S. Steel Edgar Thompson	Blast Furnace No. 1 Casthouse	None
	Blast Furnace No. 3 Casthouse	
Nucor St. James(1) (2010 Nucor BACT)	Casthouse No. 1	None
	Casthouse No. 2	

(1) The emission units at Nucor St. James have not been constructed.

There are no additional SO_2 emission control measures based on the 2010 Nucor BACT, emission control measures described in the RBLC (Appendix A) and air permits for similar sources (Appendix B). As such, the No. 14 Blast Furnace Casthouse has no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units. Furthermore, the existing SO_2 emission control measures are equivalent to those determined to be BACT in the 2010 Nucor BACT and, therefore, are considered effective emission controls.

4.2.2 Baseline Emission Rates

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not necessary to represent a projected 2028 emissions scenario.

4.2.3 Factor 1 – Cost of Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to estimate the cost of compliance for additional SO_2 emission control measures. Even in the circumstance where there was an emission control measure identified as part of the reasonable set, the associated emission control measure's cost-effectiveness would not be reasonable because the emission reduction technology would not impact visibility at the associated Class I areas (see Section 6).

4.2.4 Factor 2 – Time Necessary for Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the time that is necessary to achieve compliance for additional SO_2 emission control measures.

4.2.5 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the energy and non-air quality environmental impacts for additional SO_2 emission control measures.

4.2.6 Factor 4 – Remaining Useful Life of the Source

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the remaining useful life of the source.

4.2.7 Visibility Benefits

Since the four-factor analysis concluded the No. 14 Blast Furnace Stoves and Casthouse have no reasonable set of SO_2 emission control measures beyond what is currently installed and operated for these emission units, it is not appropriate to describe the potential visibility benefits for additional SO_2 emission control measures. However, as described in Section 6, additional SO_2 emission reductions are not appropriate and are unnecessary for Gary Works because:

1. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
2. The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
3. Any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).
4. The Casthouse's emissions are fugitive in nature (e.g., low-lying, low-velocity source) and would not impair visibility at the associated Class I areas (greater than 500 km away from Gary Works).

4.2.8 Proposed SO_2 Emission Control Measures

The four-factor analysis with visibility benefits evaluation concluded that additional SO_2 emission control measures at the No. 14 Blast Furnace Stoves and Casthouse beyond those described in Section 2.2.1 are not required to make reasonable progress in reducing SO_2 emissions. As such, Gary Works proposes to maintain the existing SO_2 emission control measures.

5 84” Hot Strip Mill Reheat Furnaces and Waste Heat Boilers

The following sections describe the four-factor analysis with visibility benefits evaluation for NO_X emission control measures (Section 5.1), the 2028 projected baseline NO_X emission rates (Section 5.1.2), the evaluation factors (Sections 5.1.3 through 5.1.7), and the proposed emission control measures (Section 5.1.7) for the 84” Hot Strip Mill Reheat Furnaces and Waste Heat Boilers.

5.1 Four-Factor Analysis - NO_X

5.1.1 NO_X Emission Control Measures

As described in Section 2.2.3, the 84” Hot Strip Mill Reheat Furnaces and Waste Heat Boilers conform to good combustion practices and operate ZoloSCAN on the Reheat Furnaces as existing NO_X emission control measures. Table 5-1 presents NO_X emission control measures for reheat furnaces and waste heat boilers at similar sources, as represented in the RBLC (Appendix A) and their respective air permits (Appendix B).

Table 5-1 Reheat Furnaces and Waste Heat Boilers NO_X Emission Control Measures at Similar Sources

Facility	Emission Unit Description	Allowed Fuels	NO_X Emission Control Measure(s)
ArcelorMittal Indiana Harbor East	No. 4 Walking Beam Furnace	Natural gas	LNB
	No. 5 Walking Beam Furnace	Natural gas	None
	No. 6 Walking Beam Furnace	Natural gas	None
ArcelorMittal Indiana Harbor West	No. 1 Reheat Furnace	Natural gas	None
	No. 2 Reheat Furnace		
	No. 3 Reheat Furnace		
ArcelorMittal Burns Harbor	Reheat Furnace No. 1	Natural gas Coke oven gas Propane	None
	Reheat Furnace No. 2		
	Reheat Furnace No. 3		
	HSM WBF No. 1	Natural gas	LNB
	HSM WBF No. 2		
AK Steel Dearborn	EUREHEATFURN1	Not listed	None
	EUREHEATFURN2		
	EUREHEATFURN3		

Facility	Emission Unit Description	Allowed Fuels	NO_X Emission Control Measure(s)
AK Steel Middletown	No. 1 Slab Reheat Furnace/Waste Heat Boiler	Natural gas Fuel oil Coke oven gas	None
	No. 2 Slab Reheat Furnace/Waste Heat Boiler		
	No. 3 Slab Reheat Furnace/Waste Heat Boiler		
	No. 4 Slab Reheat Furnace/Waste Heat Boiler		
ArcelorMittal Cleveland	80" Hot Strip Mill Reheat Furnaces 1, 2, 3	Natural gas Fuel oil	LNB
	Walking Beam Furnace	Natural gas	None

LNB reduces NO_X emissions by decreasing the burner flame temperature from staging either the combustion air or fuel injection rates into the burner. Gary Works identified LNB to be part of the reasonable set of NO_X emission control measures for the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers based on the emission control measures described in the RBLC (Appendix A) and the air permits for similar sources (Appendix B).

The RBLC search (Appendix A) identified two instances of Selective Catalytic Reduction (SCR)[19] for NO_X emission control; A reheat furnace at Thyssenkrupp Steel and Stainless USA, LLC (RBLC ID: AL-0230) and a combined stack with six waste heat boilers and six rotary hearth furnaces at New Steel International, Inc., Haverhill (RBLC ID: OH-0315). The Thyssenkrupp Steel and Stainless USA, LLC (RBLC ID: AL-0230) RBLC entry included an associated note stating: "This covers NO_X for the nitric & hydrofluoric acid pickling with caustic scrubber & DE-NO_X SCR (LA29)." Therefore, it was assumed that the operations are materially different and are not comparable to Gary Works. The New Steel International, Inc., Haverhill (RBLC ID: OH-0315) facility was never constructed and, as such, SCR has not been installed and successfully operated on a similar source under similar physical and operating conditions. Therefore, SCR is not part of a reasonable set of NO_X emission control measures for the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers.

