UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

NOV 17 2016

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: Draft $PM_{2.5}$ Precursor Demonstration Guidance

FROM: Stephen D. Page, Director
Office of Air Quality Planning and Standards

TO: Regional Air Division Directors, Regions 1 – 10

The Environmental Protection Agency (EPA) is providing a draft version of "$PM_{2.5}$ Precursor Demonstration Guidance" to state, local and tribal air agencies, as well as the public, for consideration, review, and comment. This document reflects the EPA's recommendations to assist air agencies to develop and submit optional $PM_{2.5}$ precursor demonstrations as permitted by the recently finalized $PM_{2.5}$ State Implementation Plan (SIP) Requirements Rule ($PM_{2.5}$ SIP Requirements Rule) (81 FR 58010).

The $PM_{2.5}$ SIP Requirements Rule contains details on planning requirements that apply to areas designated nonattainment for any $PM_{2.5}$ NAAQS. The rule addresses the statutory SIP requirements for state, local and tribal air agencies, such as: general requirements for attainment plan due dates and attainment dates; emissions inventories; attainment demonstrations; provisions for demonstrating reasonable further progress (RFP); quantitative milestones; contingency measures; and nonattainment New Source Review (NNSR) permitting programs.

The $PM_{2.5}$ SIP Requirements Rule identifies the $PM_{2.5}$ precursor pollutants that must be evaluated in the development of all $PM_{2.5}$ nonattainment area SIPs (SO_2, NO_x, VOC and ammonia). The rule requires that all $PM_{2.5}$ precursors be evaluated for potential control measures in any $PM_{2.5}$ attainment plan or any NNSR program. However, the rule permits air agencies to submit an optional precursor demonstration designed to show that for a specific $PM_{2.5}$ nonattainment area, emissions of a particular precursor from sources within the nonattainment area do not or would not contribute significantly to $PM_{2.5}$ levels that exceed the standard in the area. If the EPA approves the demonstration, the attainment plan or NNSR program for a particular $PM_{2.5}$ nonattainment area may exclude that precursor from certain control requirements under the Clean Air Act, depending on the type of demonstration provided.

This guidance is designed to assist air agencies who may wish to submit $PM_{2.5}$ precursor demonstrations as permitted by the $PM_{2.5}$ SIP Requirements Rule. This guidance is intended for use by air agencies; the EPA Headquarters and Regional offices; and the public. This document does not substitute for provisions or regulations of the Clean Air Act, nor is it a regulation itself. As the term "guidance" suggests, it provides recommendations or guidelines, as authorized under the Clean Air Act, that will be useful to air agencies in developing the precursor demonstrations by which the EPA can ultimately determine whether sources of a particular precursor contribute significantly to $PM_{2.5}$ levels that exceed the standard in a particular nonattainment area. Thus, it does not impose binding, enforceable

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requirements on any party, nor does it assure that the EPA will approve a precursor demonstration in all instances where the guidance is followed, as the guidance may not apply to a particular situation based upon the circumstances of a particular nonattainment area.

REVIEW AND COMMENT

The EPA will accept comments on the draft $PM_{2.5}$ Precursor Demonstration Guidance submitted by January 31, 2017. Comments should be electronically submitted to Brian Timin of EPA's Air Quality Assessment Division at *timin.brian@epa.gov* or Patrick Lessard of the Air Quality Policy Division at *lessard.patrick@epa.gov*. The draft guidance document is available electronically on the EPA's website: https://www.epa.gov/pm-pollution/implementation-national-ambient-air-quality-standards-naaqs-fine-particulate-matter#additional-resources.

Please distribute to air agencies in your Region. If you have any questions concerning this document, please contact Brian Timin at (919) 541-1850 or *timin.brian@epa.gov* or Patrick Lessard at (919) 541-5383 or *lessard.patrick@epa.gov*.

Attachment

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

$PM_{2.5}$ Precursor Demonstration Guidance

EPA-454/P-16-001
November 2016

$PM_{2.5}$ Precursor Demonstration Guidance

U.S. Environmental Protection Agency
Office of Air Quality Planning and Standards
Air Quality Assessment Division and Air Quality Policy Division
Research Triangle Park, NC

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Acronyms Used in this Guidance

BACT	Best Available Control Technology
CAA	Clean Air Act
CAMx	Comprehensive Air Quality Model with Extensions
CI	Confidence Interval
CMAQ	Community Multiscale Air Quality model
CSN	Chemical Speciation Network
CTM	Chemical transport model
DDM	Direct Decoupled Method
DV	Design Value
EC	Elemental carbon
EGU	Electric Generating Units
EPA	Environmental Protection Agency
FEM	Federal Equivalent Method
FRM	Federal Reference Method
IMPROVE	Interagency Monitoring of Protected Visual Environments
Km	Kilometer
LAER	Lowest Achievable Emissions Rate
NAAQS	National ambient air quality standards
NNSR	Nonattainment New Source Review
NOx	Oxides of nitrogen
NSR	New Source Review
OM	Organic matter
PM	Particulate matter
PM_{10}	Particulate matter with diameter 10 microns or less
$PM_{2.5}$	Particulate matter with diameter 2.5 microns or less
PSD	Prevention of Significant Deterioration
RACM	Reasonably Available Control Measures
RACT	Reasonably Available Control Technology
RFP	Reasonable Further Progress
RRF	Relative response factor
SANDWICH	Sulfate, adjusted nitrate, derived water, inferred carbonaceous balance
SIL	Significant Impact Levels
SIP	State Implementation Plan
SMAT	Software for the Modeled Attainment Test
SOA	Secondary Organic Aerosol
SO_2	Sulfur dioxide
VOC	Volatile Organic Compound

1.0 Introduction

The Environmental Protection Agency (EPA) has finalized a fine particulate matter ($PM_{2.5}$) State Implementation Plan (SIP) Requirements Rule[1] ($PM_{2.5}$ SIP Requirements Rule), which contains details on planning requirements that apply to areas designated nonattainment for any $PM_{2.5}$ national ambient air quality standards (NAAQS). The rule addresses the statutory SIP requirements for state, local and tribal air agencies, (hereafter known as "air agencies"), such as: general requirements for attainment plan due dates and attainment dates; emissions inventories; attainment demonstrations; provisions for demonstrating reasonable further progress (RFP); quantitative milestones; contingency measures; and nonattainment New Source Review (NNSR) permitting programs.

The $PM_{2.5}$ SIP Requirements Rule identifies the $PM_{2.5}$ precursor pollutants that apply to all $PM_{2.5}$ nonattainment area SIPs (sulfur dioxide (SO_2); oxides of nitrogen (NO_x); volatile organic compounds (VOC); and ammonia (NH_3)). The rule establishes that $PM_{2.5}$ precursors must be evaluated for potential control measures in any $PM_{2.5}$ attainment plan or any NNSR program. The rule does not include any national presumption that excludes sources of emissions of a particular precursor from further analysis for attainment plan or NNSR control requirements in a $PM_{2.5}$ nonattainment area. However, the rule indicates that air agencies may choose to submit an optional precursor demonstration designed to show that for a specific $PM_{2.5}$ nonattainment area, emissions of a particular precursor from sources within the nonattainment area do not or would not contribute significantly to $PM_{2.5}$ levels that exceed the standard. If the EPA approves the demonstration, the attainment plan for a particular $PM_{2.5}$ nonattainment area may exclude that precursor from certain control requirements under the Clean Air Act (CAA or Act) (*e.g.*, reasonably available control measures (RACM); reasonably available control technology (RACT); reasonable further progress (RFP); or NNSR), depending on the type of demonstration provided.

This guidance is designed to assist air agencies who may wish to submit $PM_{2.5}$ precursor demonstrations as permitted by the $PM_{2.5}$ SIP Requirements Rule.[2] This guidance is intended for use by air agencies; the EPA Headquarters and Regional offices; and the public. This document does not substitute for provisions or regulations of the CAA enumerated above, nor is it a regulation itself. As the term "guidance" suggests, it provides recommendations or guidelines, as authorized under CAA section 189(e), that will be useful to air agencies in developing the precursor demonstrations by which the

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[1] *See* Fine Particulate Matter National Ambient Air Quality Standards: State Implementation Plan Requirements ($PM_{2.5}$ SIP Requirements Rule), 81 FR 58010 (Aug. 24, 2016).

[2] By default, all $PM_{2.5}$ precursors are plan precursors and precursor demonstrations are not required for $PM_{2.5}$ SIPs. However, if a state wishes to exclude a precursor from planning requirements, a precursor demonstration is required.

EPA can ultimately determine whether sources of a particular precursor contribute significantly to $PM_{2.5}$ levels that exceed the standard in a particular nonattainment area. Thus, it does not impose binding, enforceable requirements on any party, nor does it assure that the EPA will approve a precursor demonstrations in all instances where the guidance is followed, as the guidance may not apply to a particular situation based upon the circumstances of a particular nonattainment area.

Where appropriate, air agencies retain the discretion to develop precursor demonstrations on a case-by-case basis that differ from this guidance. Final decisions by the EPA to approve a particular precursor demonstration as part of a plan submission will only be made based on the requirements of the statute and applicable regulations, and will only be made following an air agency's final submission of the precursor demonstration to the EPA, and after appropriate notice and opportunity for public review and comment. Interested parties may raise questions and objections about the appropriateness of the application of this guidance to a particular nonattainment area; the EPA and air agencies should consider whether or not the recommendations in this guidance are appropriate for each situation.

1.1 Precursor Demonstrations

The $PM_{2.5}$ SIP Requirements Rule permits states to submit separate precursor demonstrations to exclude sources of a particular precursor from control requirements under either the attainment plan or the NNSR program.

For a plan designed to demonstrate attainment of the standard as expeditiously as practicable, and no later than a future required attainment date, an air agency could choose to provide an optional precursor demonstration showing that existing emissions of a particular precursor "do not contribute significantly to $PM_{2.5}$ levels that exceed the standard in the area."[3] As noted in the preamble to the $PM_{2.5}$ SIP Requirements Rule, the EPA has described a potential two-step analytical process. The first analysis would be to determine whether all emissions of the precursor(s) "contribute" to total $PM_{2.5}$ concentrations (a "concentration based analysis"). This analysis can be in the form of (1) a "comprehensive precursor demonstration," which would evaluate the change in $PM_{2.5}$ air quality resulting from all existing emissions sources on $PM_{2.5}$ levels in the area; or (2) a "major stationary source precursor demonstration," which would evaluate the change in $PM_{2.5}$ air quality resulting from only existing major stationary sources on $PM_{2.5}$ levels in the area. This analysis can be documented through the assessment of recent air quality monitoring data for $PM_{2.5}$ component species in the area or through air quality modeling.

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[3] *See* 40 CFR 51.1006(a)(1).

The final rule also provides for an optional second step, whereby, if the concentration-based analysis does not support a finding of insignificant contribution, based on the facts and circumstances of the area, then the air agency could still choose to conduct an optional analysis for a plan designed to demonstrate attainment of the standard (a "sensitivity-based analysis").[4] This analysis can also be in the form of a "comprehensive precursor demonstration," which would evaluate the effect of reducing emissions from all existing emissions sources on $PM_{2.5}$ levels in the area; or a "major stationary source precursor demonstration," which would evaluate the effect of reducing emissions from only existing major stationary sources on $PM_{2.5}$ levels in the area. If the EPA approves a comprehensive precursor demonstration for a particular nonattainment area, the air agency would not be required to control emissions of the relevant precursor in the attainment plan for the area.[5] Similarly, if the EPA approves a major stationary source precursor demonstration for a particular nonattainment area, the air agency would not be required to control emissions of the relevant precursor from major stationary sources in the attainment plan for the area.[6]

Under the final rule, a separate analysis is available for air agencies who seek to demonstrate that new major source growth associated with a particular precursor would not contribute significantly to $PM_{2.5}$ levels that exceed the standard in the nonattainment area.[7] For this demonstration, an air agency would need to provide a separate NNSR precursor demonstration that evaluates the effect of emissions increases from major stationary sources of a particular precursor at (hypothetical) new and existing locations within the nonattainment area. If the EPA approves this type of demonstration for a particular nonattainment area, the air agency would be able to exempt new major stationary sources and major modifications of the particular precursor from the NNSR requirements for $PM_{2.5}$ in 40 CFR 51.165.[8]

This guidance document contains additional details on the recommended procedures for completing each of the three $PM_{2.5}$ precursor demonstrations defined in the final rule, including techniques for conducting these analyses and recommended insignificance thresholds for this purpose. See the $PM_{2.5}$ SIP Requirements Rule for more information on these precursor demonstrations, including details on the specific SIP elements that do not need to be addressed based on the approval of a particular precursor demonstration.[9]

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[4] *See* 40 CFR 51.1006(a)(1)(ii) and 51.1006(a)(2)(ii).

[5] *See* 40 CFR 51.1006(a)(1)(iii).

[6] *See* 40 CFR 51.1006(a)(2)(iii).

[7] *See* 40 CFR 51.1006(a)(3).

[8] *See* 40 CFR 51.1006(a)(3)(ii).

[9] *See* $PM_{2.5}$ SIP Requirements Rule at 81 FR 58017.

Policy Guidance

2.0 Overview

As discussed above, the $PM_{2.5}$ NAAQS SIP Requirements Rule establishes that SO_2, NO_x, VOC, and ammonia are precursors for which sources are presumptively evaluated for potential control measures in an attainment plan or any NNSR program for any $PM_{2.5}$ nonattainment area. The rule also indicates that an air agency may choose to submit an optional precursor demonstration designed to show that, for a particular $PM_{2.5}$ nonattainment area, emissions of a particular precursor from sources within the nonattainment area do not or would not contribute significantly to $PM_{2.5}$ levels that exceed the standard. This section discusses the factors that EPA recommends using to determine the degree of impact that reflects a significant contribution on annual and 24-hour $PM_{2.5}$ concentrations. Later sections of the guidance describe specific details about how to conduct recommended technical analyses for the three types of precursor demonstrations (comprehensive, major source, and NNSR) included in the final rule.

2.1 Interpretation of "Contribute Significantly" in Section 189(e) of the Clean Air Act and the $PM_{2.5}$ SIP Requirements Rule

Section 189(e) of the Clean Air Act requires that control requirements "for major stationary sources of PM_{10} shall also apply to major stationary sources of PM_{10} precursors, except where the Administrator determines that such sources do not contribute significantly to PM_{10} levels which exceed the standard in the area." Consistent with the D.C. Circuit's decision in *NRDC v. EPA*, 706 F.3d 428 (D.C. Cir. 2013), this provision also applies to the regulation of sources of $PM_{2.5}$ precursors in designated $PM_{2.5}$ nonattainment areas. To implement this exception provided by that provision, the $PM_{2.5}$ SIP Requirements Rule permits states to submit separate precursor demonstrations to exclude sources of a particular precursor from control requirements under either the attainment plan or the NNSR program. Consistent with the statute, section 51.1006 of EPA's regulations states that a precursor demonstration must show that sources "do not contribute significantly to $PM_{2.5}$ levels that exceed the standard in the area."[10]

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[10] *See* $PM_{2.5}$ SIP Requirements Rule, 81 FR 58010 (August 24, 2016). Page 58018 states: "Even though CAA section 189(e) only explicitly contemplates exceptions to control requirements for $PM_{2.5}$ precursors from major stationary sources in nonattainment areas, the EPA believes that by analogy it has authority to promulgate regulations that allow states to determine that it is not necessary to regulate $PM_{2.5}$ precursors from other sources in nonattainment areas as well, under appropriate circumstances."

The phrase “contribute significantly” and the included terms “contribute” and “significantly” are not defined in section 189, section 302 or any other part of the CAA. EPA’s regulations likewise do not include a definition of the term “contribute significantly.”[11]

The United States Court of Appeals for the District of Columbia Circuit (D.C. Circuit) has observed that the term “contribute” is ambiguous. *Catawba County, N.C. v. EPA*, 571 F.3d 20, 38-39 (D.C. Cir. 2009). In this case, the court considered the use of this term in section 107(d) of the CAA, which governs EPA actions to designate specific areas as in attainment or nonattainment with the NAAQS. Under this provision, a nonattainment area must include any area that does not meet the NAAQS or “that contributes to ambient air quality in a nearby area that does not meet” the NAAQS. The petitioners argued that the EPA was required to interpret the word “contribute” in this context to require a “significant causal relationship” in order to include a nearby area in a nonattainment area. The petitioners also argued that the EPA must establish a quantified amount of impact that qualifies as a contribution before the EPA could include a nearby area in a nonattainment area. *Id.* The court held that “section 107(d) is ambiguous as to how EPA should measure contribution and what degree of contribution is sufficient to deem an area nonattainment.” Consequently, the court held that EPA was not compelled to apply the petitioners’ preferred meaning of the term “contribute” in the context of section 107(d). The court recognized that the EPA had the discretion to interpret the term “contribute” in section 107(d) of the Act to mean “sufficiently contribute” and that EPA could use a multi-factor test, rather than a quantified threshold, to determine when a nearby area contributed to nonattainment.

Section 189(e) is one of several provisions in the CAA that uses the term “contribute,” or similar forms of this term. The reasoning of the *Catawba County* opinion supports the view that EPA has the discretion under section 189(e) to exercise judgment to determine the degree of impact that “contributes” to adverse air quality conditions based on the particular context in which the term “contribute” is used in the Act. *See,* 571 F.3d at 39. Furthermore, this opinion supports EPA’s discretion to identify qualitative or quantitative criteria or factors that may be used to determine whether something “contributes,” as long as the Agency provides a reasoned basis to justify using such criteria or factors to represent a “contribution.”