LNB for the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers is evaluated as a NO_X emission control measure in Sections 5.1.3 through 5.1.6.

5.1.2 Baseline Emission Rates

The four-factor analysis requires the establishment of a baseline scenario for evaluating a potential emission control measure. At page 29 of the 2019 RH SIP Guidance in the section entitled "Baseline

[19] SCR reduces NO_X emissions with ammonia or urea injection in the presence of a catalyst.

control scenario for the analysis," excerpted below, EPA considers the projected 2028 emissions scenario as a "reasonable and convenient choice" for the baseline control scenario:

> *"Typically, a state will not consider the total air pollution control costs being incurred by a source or the overall visibility conditions that would result after applying a control measure to a source but would rather consider the incremental cost and the change in visibility associated with the measure relative to a baseline control scenario. The projected 2028 (or the current) scenario can be a reasonable and convenient choice for use as the baseline control scenario for measuring the incremental effects of potential reasonable progress control measures on emissions, costs, visibility, and other factors. A state may choose a different emission control scenario as the analytical baseline scenario. Generally, the estimate of a source's 2028 emissions is based at least in part on information on the source's operation and emissions during a representative historical period. However, there may be circumstances under which it is reasonable to project that 2028 operations will differ significantly from historical emissions. Enforceable requirements are one reasonable basis for projecting a change in operating parameters and thus emissions; energy efficiency, renewable energy, or other such programs where there is a documented commitment to participate and a verifiable basis for quantifying any change in future emissions due to operational changes may be another. A state considering using assumptions about future operating parameters that are significantly different than historical operating parameters should consult with its EPA Regional office."*

Based on EPA guidance, the estimate of a source's 2028 emissions is based, at least in part, on information on the source's operation and emissions during a representative historical period. For the purpose of the four-factor analysis, Gary Works considered the representative historical period to be 2016-2019 and conservatively selected the maximum annual emissions within the associated four-year period to represent projected 2028 baseline emissions. The estimated 2028 baseline NO_X emissions are shown in Table 5-2.

Table 5-2 Estimated 2028 Baseline NO_X Emissions for the Identified Emission Units

Unit	2028 Projected Baseline Natural Gas Throughput Assumption (MMscf/year)	Natural Gas NO_X Emission Factor[(1)] (lb/MMBtu)	Estimated 2028 NO_X Emissions (tons/year)
Reheat Furnace No. 1	9,960	275	1,293
Reheat Furnace No. 2			
Reheat Furnace No. 3			
Reheat Furnace No. 4			
Waste Heat Boiler No. 1	651	275	89
Waste Heat Boiler No. 2	623	275	86

(1) AP-42 Section 1.4; Table 1.4-1; July 1998

5.1.3 Factor 1 – Cost of Compliance

Gary Works completed cost estimates for LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers. Due to the limited time available in responding to IDEM's request, a source-specific technical feasibility study and preliminary engineering design were not conducted. The cost of compliance analysis is based on information provided by a vendor regarding burner performance and equipment costs. The installation costs were estimated by Gary Works' engineering staff and are based on experience with projects of similar scope. The capital cost estimates are considered by Gary Works' engineering staff, based on their considerable experience with projects at Gary Works and in the industry, to be conservatively low. Cost summary spreadsheets for LNB installation on the 84" Hot Strip Mill Reheat Furnaces No. 1 through No. 4, Waste Heat Boiler No. 1, and Waste Heat Boiler No. 2 are provided in Appendix C.1, C.2, and C.3, respectively.

The cost-effectiveness analysis compares the annualized cost of the emission control measure per ton of pollutant removed and is evaluated on dollar per ton basis using the annual cost (annualized capital cost plus annual operating costs) divided by the annual emissions reduction (tons) achieved by the control device. For purposes of this screening evaluation and consistent with the typical approach described in the EPA Control Cost Manual[20], a 20-year life (before new and extensive capital is needed to maintain and repair the equipment) at 5.5% interest is assumed in annualizing capital costs.

The resulting cost-effectiveness calculations are summarized in Table 5-3.

Table 5-3 LNB Control Cost Summary, per Unit Basis

Emission Unit	Total Annualized Costs ($/yr)	Annual Emissions Reduction (tpy)	Pollution Control Cost Effectiveness ($/ton)
84" Hot Strip Mill Reheat Furnaces No. 1 through No. 4	$2,978,000	211	$14,100
Waste Heat Boiler No. 1	$355,000	58	$6,100
Waste Heat Boiler No. 2	$355,000	56	$6,300

Based on the cost effectiveness values, LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers are not cost-effective. Independent of the cost-effectiveness evaluation, installation of LNBs on the associated units is not justifiable because the emission control measures would not appreciably improve visibility at the associated Class I areas.

[20] US EPA, "EPA Air Pollution Control Cost Manual, Sixth Edition," January 2002, EPA/452/B-02-001. The EPA has updated certain sections and chapters of the manual since January 2002. These individual sections and chapters may be accessed at https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-reports-and-guidance-air-pollution as of the date of this report., page 2-26

Sections 5.1.4 through 5.1.6 provide a summary of the remaining three factors evaluated for the NO_X emission control measures, understanding that these projects represent substantial capital investments that are not justified on a cost per ton or absolute cost basis.

5.1.4 Factor 2 – Time Necessary for Compliance

The amount of time needed for full implementation of the emission control measure or measures varies. Typically, time for compliance includes the time needed to develop and approve the new emissions limit into the SIP by state and federal action, time for IDEM to issue Gary Works a significant source modification permit, then time for Gary Works to engineer, fund, install, commission, and test the project necessary to meet the SIP limit.

The technologies would require significant resources and time of at least two to three years to engineer, permit, and install the equipment. However, prior to beginning this process, the SIP must first be submitted by IDEM in July 2021 and then approved by EPA, which is anticipated to occur within 12 to 18 months after submittal (approximately 2022 to 2023). Thus, the installation date would occur between 2024 and 2026.

5.1.5 Factor 3 – Energy and Non-Air Quality Environmental Impacts of Compliance

LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers will result in a small decrease in thermal efficiency due to lower flame temperatures. However, the energy and non-air quality environmental impacts associated with the implementation of LNB are negligible for this analysis.

5.1.6 Factor 4 – Remaining Useful Life of the Source

Because Gary Works is assumed to continue operations for the foreseeable future, the useful life of the individual emission control measures (assumed 20-year life, per Section 2.1.1.5) is used to calculate emission reductions, amortized costs and cost-effectiveness on a dollar per ton basis.

5.1.7 Visibility Benefits

LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers is not appropriate and unnecessary because:

1. The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
2. The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and
3. LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers do not justify the associated cost, as described in Section 5.1.3, because the emission control measure will not appreciably improve visibility in these Class I areas.

5.1.8 Proposed NO_X Emission Control Measures

Based on the analysis conducted in Sections 5.1.3 through 5.1.7, Gary Works has determined that installation of additional NO_X emissions measures at the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers beyond those described in Section 2.2.3 are not required to make reasonable progress in reducing NO_X emissions. As such, Gary Works proposes to maintain the existing NO_X emission control measures.

6 Visibility Impacts Review

Section 6.1 describes the current visibility conditions compared to the 2028 URP and whether emission reductions are necessary to have the 2028 visibility conditions below the 2028 URP. Section 6.2 presents a more complex surrogate analysis for visibility impacts which considers the air trajectories prior to the most impaired visibility days rather than only considering emission rates (Q) and distances (d). The analysis provides the frequency when emissions from Gary Works may have been a contributor to the haze on the selected most impaired days.

6.1 Analysis of Ambient Data

The RHR requires that the SIP include an analysis of "baseline, current, and natural visibility conditions; progress to date; and the uniform rate of progress."[21] The SIP "must consider the uniform rate of improvement in visibility and the emission-reduction measures needed to achieve it for the period covered by the implementation plan."[22]

An analysis of current visibility conditions was completed at the three Class I areas closest to Gary Work's facility (Mammoth Cave, Mingo, and Seney) to determine the current status compared to the natural visibility goal, the 2028 URP, and to the possible reasonable progress goals for the SIP for the second implementation period, which ends in 2028.

Visibility monitoring data was obtained from the IMPROVE monitors at Mammoth Cave (MACA1), Mingo (MING1), and Seney (SENE1).[23] The data was compared to the RHR visibility metric, which is based on the rolling 5-year average of the 20% most anthropogenically impaired days and the 20% clearest days, with visibility being measured in deciviews (dv).

Figure 6-1 through Figure 6-3 show the rolling 5-year average visibility impairment versus the 2028 URP glidepath[24] at Mammoth Cave (MACA1), Mingo (MING1), and Seney (SENE1), respectively. This data illustrates that regional haze impairment at these three Class I areas has been declining (i.e., visibility has been improving) since 2007 for both Seney and Mingo, and 2008 for Mammoth Cave. The trends in visibility impairment fell below the expected 2028 URP goal in 2017 for Seney and Mammoth Cave, and was 0.6 dv from the 2028 goal for Mingo in 2018. All of the data demonstrates that visibility continues to improve in each of these Class I areas.

---

[21] 40 CFR 51.308(f)(1)

[22] 40 CFR 51.308(d)(1)

[23] http://vista.cira.colostate.edu/Improve/improve-data/

[24] https://public.tableau.com/profile/mpca.data.services#!/vizhome/RegionalHaze_visibility_metrics_public/Visibilityprogress

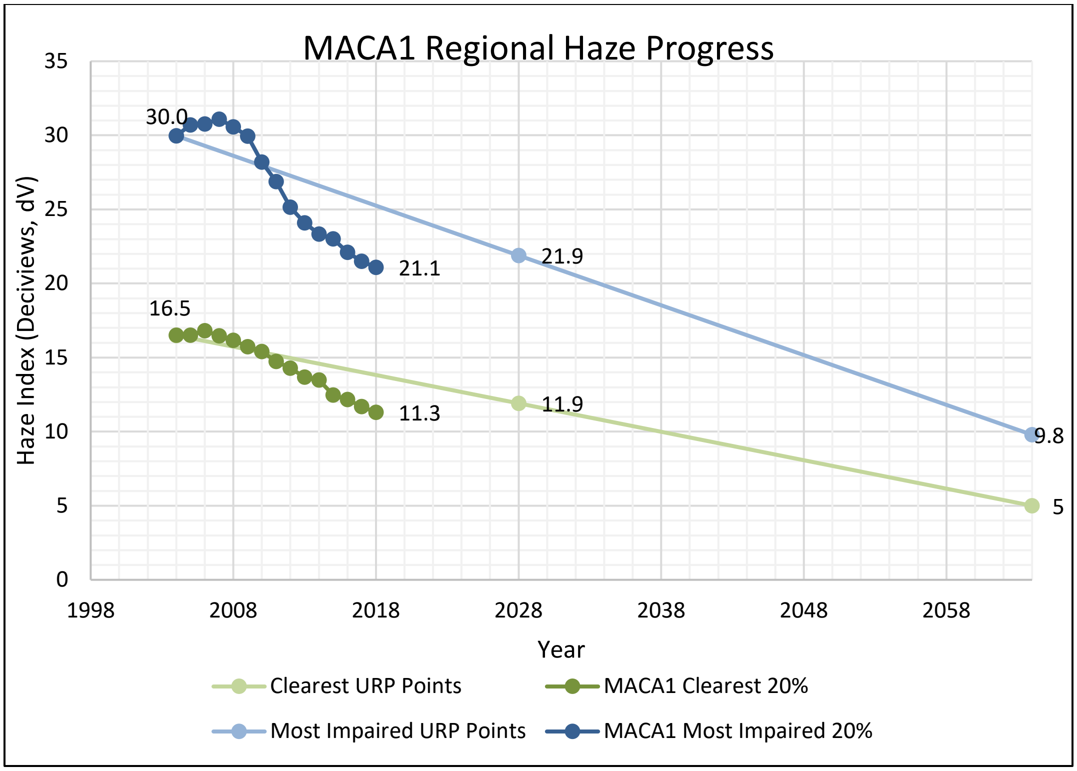

Figure 6-1 Visibility Trend versus 2028 URP – Mammoth Cave National Park (MACA1)