Although there is ambiguity regarding the degree of impact that “contributes” to an air quality condition, Congress has provided at least some direction regarding the degree of contribution that is required under section 189(e) of the Act. In this provision, Congress included the term “significantly” after the word “contributes.” This indicates that Congress intended to exempt sources of $PM_{2.5}$ precursor emissions from control

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[11] EPA’s New Source Review Permitting regulations contain a definition of the term “significant,” but this definition does not modify the term “contribute” and applies in a different context. *See e.g.*, 40 CFR 51.166(b)(2), (b)(23), (j)(2)-(3).

requirements where there is an impact greater than a simple contribution, but how much greater is not specified.

The D.C. Circuit has also observed that the term “significant” is ambiguous and may be subject to different meanings in different contexts. *Michigan v. EPA*, 213 F.3d 663, 677-(D.C. Cir. 2000). In this case, the court considered the use of this term in section 110(a)(2)(D)(i)(I) of the CAA, which requires state plans to prohibit those emissions which “contribute significantly” to nonattainment of a NAAQS in a downwind state. The EPA defined the amount of emissions from each state that “contribute significantly” to nonattainment as those emissions exceeding a specified threshold and which could be reduced using “highly cost-effective controls.” *Id.* at 675. petitioners challenged the EPA’s reliance on cost-effectiveness to define the level of upwind state contribution that qualified as “significant.” petitioners presented conflicting arguments to the court as to whether the statute permitted any consideration of cost, and, as such, the court determined that it could therefore discern no clear congressional intent to preclude the consideration of cost. *Id.* at 676-77. The court explained that “[t]he term ‘significant’ does not itself convey a thought that significance should be measured only in one dimension – here, in the petitioners’ view, health alone.” *Id.* at 677. Rather, the court explained that the meaning of “significant” may depend on its context and can, in some contexts, “beg a consideration of costs.” *Id.* Thus, the court held that “nothing in the text, structure, or history of [section] 110(a)(2)(D) . . . bars EPA from considering costs in its application.” *Id.* at 679. Consistent with the reasoning in *Michigan*, the use of the term “significant” in section 189(e) is ambiguous and is subject to a reasonable interpretation based on the context of the term’s use. Thus, it is within the Agency’s discretion to identify additional qualitative or quantitative criteria or factors to determine whether a contribution is “significant,” as long as the Agency provides a reasoned basis to justify using such additional criteria or factors.

2.2 Criteria for Identifying an Insignificant Contribution

This guidance document on precursor demonstrations for the $PM_{2.5}$ SIP Requirements Rule describes the factors that the EPA recommends that states consider when seeking to demonstrate that sources of a particular precursor “do not contribute significantly” to $PM_{2.5}$ levels that exceed the NAAQS, for the specific purpose of attainment plan and NNSR program implementation for nonattainment areas. These factors include quantitative “contribution” values that are described in the 2016 EPA document, “Technical Basis for the EPA’s Development of Significant Impact Thresholds for $PM_{2.5}$ and Ozone” (EPA, 2016a), hereafter, referred to as the “Technical Basis Document.”

The EPA first began developing these values for use in the PSD permitting program to implement section 165(a)(3) of the CAA, which requires that an applicant for a PSD permit demonstrate that the proposed source will not “cause or contribute” to a violation of any NAAQS or PSD increment. The statistical methods and analysis detailed in the Technical Basis Document focus on using the concept of statistical significance to identify levels of change in air quality concentrations that can be considered to represent a contribution to air quality degradation. The EPA believes the values derived through this method may be used as quantified levels of air quality change that "cause or contribute" to an exceedance of the NAAQS. Conversely, an impact below any such level may be viewed as an impact that does not contribute to an exceedance of the NAAQS.

Since section 189(e) also uses the term "contribute," these values have relevance in this context also. However, as discussed above, in section 189(e) the term "contribute" is modified by the term "significantly." As a result, the EPA believes that other factors should be considered in determining the degree of air quality impact that "contributes significantly" to $PM_{2.5}$ levels that exceed the applicable NAAQS. Under the $PM_{2.5}$ SIP Requirements Rule, the significance of a precursor's contribution is to be determined "based on the facts and circumstances of the area."[12]

The concept of statistical significance and insignificance is well established, with a basis in commonly accepted scientific and mathematical theory. The Technical Basis Document notes that the statistical methods and data reflected in that analysis may be applicable for multiple regulatory applications where EPA seeks to identify a level of change in air quality that is either significant or insignificant. As described below, a precursor demonstration for a $PM_{2.5}$ SIP is an example of a regulatory application for which the EPA believes it is appropriate to rely on the Technical Basis Document analysis and associated thresholds to first determine whether there is a "contribution" before looking at other factors to determine if the contribution is significant.

The Technical Basis Document describes that compliance with the NAAQS is determined by comparing the measured "design value" (DV) at an air quality monitor to the level of the NAAQS for the relevant pollutant.[13] The EPA believes that an insignificant level of change in ambient air quality can be defined and quantified based on characterizing the observed variability of ambient air quality levels. The Technical Basis Document analysis has been designed to take into account the ambient data used to determine DVs for both the annual and 24-hour $PM_{2.5}$ NAAQS. The EPA's technical approach, referred to as the "Air Quality Variability" approach, relies upon the fact that there is spatial and temporal variability in the observed ambient data and then uses statistical theory and methods to identify a level of change in DVs that is not statistically discernible from the original DV, thereby representing an "insignificant" change in air quality.

Based on these observed ambient data, the EPA's technical analysis has determined the changes in air quality levels of $PM_{2.5}$ that may be considered an insignificant impact through applying a well-established statistical technique known as bootstrapping. Bootstrapping is a method that allows one to determine the accuracy of sample

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[12] 40 CFR 51.1006.

[13] A design value is a statistic that describes the air quality status of a given location to be compared to the level of the NAAQS. More information may be found at https://www.epa.gov/air-trends.

statistics (*e.g.*, mean, percentiles) for a population of data (Efron, 1979; Efron, 2003). The bootstrap approach applied in the Technical Basis Document uses a non-parametric, random resampling with replacement, which recreates the sample dataset (*e.g.*, in this case, the ambient data underlying the DVs), resulting in many resampled datasets. This approach allows one to determine measures of accuracy of sample statistics based on these resampled datasets when the underlying distribution of the statistic is not known (Efron, 1993).

The bootstrap technique, as applied in the Air Quality Variability analysis, quantifies the degree of air quality variability in an area and then allows one to determine appropriate confidence intervals (CIs), *i.e.*, statistical measures of the variability associated with the monitor-based DVs, to inform the degree of air quality change that can be considered "insignificant." This approach for quantifying a degree of impact that contributes to $PM_{2.5}$ air quality is fundamentally based on the idea that an anthropogenic perturbation of air quality that is within a specified range may be considered indistinguishable from the inherent variability in the measured atmospheric concentrations and is, from a statistical standpoint, *insignificant* at the given confidence level.

Specifically, the analysis uses 15 years (2000-2014) of nationwide ambient $PM_{2.5}$ measurement data to generate a large number of resampled datasets for $PM_{2.5}$ DVs at each monitor. These resampled datasets were used to determine statistical CIs that provide a measure of the inherent variability in air quality at the monitor location. This variability may be driven by the frequency of various types of meteorological and/or emissions conditions affecting a particular location. The analysis estimates a range of CIs for each monitor; the 50 percent CI was selected to quantify the level of air quality change that can be considered "statistically insignificant" for the purposes of meeting requirements under the Prevention of Significant Deterioration (PSD) program. The Technical Basis Document explains the analysis design and describes how the results are applicable to Significant Impact Levels (SILs) in the PSD program.

We believe the Air Quality Variability analysis described in the Technical Basis Document is also suitable for determining in the first instance whether emissions of a $PM_{2.5}$ precursor "contribute" to $PM_{2.5}$ levels that exceed the NAAQS, as part of a precursor demonstration under the $PM_{2.5}$ SIP Requirements Rule. The concept of insignificance as expressed in the Technical Basis Document is that an anthropogenic perturbation of air quality that is less than the inherent variability in the measured atmospheric concentration is, from a statistical standpoint, insignificant. The insignificant impact analysis is a general statistical analysis of ambient air quality variability. It is not dependent on the source of the anthropogenic perturbation (*e.g.*, single point source, versus multiple sources across an area). The analysis is based on ambient data measurements, which are driven by the variability in meteorology and emissions from *all* sources. This includes near source and long range impacts from single sources and groups of sources (including major stationary sources, cars, minor sources, etc.). Accordingly, this statistical insignificance concept is equally appropriate to apply in a number of circumstances (*e.g.*, PSD and attainment plans). In this case, the statistical analysis is directly applicable to precursor demonstrations that attempt to show that a particular perturbation in anthropogenic emissions does not contribute significantly to $PM_{2.5}$ levels which exceed the standard in the area. This includes both comprehensive demonstrations (examining the impacts from all emissions sources) and major stationary source demonstrations (examining the impacts from only major stationary sources).