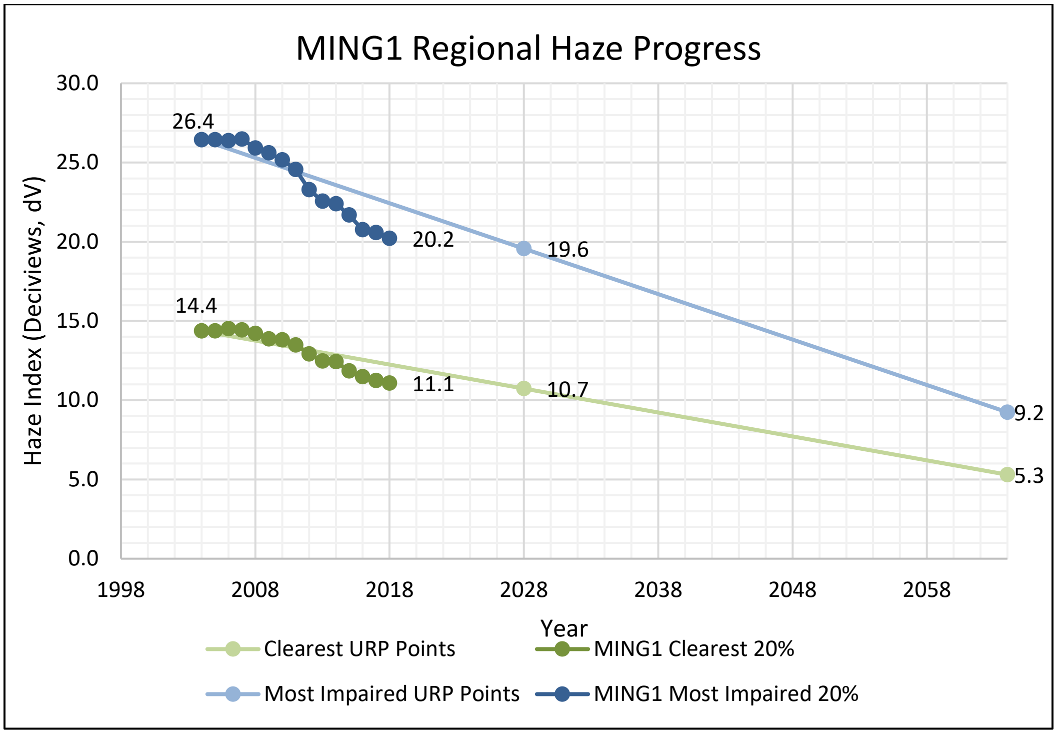

Figure 6-2 Visibility Trend versus 2028 URP – Mingo National Wildlife Refuge (MING1)

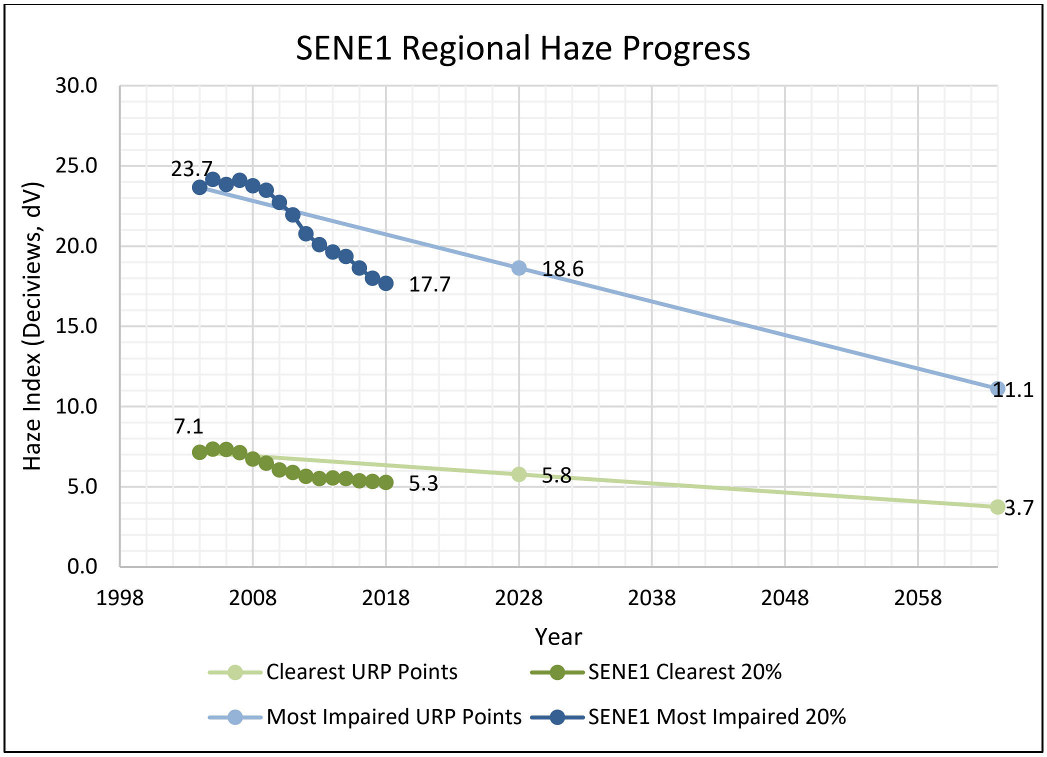

Figure 6-3 Visibility Trend versus 2028 URP – Seney National Wildlife Refuge (SENE1)

The downward visibility trend for each of the Class I monitors described above can be attributed to the reductions across various regional sources. These reductions are a result of a number of different actions taken to reduce emissions from several sources, including:

- Installation of BART during the first RHR implementation period
- Emission reductions from a variety of industries due to updated rules and regulations
- Transition of power generation systems from coal to natural gas and renewables (wind and solar)
- NO_X and SO_2 emission reductions from mobile sources due to numerous federal regulatory programs (e.g., increased fuel economy and low sulfur fuels standards)

The IMPROVE monitoring network data demonstrates sustained progress towards visibility goals and the 5-year average visibility impairment on the most impaired days is already below the 2028 URP at two of the Class I areas which were considered (Mammoth Cave and Seney). In addition, the 5-year visibility impairment at the third Class I area (Mingo) is only slightly above the 2028 URP (20.2 dV observed versus 19.6 dV for the 2028 URP) and has been trending downward since 2007. Furthermore, the 2019 RH SIP Guidance states that "visibility impacts and/or potential benefits may be considered in the source selection step in order to prioritize the examination of certain sources for further analysis of emission control measures."[25] Since the 5-year average visibility impairment on the most impaired days is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP, it is not necessary for Gary Works to install additional emission control measures to make reasonable progress at these Class I areas.

6.2 Visibility Impacts

A reverse particle trajectory analysis was completed from the three Class I areas closest to Gary Works (Mammoth Cave, Mingo, and Seney) to determine visibility impacts from Gary Works. These analyses were used to determine how emissions from Gary Works could impact visibility in Class I areas on the most impaired days. These analyses could also be used to determine if emission reductions at Gary Works could result in visibility improvement on the most impaired days at these Class I areas.

A trajectory analysis considers the transport path of a particular air mass and the associated particles within the air mass to see if the air mass traveled over certain locations. A reverse trajectory analysis was performed beginning at each Class I area for the calculated most impaired days during 2017-2018. The impairment metric (dv) from the IMPROVE Aerosol RHR III dataset[26] was used to calculate the 20% most impaired days for 2017 and 2018. The NOAA Hysplit model[27] was used to calculate 48-hour reverse trajectories beginning at 6:00 PM at a height of 10m from each Class I area on the day from the calculated 20% most impaired days ("the most impaired trajectories"). This methodology was modeled after the Minnesota Pollution Control Agency's trajectory analysis for their Class I areas.[28] The trajectories that cross near Gary Works are shown in Figure 6-4 and all of the most impaired trajectories in 2017 and 2018 for each Class I area is shown in Figure 6-5 through Figure 6-7.

The analysis considered the 20% most impaired trajectories for each Class 1 area based on 2017 and 2018 IMPROVE data. As shown in Figure 6-4, just 2.5% of the most impaired trajectories cross near Gary Works out of a total of 137 most impaired days. In addition, Figure 6-5 through Figure 6-7 illustrate that the majority of the most impaired trajectories are not traveling from the general direction of Gary Works. Furthermore, most of the 48-hour reverse trajectories end before reaching the Gary Works facility location, indicating that the nearest Class I areas are at a distance far enough away from the facility and

---

[25] USEPA, Guidance on Regional Haze State Implementation Plans for the Second Implementation Period, 08/20/2019, Page 34.

[26] Malm, W. C., J. F. Sisler, D. Huffman, R. A. Eldred, and T. A. Cahill (1994), Spatial and seasonal trends in particle concentration and optical extinction in the United States, J. Geophys. Res., 99, 1347-1370. http://views.cira.colostate.edu/fed/SiteBrowser/Default.aspx

[27] Stein, A.F., Draxler, R.R, Rolph, G.D., Stunder, B.J.B., Cohen, M.D., and Ngan, F., (2015). NOAA's HYSPLIT atmospheric transport and dispersion modeling system, Bull. Amer. Meteor. Soc., 96, 2059-2077, http://dx.doi.org/10.1175/BAMS-D-14-00110.1

[28] MPCA – Regional Haze Tableau Public. https://public.tableau.com/profile/mpca.data.services#!/vizhome/RegionalHaze_visibility_metrics_public/Visibilityprogress

therefore visibility impairment from the Gary Works facility is unlikely. This information generally demonstrates sources from other regions, and not Gary Works, are contributing to the visibility on the most impaired days at the monitors. For example, the emissions are likely coming from other metropolitan areas such as Louisville, St. Louis, Indianapolis, Columbus, Cincinnati, and Nashville. As such, the installation of additional emission control measures at Gary Works would not improve visibility in these Class I areas.