As noted above, the 50 percent CI was selected to quantify the level of air quality change that can be considered "statistically insignificant" for the purposes of meeting requirements under the PSD program. The 50 percent level was chosen as a conservative (low) level, below which would clearly represent an insignificant impact[14] on air quality. We believe the same logic applies to identifying an impact that "contributes" in the context of precursor demonstrations and therefore we recommend use of the same 50 percent CI (and numerical thresholds) for precursor demonstrations. The threshold can be considered a value below which air quality impacts (from both emissions decreases and increases) are insignificant, and thus to do not "contribute" to $PM_{2.5}$ concentrations that exceed the standard.

In addition, the statistical insignificance analysis calculates the inherent variability in the ambient data both above and below the median observed concentrations. In this way, the variability analysis is equally applicable to examining the impact of both emissions *increases* (which would generally lead to higher observed or modeled concentrations) and emissions *decreases* (which would generally lead to lower observed or modeled concentrations), relative to a base case.

The Technical Basis Document recommends specific concentration values that represent the change in $PM_{2.5}$ air quality that can serve to quantify air quality impacts that "contribute" to $PM_{2.5}$ concentrations in each area. Consistent with the Technical Basis Document analysis, the EPA recommends using the following values for this purpose, as part of an optional precursor demonstration under the $PM_{2.5}$ SIP Requirements Rule:

- 0.2 $\mu g/m^3$ for the annual $PM_{2.5}$ NAAQS, and

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[14] In this context, EPA is purposefully using the term "impact" and intends for this term to have a meaning that is distinct from "contribution." Our reason for drawing this distinction is to promote clarity when applying the results of this statistical analysis within the context of statutory provisions that use the terms "contribute" and "contribute significantly." Consistent with the application of the Technical Basis Document in the PSD context, this memorandum uses the term "significant impact" to describe a degree of change in air quality that EPA's statistical analysis shows to be more than "negligible" or "trivial" and thus can be regarded as an impact that "contributes" to air quality concentrations. Given that Congress gave more specific direction that we consider whether precursor emissions "contribute significantly" in the context of section 189(e), we have endeavored in this guidance to use the term "contribute significantly" or "significant contribution" only when discussing whether the criteria in section 189(e) for a precursor exemption has been satisfied.

- 1.3 µg/m^3 for the $PM_{2.5}$ 24-hour NAAQS.

The EPA believes that these recommended thresholds are appropriate guidelines for identifying an air quality change that is "insignificant" and thus does not "contribute" to $PM_{2.5}$ concentrations subject to the current $PM_{2.5}$ NAAQS.[15]

Depending on the type of precursor demonstration conducted, the "perturbation" in air quality can be represented in different ways: as the precursor's impact on ambient $PM_{2.5}$ levels due to emissions from all sources or all major stationary sources in the nonattainment area; a decrease in precursor emissions from all sources or all major stationary sources in the nonattainment area; or, in the case of a NNSR demonstration, as an increase in precursor emissions from major stationary sources. As explained above, the thresholds should be appropriate for interpreting the significance of the perturbation for each of these analyses, regardless of whether the evaluation involves the impact of one or more new sources intending to locate in the nonattainment area, or examining the combined impact on $PM_{2.5}$ concentrations from multiple existing sources of emissions.

2.3 Locations at Which to Evaluate Air Quality Changes

For the comprehensive or major stationary source precursor demonstrations, the EPA believes that air quality changes of concern should be evaluated at existing or relevant historical $PM_{2.5}$ monitor locations (*i.e.*, as part of an air quality modeling analysis) because it is at those locations where NAAQS compliance will be determined. The evaluation of air quality changes at monitor locations for attainment plan precursor demonstrations is consistent with the $PM_{2.5}$ SIP Requirements Rule's treatment of monitor locations for modeled attainment demonstrations for $PM_{2.5}$ nonattainment areas.[16]

For an NNSR precursor demonstration, the EPA believes that the analysis should evaluate the potential air quality change from potential future major sources in generally all parts of the nonattainment area (*i.e.*, all grid cells in an air quality modeling analysis) rather than just at monitor locations. The reason for this is that the overall objective of the NNSR program is to prevent future violations. While a monitor-based analysis makes sense for nonattainment area planning, where the existing $PM_{2.5}$

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[15] As described in the Technical Basis Document, the monitoring site variability is first calculated as a percentage of the measured $PM_{2.5}$. Then the median percent variability from all sites is multiplied by the level of the NAAQS to get the threshold concentrations. Therefore, these thresholds represent a percentage of the 2006 24-hour NAAQS (35 µg/m3) and the 2012 annual NAAQS (12 µg/m3). Different thresholds may be applicable to other levels and/or forms of the NAAQS (either past or future).

[16] *See* $PM_{2.5}$ SIP Requirements Rule at 81 FR 58051.

ambient monitoring network is designed to represent air quality based on the geographic orientation and magnitude of existing sources, this contrasts with NNSR, where new major stationary sources might locate in parts of the nonattainment area that are not currently well represented by the current monitoring network. It is therefore important to examine the sensitivity of the entire nonattainment area to potential increases in precursor emissions to support a request to exempt sources of that precursor from NNSR permitting. This recommendation is consistent with how new major sources are treated in modeling analyses required to be conducted for the PSD program (USEPA, 2014a).

2.4 Considering Additional Information

An approvable precursor demonstration must show that the air quality change at all relevant locations (as described above) does not "contribute significantly" to PM2.5 levels that exceed the standard. The EPA generally expects that a precursor demonstration will be adequate to support exempting sources of a precursor from control requirements if the analysis shows that the air quality impact at all relevant locations does not exceed the recommended contribution thresholds in the Technical Basis Document (i.e., 0.2 μg/m^3 for the annual $PM_{2.5}$ NAAQS, and 1.3 μg/m^3 for the $PM_{2.5}$ 24-hour NAAQS).

If the estimated air quality impact exceeds the recommended contribution thresholds in the Technical Basis Document, this fact does not necessarily preclude approval of the precursor demonstration. There may be cases where it could be determined that precursor emissions have an impact above the recommended contribution thresholds, yet do not "significantly contribute" to levels that exceed the standard in the area (pursuant to section 189(e)). Under the $PM_{2.5}$ SIP Requirements Rule, the significance of a precursor's contribution is to be determined "based on the facts and circumstances of the area."

Air agencies may thus provide the EPA with information related to other factors they believe should be considered in determining whether the contribution of emissions of a particular precursor to levels that exceed the NAAQS is "significant" or not. Such factors may include: the amount by which a precursor's contribution exceeds the recommended contribution thresholds; the severity of nonattainment at relevant monitors and/or grid cell locations in the area; source characteristics (*e.g.*, source type, stack height, location); anticipated growth or loss of sources; analyses of speciation data and precursor emission inventories; chemical tracer studies; special intensive measurement studies to evaluate specific atmospheric chemistry in an area; and trends in ambient speciation data and precursor emissions.

The air agency may provide other information not listed here as well. Any air agency providing additional information should provide a clear rationale explaining how such information supports their claim that the precursor does or does not contribute significantly to $PM_{2.5}$ levels that exceed the standard. The EPA will consider such additional information in its review of the precursor demonstration.

Technical Guidance

3.0 Concentration-Based Analysis

$PM_{2.5}$ precursor demonstrations are only required for air agencies wishing to exclude pollutants from $PM_{2.5}$ precursor nonattainment requirements. If an air agency chooses to perform a precursor demonstration for an attainment plan (either a comprehensive or major stationary source analysis), the final rule requires that the demonstration must include a concentration-based analysis.[17] This demonstration can consist of analyses using ambient data or it could optionally include air quality modeling. The goal of the comprehensive plan analysis is to examine the overall impact on $PM_{2.5}$ air quality in the nonattainment area as a result of emissions of a particular precursor from all existing sources (including point, mobile, and area sources). A major stationary source analysis should examine the overall impact on $PM_{2.5}$ air quality as a result of emissions of a particular precursor from all existing major stationary sources.

The recommended starting point for such an analysis is an evaluation of all available ambient air quality monitoring data for the area (and possibly nearby areas). The EPA recommends an examination of total $PM_{2.5}$ data (in the form of Federal Reference Method (FRM) measurements, Federal Equivalent Methods (FEM) measurements, Interagency Monitoring of Protected Visual Environments (IMPROVE) data, and/or other special study or research data), and ambient $PM_{2.5}$ speciation data which characterizes the composition of total mass. $PM_{2.5}$ species data are critical for this analysis, since they allow for an accounting of ambient secondary $PM_{2.5}$ concentrations and provide a way to link precursor emissions to secondary $PM_{2.5}$ components. See details on $PM_{2.5}$ species components and accounting for the various measured species in Section 3.1, below.