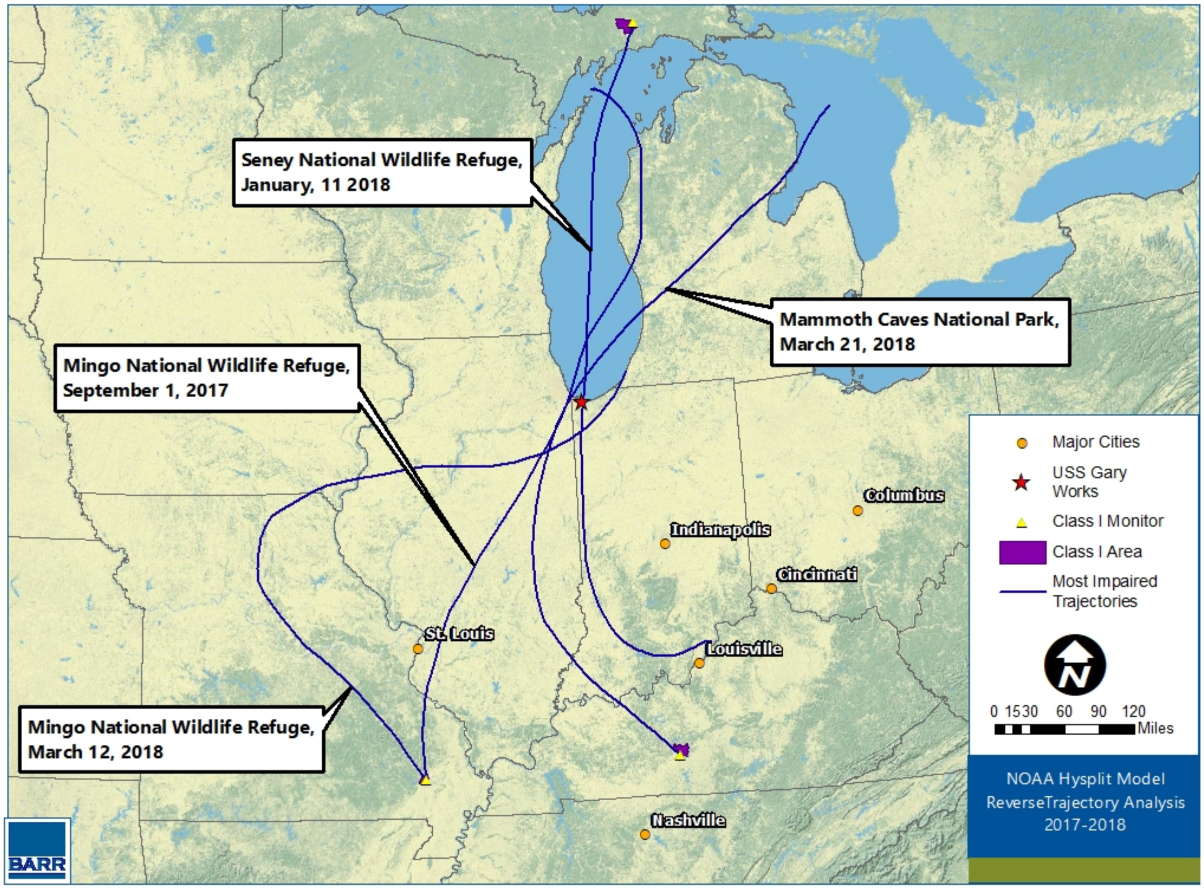

Figure 6-4 Mammoth Cave, Mingo, and Seney: The Most Impaired Trajectories that Cross Near Gary Works from for 2017-2018 (4 out of 150)

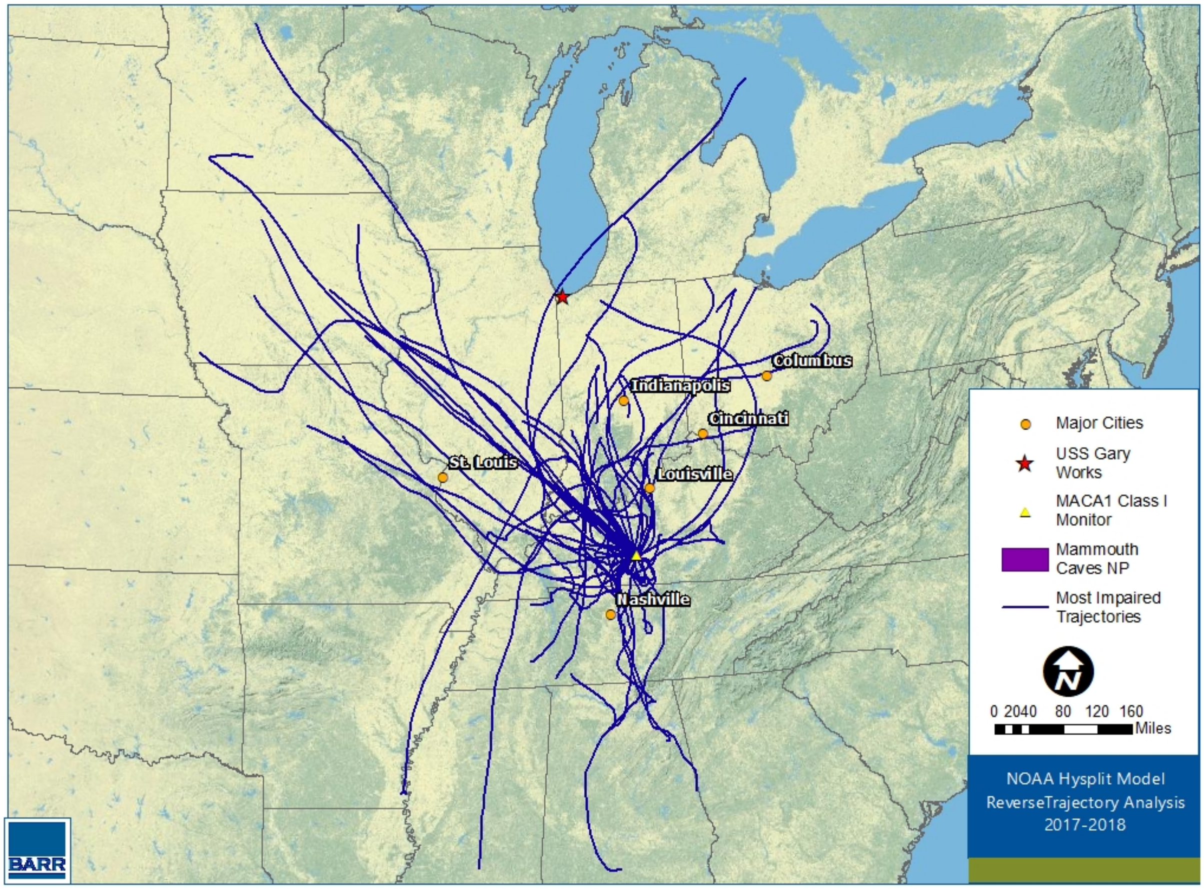

Figure 6-5 Mammoth Cave National Park: Most Impaired Trajectories for 2017-2018 from Reverse Trajectory Analysis (1 out of 50)

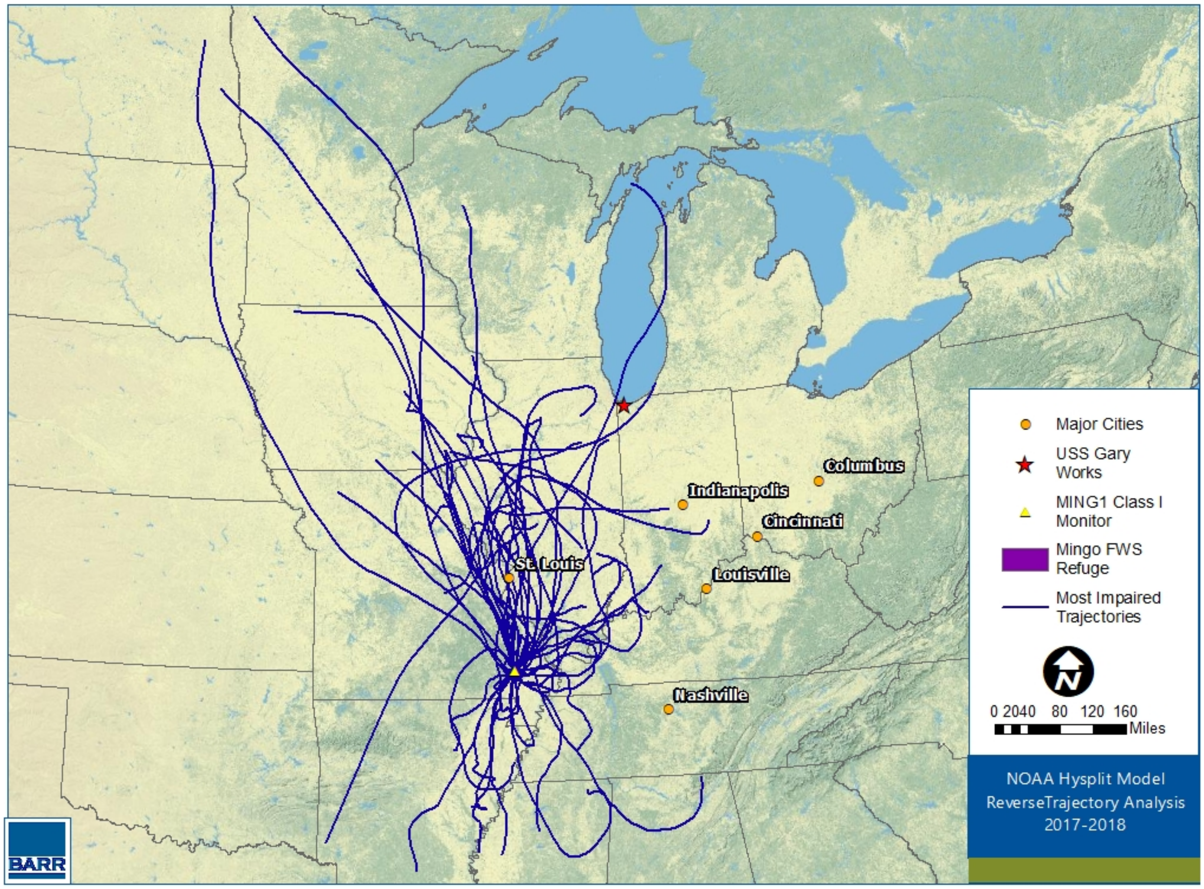

Figure 6-6 Mingo National Wildlife Refuge: Most Impaired Trajectories for 2017-2018 from Reverse Trajectory Analysis (2 out of 50)