3.1 Ambient Data Analysis of Secondarily-Formed $PM_{2.5}$

$PM_{2.5}$ is a complex and highly variable mixture, but the majority of $PM_{2.5}$ mass is comprised of five constituents: (i) organic matter (OM); (ii) elemental carbon (EC); (iii) crustal material; (iv) ammonium sulfate ($(NH_4)_2SO_4$); and (v) ammonium nitrate (NH_4NO_3) (Hand, 2012) (Seinfeld, 2006). In general, EC and crustal $PM_{2.5}$ are considered "primary" components (*i.e.*, they are emitted directly from sources and are not the product of chemical reactions of precursor gases in the atmosphere). Ammonium sulfate and ammonium nitrate are considered "secondarily formed" $PM_{2.5}$ components

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[17] *See* 40 CFR 51.1006(a)(1).

because they are the product of chemical reactions of precursor gases in the atmosphere.[18] OM can have both primary and secondary components. Since this guidance addresses precursors to secondary $PM_{2.5}$, we will focus the discussion on the most common secondary $PM_{2.5}$ components.

A large number of possible chemical reactions, often non-linear in nature, can convert the gases SO_2, NO_x, VOC and ammonia to $PM_{2.5}$. Thus, these gases are precursors to $PM_{2.5}$. OM is the fraction of ambient $PM_{2.5}$ with the most diverse chemical composition, containing potentially thousands of different organic compounds (*i.e.*, those compounds containing carbon) composed primarily of carbon, hydrogen, oxygen and nitrogen. Both primary particles and secondary particles contribute to ambient OM concentrations. Secondary OM particle formation involves oxidation of both anthropogenic and biogenic (plant-derived) VOC, and can involve other, more complex chemical reactions. Sulfate (SO_4), nitrate (NO_3) and ammonium (NH_4), react in the ambient air to form ammonium sulfate ($(NH_4)_2SO_4$) and ammonium nitrate (NH_4NO_3). If there is not enough ammonia in the ambient air to neutralize fully the available sulfate, ammonium bi-sulfate (NH_4HSO_4) or sulfuric acid (H_2SO_4) may also form. In addition, particle-bound water is often also associated with sulfate and nitrate $PM_{2.5}$. A brief discussion of SO_4, NO_3 and Secondary Organic Aerosol (SOA) formation, as well as the role of ammonia in their formation, follows.

3.1.1 Ammonium Sulfate

SO_2 is a gas-phase species emitted mostly from the combustion of fossil fuels (the largest source is coal combustion from electric utility boilers). When SO_2 oxidizes, it forms aerosol sulfuric acid. In the presence of ammonia, however, sulfuric acid will react to form ammonium sulfate [$(NH_4)_2SO_4$], a less acidic compound and one of the five major components of $PM_{2.5}$. If there is not enough ammonia present to fully neutralize the sulfuric acid, part of it may convert to ammonium bi-sulfate (NH_4HSO_4), which is more acidic than ammonium sulfate [$(NH_4)_2SO_4$], but less so than sulfuric acid. All three products [H_2SO_4, NH_4HSO_4, and $(NH_4)_2SO_4$] solely reside as particle-phase (or aqueous-phase) species in the atmosphere. There is a large amount of emerging scientific evidence that SO_2 may also contribute to the formation of SOA from biogenic VOC emissions (*see* section later on SOA). Sulfate levels in the ambient air peak in summer months due to increased SO_2 emissions, generally from electric generating units (EGUs), and from meteorological conditions that are conducive to sulfate formation.

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[18] There is a small primary component to both sulfate and nitrate ions, but the vast majority of measured sulfate and nitrate is secondary in nature.

3.1.2 Ammonium Nitrate

The main sources of oxides of nitrogen (NO_x) emissions are combustion of fossil fuel in boilers (e.g., electric utility boilers) and internal combustion engines (e.g., cars and trucks). NO_x reacts in the atmosphere to form nitric acid. Nitric acid converts to ammonium nitrate, one of the five main components of $PM_{2.5}$, in the presence of ammonia. Low temperatures and high relative humidity create ideal conditions for the formation of ammonium nitrate, typically leading to higher atmospheric levels in winter months and lower levels in summer months (Hand, 2012). At high temperatures and low relative humidity, particulate nitrate (most commonly in the form of ammonium nitrate) converts back into its component species of nitric acid (HNO_3) and ammonium ion (NH_4). Therefore, nitrate ion (NO_3) cannot exist in particulate form without being neutralized by ammonia or another neutralizing cation.[19] Similarly, ammonia would not exist in particle form if not for the presence of acidic species (sulfate or nitrate) with which it can combine to form a particle.

3.1.3 SOA

VOCs (both anthropogenic and biogenic) are key precursors to the SOA component of $PM_{2.5}$. The relative importance of these compounds in the formation of organic particles varies between geographic areas, depending upon local emission sources, atmospheric chemistry and season of the year. It should be further noted that not all inventoried VOC might be contributing to the formation of organic particles. For example, chemical reactions involving VOC are generally accelerated in warmer temperatures, and for this reason, studies show that SOA typically comprises a higher percentage of $PM_{2.5}$ in the summer than in the winter (Pandis, 1992).

Anthropogenic sources of VOC include mobile sources, petrochemical manufacturing, oil and gas emissions and solvents (USEPA, 2016b). In addition, some biogenic VOC, emitted by vegetation, such as trees, can contribute significantly to SOA formation, especially in heavily forested areas, such as the Southeast U.S. It should be noted, however, that anthropogenic impacts on SOA are likely highest in the wintertime when biogenic SOA levels are lower; conversely, in the summertime, the influence of biogenic emissions on SOA is likely higher (Carlton, 2010a). Despite significant progress that has been made in understanding the origins and properties of SOA, it remains the least understood component of $PM_{2.5}$ and continues to be a significant topic of research and investigation.

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[19] If ammonia is not available, nitric acid can also be neutralized by calcium (Ca) or sodium (Na) (if available) to form calcium nitrate [$Ca(NO_3)_2$] and sodium nitrate ($NaNO_3$), respectively. Unlike ammonium nitrate, $Ca(NO_3)_2$ and $NaNO_3$ do not convert back to the gas phase at higher temperatures.

3.1.4 Role of NO_x and SO_2 in Secondary PM Chemistry

In addition to the influencing secondary particulate nitrate formation, NO_x also reacts with anthropogenic and biogenic VOC to enhance the secondary formation of sulfate and organic compounds that make up SOA (Carlton, 2010b). NO_x is thus involved in all secondary PM chemistry, not just in particulate nitrate formation. Similarly, recent research has indicated that SO_2 can impact SOA formation (Surrat, 2010). One recent study found that chemical reactions involving SO_2 and NO_x combined may be responsible for up to 70% of the total measured organic aerosol in the Southeast U.S. in the summer (Xu, 2015). Consequently, when NO_x or SO_2 emissions are decreased or increased in the atmosphere, there can be effects on all secondary $PM_{2.5}$ species, including ammonium ion, nitrate ion, sulfate ion, and SOA.

3.1.5 Assigning $PM_{2.5}$ Species to Precursors - Summary

Ambient $PM_{2.5}$ species data are generally measured and reported as OM, EC, crustal, nitrate, sulfate, and ammonium. For the purpose of precursor demonstrations, elemental carbon and crustal $PM_{2.5}$ can be ignored (since they are primary species). One basic way of developing a concentration-based analysis for a particular precursor is to calculate the portion of the total $PM_{2.5}$ mass measured at the relevant location that is associated with the precursor. The EPA's default recommendation for "assigning" the measured secondary $PM_{2.5}$ species to their respective precursors is shown in Table 1 below:

Table 1. Default Recommended Assignment of $PM_{2.5}$ Precursors to $PM_{2.5}$ Species

$PM_{2.5}$ Precursor	**Recommended Assignment to $PM_{2.5}$ Species**	**Comment**
NO_x	Nitrate ion + portion of ammonium associated with nitrate	Include all measured nitrate ion plus the ammonium that is in the form of ammonium nitrate (do not include the ammonium attached to sulfate).
SO_2	Sulfate ion	All measured sulfate ion.
NH_3	Ammonium + nitrate ion	Include all measured ammonium and nitrate ion.
VOC	SOA	Estimate the secondary component of OM. This can be further disaggregated into the impact on SOA from anthropogenic VOC sources.

Further explanation of the recommended assignments outlined in Table 1 is provided as follows:

- **NO_x** - the default recommendation assigns measured nitrate to NO_x as well as the portion of ammonium that is attached to nitrate in the form of ammonium nitrate. When considering the impact of NO_x on $PM_{2.5}$, NO_x directly influences the formation of ammonium nitrate. However, nitrate ion cannot exist in the atmosphere as a particle without being neutralized by ammonia (it would exist as a gas in the form of nitric acid). Therefore, the ammonium portion of ammonium nitrate should also be counted when evaluating whether NO_x contributes to $PM_{2.5}$ mass.