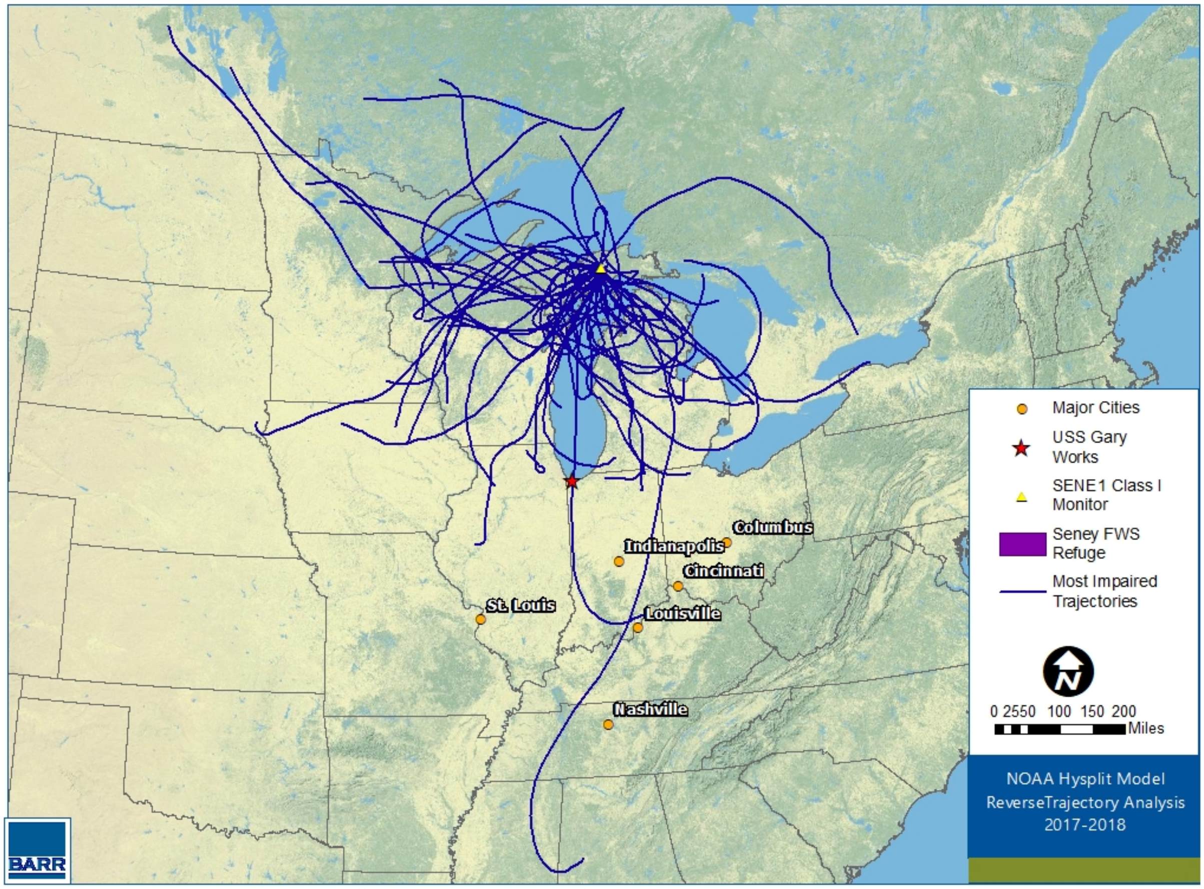

Figure 6-7 Seney National Wildlife Refuge: Most Impaired Trajectories for 2017-2018 from Reverse Trajectory Analysis (1 out of 50)

7 Conclusion

As described in Section 3 and Section 4, the No. 3 Sinter Plant Sinter Strands and No. 14 Blast Furnace (Stoves and Casthouse) four-factor analyses with visibility benefits evaluations concluded that:

- There is no reasonable set of NO_X and SO_2 emission control measures beyond what is currently installed and operated for these emission units (see Sections 3.1.1, 3.2.1, 4.1.1, and 4.2.1).
- The existing emission control measures are equivalent to those determined to be BACT in a recent BACT analysis and, therefore, are considered effective emission controls (see Sections 3.1.1, 3.2.1, 4.1.1, and 4.2.1).
- Additional NO_X and SO_2 emission reductions are not appropriate and are unnecessary for these sources because:
    - The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
    - The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors and, therefore, any installation of additional emission control measures at Gary Works will not appreciably improve visibility in these Class I areas (see Section 6.2).
- Therefore, the No. 3 Sinter Plant Sinter Strands and No. 14 Blast Furnace (Stoves and Casthouse) existing NO_X and SO_2 emission performance are sufficient for the IDEM's regional haze reasonable progress goal (see Sections 3.1.8, 3.2.8, 4.1.8, and 4.2.8).

As described in Section 5, the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers NO_X four-factor analysis with visibility benefits evaluation concluded that:

- The reasonable set of NO_X emission control measures beyond what is currently installed and operated for these emission units consists of LNB (see Section 5.1.1).
- LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers are not cost-effective, based on the associated cost-effectiveness values ($ per ton of emissions reduction). Furthermore, the additional capital and operating costs may negatively impact Gary's ability to compete in the economic market (see Section 5.1.3).
- Independent of the cost-effectiveness evaluation, which alone indicates that no additional emission control measures are necessary and appropriate, the additional NO_X emission control measures and their associated NO_X emission reductions are also not necessary and appropriate for Gary Works because:
    - The 5-year average visibility impairment on the most impaired days at the associated Class I areas of interest is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP (see Section 6.1),
    - The trajectory analysis demonstrates that Gary Works does not appreciably contribute to visibility impairment to the Class I areas on the most impaired days at the monitors (see Section 6.2), and

    - Thus, the NO_x emission reduction associated with LNB installation on the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers does not justify the associated cost, as described in Section 5.1.3, because the emission control measure will not appreciably improve visibility in these Class I areas (see Section 5.1.7).
- Therefore, the 84" Hot Strip Mill Reheat Furnaces and Waste Heat Boilers existing NO_X emission performance are appropriate and sufficient for the IDEM's regional haze reasonable progress goal (see Section 5.1.8).

In addition to the four statutory factors, this analysis also considered the current visibility and the potential visibility benefits from installing additional emission control measures on the associated sources at the facility. An analysis of current visibility conditions was completed at the three Class I areas closest to Gary Work's facility (~500-570 km away): Mammoth Cave in Kentucky, Seney in northern Michigan and Mingo in Missouri. As shown in Section 6.1, the 5-year average visibility impairment on the most impaired days is already below (Mammoth Cave and Seney), or trending towards (Mingo), the 2028 URP. Thus, it is not necessary for Gary Works to install additional emission control measures to make reasonable progress at these distant Class I areas and, as shown below, any reductions in emissions at Gary Works will not appreciably improve visibility in these Class I areas.

Furthermore, a reverse particle trajectory analysis was completed from these same Class I areas (Mammoth Cave, Mingo, and Seney) to determine how emissions from Gary Works could impact visibility in Class I areas on the 20% most impaired days. As shown in Section 6.1, the majority (97.5%) of the most impaired trajectories are not traveling from the general direction of Gary Works. Furthermore, most of the 48-hour reverse trajectories end before reaching the Gary Works facility location, indicating that the nearest Class I areas are at a distance far enough away from the facility, and therefore Gary Works is not reasonably expected to contribute to visibility impairment of the Class I areas. As such, the installation of additional emission control measures at Gary Works would not improve visibility in these Class I areas on the most impaired days.

Lastly, additional emission control measures could impact the economic viability of the company to continue to operate in competitive economic markets. Gary Works, as well as the entire integrated iron and steel mill industry, is highly sensitive to incremental capital and operating costs due to substantial fluctuation in global economic markets. Considering the current visibility progress and that Gary Works does not appreciably contribute to visibility impairment at the pertinent Class I areas, any additional emission control measures that would be a substantial barrier for the facility to continue to operate would be unreasonable and inappropriate.