- **SO_2** - The default recommendation assigns measured sulfate to SO_2. Note that the ammonium attached to sulfate (mostly in the form of ammonium sulfate) is not counted toward the SO_2 impact on $PM_{2.5}$ mass because sulfate can exist in the atmosphere as a particle in the form of sulfuric acid even if it is not neutralized by ammonia.

- **NH_3** - The default recommendation assigns all measured ammonium to NH_3 as well as the entire nitrate ion mass. This is for the same reason that part of ammonium is assigned to NO_x. Ammonium nitrate cannot exist in the atmosphere as a particle without being neutralized by ammonia. Therefore, if no ammonia were present, nitrate would exist only as a gas (in the form of nitric acid). As a result, all of the mass of ammonium nitrate should also be counted towards ammonia's impact on $PM_{2.5}$ mass. [20]

- **VOC** - The default recommendation assigns measured SOA to VOC. The most conservative assumption is to assume that all of the measured organic aerosol mass is SOA.[21] However, SOA is only a portion of measured organic mass and is not directly measured. Therefore, in some cases, the SOA portion can be estimated through data analysis techniques (Cabada, 2004; Saylor, 2006; Lewandowski, 2008; and Rutter, 2014). In some areas, a high percentage of SOA originates from biogenic sources (especially in the summer). Therefore, if SOA is estimated as a percentage of total organic mass, the SOA concentration can be

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[20] If an air agency submits precursor demonstrations for both ammonia and NOx, the nitrate component should be counted towards the contribution of both precursors to ambient $PM_{2.5}$ levels. This is appropriate since particulate ammonium nitrate formation is dependent on having both nitric acid (from NOx) and ammonia available.

[21] The measured organic carbon should be multiplied by an appropriate factor (typically 1.4 to 1.8) to convert from organic carbon to organic mass (which includes additional mass attached to the carbon).

further refined by estimating the portion of SOA that is a result of anthropogenic VOC emissions.[22]

The default recommendations above are the simplest and most straightforward assignment of precursors to species. However, other methods may be used to estimate alternative $PM_{2.5}$ concentration apportionment. For example, the $PM_{2.5}$ attainment demonstration modeling guidance recommends the use of the "sulfate, adjusted nitrate, derived water, inferred carbonaceous material balance approach" (SANDWICH) (Frank, 2006) to adjust measured $PM_{2.5}$ species data to match better the total $PM_{2.5}$ mass, which is measured on FRM filters. The FRM mass, which is compared to the NAAQS to determine attainment/nonattainment, suffers from various artifacts, which can affect the concentration of some $PM_{2.5}$ species collected on Teflon filters. For example, organic mass experiences both positive and negative artifacts, and nitrate mass is generally lower (negative artifact) on FRM filters compared to species measurements, due to temperature and humidity influences. In addition, the SANDWICH technique estimates particle bound water mass, which is attached to both sulfate and nitrate particles. The water mass should be counted in assessing a contribution to $PM_{2.5}$ because it is collected on the filter and counted as PM mass that is part of total $PM_{2.5}$. In addition to SANDWICH, there may be other technically credible adjustments that can be applied to measured species data, depending on the nature of the species, the area of the country, and the season in which the measurement occurs. All adjustments to ambient data should be discussed with the EPA Regional office and carefully documented and explained.

3.1.6 Evaluating Concentration Based Analysis Results

The estimated impact on $PM_{2.5}$ mass from a specific precursor should be compared to the recommended "contribution" thresholds for the annual average and/or 24-hour NAAQS that were identified in Section 2.2.

3.1.7 Additional Information

In addition to ambient $PM_{2.5}$ species data, other information can be used to support the concentration-based analyses. Emissions inventory data for the nonattainment area can help support claims that a precursor does not contribute significantly to $PM_{2.5}$ concentrations in the nonattainment area, particularly when emissions of the precursor are small. Other considerations in the demonstration can be the size of the nonattainment area, the population of the nonattainment area, geographical considerations (such as an isolated mountain valley area), meteorological

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[22] Due to the difficulty in calculating SOA and the contribution of VOC to ambient $PM_{2.5}$ data, air quality modeling may be the most straightforward way to determine the VOC contributions (see Section 5).

considerations, etc. The default recommendation is to compare the measured ambient $PM_{2.5}$ species data to the relevant air quality "contribution" threshold. However, there are other techniques that can be used to attempt to further account for the impact of sources in the nonattainment area on ambient data concentrations. Analyses to support the disaggregation of ambient data into the local nonattainment area impact should be as detailed as possible, focused on the precursor(s) of interest in the demonstration, and discussed with the appropriate EPA Regional office. Note also that air quality modeling is the most technically credible way to calculate the concentration of $PM_{2.5}$ mass due to emissions sources from within the nonattainment area. See Section 3.2 below for more details.

3.2 Air Quality Modeling

Air quality modeling can also be used to quantify the impact of precursors on $PM_{2.5}$ concentrations in a nonattainment area. In general, air quality modeling is resource intensive, but it is the most direct method to capture the non-linear and complicated associations between $PM_{2.5}$ precursors and $PM_{2.5}$ concentrations. For example, in the ambient data analysis section above, we delineated many caveats and assumptions that need to be considered when estimating the impact of precursor emissions on measurements of specific $PM_{2.5}$ species. Many of those assumptions are not necessary when evaluating air quality modeling outputs (although there are different considerations and assumptions that are involved). A photochemical grid model takes into account the complicated chemical interactions among precursors and tracks the individual species concentrations, including species like SOA[23], which cannot be directly measured. Photochemical modeling also allows a more precise accounting of impacts from precursor emissions in the nonattainment area. In addition, since air quality modeling is both a statutory and regulatory requirement for Moderate and Serious $PM_{2.5}$ attainment demonstrations,[24] most nonattainment areas will have photochemical air quality modeling available to support their modeled attainment demonstration.

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[23] Photochemical modeling of SOA is generally more uncertain than the other $PM_{2.5}$ components. SOA formation is not yet fully understood mechanistically and therefore cannot yet be reliably modeled. Because we lack reliable tools for distinguishing between primary and secondary organic aerosol in the ambient air and have even less confidence that models can reliably simulate SOA formation, it is difficult to validate a modeled conclusion that VOC precursor emissions have an insignificant contribution to $PM_{2.5}$. Therefore, especially in the case of VOC as a precursor, additional evidence should be submitted to help validate modeling results. Additional information could include ambient data analyses, special study data and research, and detailed emissions information (for example, VOC speciation data showing that the makeup of the nonattainment area VOC emissions are not likely to form SOA).

[24] *See* CAA section 189(a)(1)(B), CAA section 189(b)(1)(A), 40 CFR 51.1009(a)(4) and 40 CFR 51.1010(a)(5).

Air agencies have several choices to analyze modeled air quality impacts of precursor emissions on $PM_{2.5}$ as part of a concentration-based analysis. The simplest approach would be to perform brute force “zero-out” model runs which involves at least two model runs; one “baseline” run with all emissions, and one with anthropogenic emissions of the precursor of interest removed from the nonattainment area in the original baseline simulation (Cohan et al., 2005). The difference between these simulations provides an estimate of the air quality change due to the precursor emissions.

An alternative approach to isolating precursor impacts in photochemical grid models is “photochemical source apportionment.” Some photochemical models have been developed with a photochemical source apportionment capability, which tracks emissions from specific sources or groups of sources and/or source regions through chemical transformation, transport, and deposition processes to estimate the apportionment of predicted $PM_{2.5}$ species concentrations (Kwok et al., 2015; Kwok et al., 2013). Source apportionment (ENVIRON, 2016; Kwok et al., 2015; Kwok et al., 2013; Wang et al., 2009) has been implemented in modeling systems such as the Comprehensive Air Quality Model with Extensions (CAMx) (ENVIRON, 2016) and the Community Multiscale Air Quality (CMAQ) (Byun and Schere, 2006).

3.2.1 Evaluating Modeling Results

The calculated impact of the precursor on total $PM_{2.5}$ concentrations should be compared to the “contribution” thresholds for annual and 24-hour $PM_{2.5}$ identified in Section 2.2. See Section 5 for more details on the choice of models, model setup, and post-processing of the model results.

4.0 Sensitivity Based Analysis

The $PM_{2.5}$ SIP Requirements Rule also allows for an optional “sensitivity-based” analysis for attainment plan demonstrations.[25] This modeling analysis examines the sensitivity of ambient $PM_{2.5}$ concentrations in the nonattainment area to certain amounts of decreases in the precursor emissions in the area. This type of optional analysis is only necessary if the concentration-based analysis described above does not adequately demonstrate insignificant impacts to $PM_{2.5}$ concentrations in the nonattainment area. By performing a sensitivity analysis, it may still be possible for an air agency to demonstrate adequately that any precursor contribution is insignificant. Where decreases in emissions of the precursor result in negligible air quality impacts (*i.e.,* the area is “not sensitive” to decreases), such a small degree of impact is not significant and can be considered to not “contribute” to PM2.5 concentrations for the purposes of determining whether control requirements should apply. Accordingly, the EPA expects

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[25] *See* 40 CFR 51.1006(a)(1)(ii) and 40 CFR 51.1006(a)(2)(ii).

that it will approve a precursor demonstration if it can be adequately shown that the area is not sensitive to precursor emissions reductions. Note that the sensitivity analysis described in this section is only applicable to evaluating emissions reductions as part of the attainment plan part of the SIP. A similar but distinct sensitivity analysis is applicable to NNSR precursor demonstrations, but addresses sensitivity to precursor emissions *increases* rather than decreases (see section 6 for more details on NNSR precursor demonstrations).

A sensitivity-based analysis demonstrates the degree to which concentrations in the nonattainment area are sensitive to decreases of a precursor. Changes in $PM_{2.5}$ concentrations at a particular location often will not be linear with respect to changes in $PM_{2.5}$ precursor emissions. As previously discussed, several $PM_{2.5}$ components are secondarily formed in the atmosphere as the result of chemical reactions between various $PM_{2.5}$ precursors. In some nonattainment areas, one precursor may be abundant while a second precursor, with which it primarily reacts, may be less abundant. In such cases, a modeled sensitivity analysis may find that $PM_{2.5}$ concentrations in the area are relatively insensitive to emissions reductions of the more abundant precursor.

4.1 Modeling for Sensitivity Demonstrations

Precursor demonstrations analyze the relationship between precursor emissions and the formation of secondary $PM_{2.5}$ components. Air quality models are the most appropriate tool to be able to predict the impact of precursor emissions reductions on $PM_{2.5}$ concentrations. Since $PM_{2.5}$ precursors form secondary $PM_{2.5}$ through chemical reactions, a chemical transport model (CTM) is best able to examine the sensitivity of precursor emissions to secondary $PM_{2.5}$ concentrations. See Section 5 for more details on CTMs.

As part of performing a sensitivity analysis, there are two additional questions that need to be addressed:

1) What amount of emissions reduction should be examined as part of a sensitivity analysis?
2) What air quality concentration threshold should be used to determine if the modeled air quality change from the precursor is insignificant?

4.1.1 Emissions Reductions for Sensitivity Analyses

When deciding on the appropriate emissions reduction to model in a sensitivity analysis, it is important to consider the nature of the question being asked. In this case, the CAA and the $PM_{2.5}$ SIP Requirements Rule allow a demonstration to show that emissions of a precursor in the area do not contribute significantly to $PM_{2.5}$ levels that exceed the standard in the area.[26] Given the emissions makeup and resultant interactions between precursors in the area, the pertinent question is whether $PM_{2.5}$ concentrations in the nonattainment area are "insensitive" to certain amounts of emissions reductions of the precursor. This question should not be confused with whether there are known available emissions reductions of a certain size within the nonattainment area. For example, an air agency may identify only a very small percentage precursor reduction from available controls. However, modeling the sensitivity of the area to that very small percentage reduction and then comparing it to EPA's recommended thresholds does not effectively answer whether the area is sensitive to the precursor. The analysis should use a percentage emissions reduction (or a series of different percentage reductions model runs) that is large enough to provide a robust answer (given non-linearities due to complex secondary $PM_{2.5}$ chemistry).

The EPA recommends modeling a range of percentage emissions reductions for all sensitivity analyses. For attainment plan analyses of existing emissions sources, a fixed tonnage reduction of a precursor would not be appropriate since the number of tons of precursors in each nonattainment area may vary by orders of magnitude. Therefore, a percentage reduction is appropriate for this type of analysis because it allows for consistency between nonattainment areas and takes into consideration the amount of existing emissions of the particular precursor in each area.

The definition of the range of percentage emissions reductions to model should consider two basic factors:

1) The reduction should be large enough to test the interaction and non-linearity of the secondary $PM_{2.5}$ components, such as those considered in the published literature.
2) The reduction should not be so large that it alters the chemistry in such a way that gives an unrealistic $PM_{2.5}$ concentration response, especially given emissions reductions that could possibly occur within the 6-10 year timeframe of Moderate and Serious area attainment demonstrations.

The percentage reduction should not be solely based on an analysis of potential emissions reductions over the next 6-10 year period. This approach could lead to claims of very small emissions reductions, which may not be large enough to truly test whether the area is sensitive to precursor emissions reductions. Therefore, the EPA is recommending a range of percentage precursor emissions reductions that is applicable to all sensitivity demonstrations.

Based on the information available at this time, the EPA recommends application of multiple percentage emissions reductions sensitivities, which span what has typically

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[26] *See* CAA section 189(e) and 40 CFR 51.1006(a).

been seen in the published literature.[27] The EPA recommends a range of 30-70% reductions in precursor emissions in the nonattainment area to test the $PM_{2.5}$ concentration sensitivity of an area. Multiple model runs can be conducted which test the $PM_{2.5}$ sensitivity within the recommended range. For example, model runs of 30%, 50%, and 70% precursor reductions would test the entire sensitivity range to see whether the insignificance threshold is exceeded within the range of reductions. Air agencies can perform multiple model runs to test various sensitivity levels and provide a range of impacts. However, modeling the highest end of the percent reduction range as the initial model run will potentially limit the resources involved in the analysis. If the modeled $PM_{2.5}$ concentration change at the highest end of the percent reduction range is below the recommended threshold, then additional lower percentage model sensitivity runs will likely not be needed. If, however, the modeled concentration change is above the threshold, then additional lower percentage sensitivity model runs are recommended to help identify the point where the threshold is exceeded. For the reasons stated above, in most cases, the EPA recommends that air agencies do not use percent reductions of less than 30% for sensitivity analyses.

Review of recent projections of expected emission changes suggests that this recommended range is not unrealistic or arbitrary. For example, the EPA compiled the estimated state level percent change in precursor emissions between 2011 and 2017 from the Cross State Air Pollution Rule (CSAPR) Update rulemaking documentation (USEPA, 2016b). This represents an emissions change, which occurred over a 6-year period, which is the same amount of time allowed for a Moderate $PM_{2.5}$ area to attain the NAAQS. Table 2 shows a summary of the emissions analysis.

Table 2. Nationwide State Level[28] Total Percent Change in Anthropogenic[29] $PM_{2.5}$ Precursors Between 2011 and 2017

$PM_{2.5}$ Precursor	Median % emissions change	High % emissions change	Low % emissions change
NOx	-31.8%	-39.9%	-7.7%
SO2	-63.6%	-89.0%	-15.2%
VOC	-18.8%	-26.9%	57.5%
NH3	0.8%	-9.3%	6.1%

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[27] The EPA examined examples in the published literature of general sensitivity modeling studies that look at the impact of across-the-board percentage reductions in precursor emissions on secondary pollutants (including $PM_{2.5}$, PM_{10}, and ozone) (Vieno, 2016; Megaritis, 2013; Harrison, 2013; Derwent, 2014; Liu, 2010; Pun, 2001). The majority of studies have used across the board percentage precursor emissions reductions of between 30% and 60%, with the most common reduction percentages being 30% and 50%.

[28] The percent change in precursor emissions was calculated for each of the lower 48 states.

[29] Emissions totals do not include biogenic (NOx or VOC) emissions or fires.

The percent change in emissions in Table 2 show a wide variation by precursor. In general, the largest reductions were seen in SO_2 emissions (median value of -64%), with NOx having the second largest reductions (median value of -32%). VOC had a larger range of changes (including some increases) and more than half of the states had estimated increases in NH_3 over the example 6-year period. The emissions data show that at least half of the states achieve more than a 30% reduction in NOx and SO_2 in the 6-year period. This shows that large emissions reductions are both likely and possible over a short period of time.

In addition, it can be seen in Table 2 that certain $PM_{2.5}$ precursors (*e.g.*, SO_2) have been reduced by as much as 60-90% over the 2011-2017 period. This does not mean that it is possible or even likely that an additional 60 plus percentage reduction in SO_2 (or any other precursor) will occur in any future 6 or 10-year period. However, it may be appropriate, depending on the circumstances in the area, to consider emissions sensitivities that are much larger than a 30% reduction. This is especially true in nonattainment areas which can expect large additional emissions reductions of certain precursors from on-the-books controls and in areas that are dominated by one or a few point sources or categories of sources that are largely uncontrolled.

Consistent with the $PM_{2.5}$ SIP Requirements Rule, the EPA may in some cases require air agencies to evaluate available emissions controls in support of a precursor demonstration that relies on a sensitivity analysis.[30] It is particularly important for states to evaluate available controls where the recommended contribution threshold is close to being exceeded at the low end of the recommended sensitivity range (*e.g.*, 30%). In these cases, the EPA may determine that to sufficiently evaluate whether the area is sensitive to reductions, the state must determine the potential precursor emission reductions achievable through the implementation of available and reasonable controls for a Moderate area (or best controls for a Serious area). For example, an area that determines it is close to exceeding the contribution threshold with a 30% precursor emissions reduction generally will need to evaluate the impact (*i.e.*, the percent reduction in the precursor) of the application of reasonably available controls of the relevant precursor. The EPA would be less likely to require an evaluation of potential controls for areas that do not exceed the contribution threshold at a higher modeled percent reduction (e.g., 50-70%). The air agency should consult the appropriate EPA Regional office to determine whether an emissions control analysis is needed to support a particular precursor demonstration.

In summary, for a comprehensive sensitivity-based analysis, the EPA recommends modeling reductions of 30%-70% of all anthropogenic emissions of the precursor (including point, mobile, and non-point sources) in the nonattainment area. For a major source sensitivity based analysis, the EPA recommends modeling reductions of 30%-70%

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[30] *See* 40 CFR 51.1009(a)(2) and 51.1010(a)(2).

of anthropogenic emissions of the precursor from existing major stationary sources in the nonattainment area. In addition, the EPA may in some cases require air agencies to evaluate available emissions controls in support of a precursor demonstration.

4.1.2 Evaluating Sensitivity Modeling Results

As noted previously, the EPA recommends comparing the estimated impacts of precursor emissions on $PM_{2.5}$ mass from sensitivity modeling to the contribution thresholds for the annual average and 24-hour NAAQS, as appropriate, identified in Section 2.2.[31] The EPA generally expects that if modeling demonstrates that reductions in the 30-70% range produce an air quality impact below these thresholds, then it would approve such a demonstration as adequate to show that the precursor is insignificant. However, the higher the modeled percentage reduction, the stronger the demonstration. Therefore, modeling the high end of the range is encouraged. The EPA recommends submittal of supporting information for all sensitivity demonstrations, especially for demonstrations that can only pass the recommended threshold(s) at the low end of the range. As noted previously, the approach set forth in the Technical Basis Document is a reasonable interpretation of insignificance, and an air agency seeking to offer a different interpretation would need to present a compelling argument why its interpretation should be accepted instead.

5.0 Modeling for Attainment Plan Precursor Demonstrations

Quantifying secondary pollutant formation requires simulating chemical reactions and thermodynamic gas-particle partitioning in a realistic chemical and physical environment. Chemical transport models treat atmospheric chemical and physical processes such as deposition and transport. There are two types of chemical transport models which are differentiated based on a fixed frame of reference (Eulerian grid based), or a frame of reference that moves with parcels of air between the source and receptor point (Lagrangian) (McMurry et al., 2004).

A variety of Lagrangian and Eulerian modeling systems exist that could potentially be used to estimate impacts on secondarily-formed $PM_{2.5}$. These modeling systems represent varying levels of complexity in the treatment of chemistry and the chemical and physical environment in which precursors exist. Photochemical grid models are three-dimensional grid-based models that treat chemical and physical processes in each grid cell and use Eulerian diffusion and transport processes to move chemical species to other grid cells (McMurry et al., 2004). Photochemical models are advantageous by providing a spatially and temporally dynamic realistic chemical and physical

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[31] Note that when calculating the $PM_{2.5}$ impact of the precursor sensitivity, all components of modeled $PM_{2.5}$ mass should be added together to get the total $PM_{2.5}$ impact from the individual precursor emissions.

environment for plume growth and chemical transformation (Baker and Kelly, 2014; Zhou et al., 2012). Publicly available and documented Eulerian photochemical grid models such as CMAQ (Byun and Schere, 2006) and CAMx (Environ, 2016) treat emissions, chemical transformation, transport, and deposition using time and space variant meteorology. These modeling systems include primarily emitted species and secondarily-formed pollutants such as ozone and $PM_{2.5}$ (Chen et al., 2014; Civerolo et al., 2010; Russell, 2008; Tesche et al., 2006). These models have been used extensively to support SIPs and to explore relationships between inputs and air quality impacts in the United States and beyond (Cai et al., 2011; Civerolo et al., 2010; Hogrefe et al., 2011).

5.1 Modeling Demonstrations

In general, attainment plan precursor demonstration modeling should follow the recommendations in the $PM_{2.5}$ photochemical modeling guidance for attainment demonstrations [*Modeling Guidance for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze* (USEPA, 2014b)]. As noted above, since air quality modeling is a required element of $PM_{2.5}$ attainment demonstrations, most air agencies will already have a photochemical grid modeling platform available to use for precursor demonstrations. Where a grid modeling platform is available for an attainment demonstration, the process of setting up and running the model will generally be the same for a precursor demonstration. If a photochemical modeling platform is not available, the air agency should consult with the appropriate EPA Regional office to discuss options. Possible alternative options include the use of a simplified box model, regional or national photochemical grid modeling that may separately be available, or other conservative techniques for estimating the impact of precursor emissions on $PM_{2.5}$ concentrations in the particular area.

5.1.1 Air Quality Modeling Process

Typically, the air quality modeling process starts with the development of base year emissions and meteorology for input to an air quality run to evaluate model performance. The photochemical $PM_{2.5}$ modeling guidance describes the process for evaluating model performance and performing diagnostic analyses. After evaluating the model and making any necessary input changes or adjustments, the model is run for a future year, which corresponds to the appropriate attainment year for the area. The air quality model outputs are then used to apply the modeled attainment test to support an attainment demonstration.

At the beginning of the modeling process, the EPA recommends a modeling protocol be developed to support the modeling exercise. A modeling protocol is intended to communicate the scope of the analysis and generally includes the types of analysis performed, the specific steps taken in each type of analysis, the rationale for the choice of modeling system, names of organizations participating in preparing and implementing the protocol, and a complete list of model configuration options. The protocol should detail and formalize the procedures for conducting all phases of the modeling study, such as describing the background and objectives for the study, creating a schedule and organizational structure for the study, developing the input data, conducting model performance evaluations, interpreting modeling results, describing procedures for using the model to demonstrate whether regulatory levels are met, and producing documentation to be submitted for review and approval.

If a modeling protocol is already available in support of an attainment demonstration, then it may not be necessary to develop a separate protocol to document a precursor demonstration. In that case, the details of the modeling and analyses to support a precursor demonstration can be incorporated into the existing structure of the modeling protocol. If a modeling protocol is not otherwise available, the EPA recommends developing a separate protocol that outlines the elements of the precursor demonstration. A modeling protocol should include the following elements at a minimum.

1. Overview of Modeling/Analysis Project
    - Participating organizations
    - Schedule for completion of the project
    - Description of the conceptual model for the project source/receptor area
    - Identify how modeling and other analyses will be archived and documented
    - Identify specific deliverables to the review authority

2. Model and Modeling Inputs
    - Rationale for the selection of air quality, meteorological, and emissions models
    - Modeling domain specifications
    - Horizontal resolution, vertical resolution and vertical structure
    - Episode selection and rationale for episode selection
    - Description of meteorological model setup
    - Description of emissions inputs
    - Specification of initial and boundary conditions
    - Methods used to quality assure emissions, meteorological, and other model inputs

3. Model Performance Evaluation
    - Identify relevant ambient data and provide relevant model performance in the modeling domain with a focus on the nonattainment area
    - List evaluation procedures
    - Identify possible diagnostic testing that could be used to improve model performance

4. Model Outputs
- Describe the process for calculating precursor impacts to annual average and/or 24-hour average $PM_{2.5}$ concentrations in the nonattainment area.

The existing attainment demonstration modeling guidance provides recommendations on all of the protocol elements above (USEPA, 2014b). This includes selecting air quality models, meteorological modeling, episode selection, the size of the modeling domain, the grid size and number of vertical layers, and model performance. Precursor demonstrations for attainment plans should generally follow the recommendations in the attainment demonstration modeling guidance.

5.2 Base Year and Future Year Model Assessments

Modeled attainment demonstrations typically include modeling for both a base year (used to evaluate model performance) and a future year, which typically corresponds to the attainment date. Meteorological fields are developed for the base year and held constant in the future year modeling. Future year emissions fields are used to simulate the impact of emissions controls (including growth) on future air quality concentrations. Attainment demonstrations use the future year modeled air quality concentrations to determine if attainment is likely to be reached by the nonattainment area attainment deadline.

The EPA recommends that a precursor demonstration generally should be based on current conditions to demonstrate that precursor emissions do not contribute significantly to $PM_{2.5}$ concentrations in the nonattainment area. The base year modeling has less uncertainty compared to the future year since model performance is known for the base year and the modeling does not depend on projections of emissions to a future year. In addition, some control requirements (*e.g.*, RACT) may apply before the maximum statutory future year attainment date. However, as explained in Section 6 of this guidance, there may be situations, such as with the NNSR precursor demonstration, where it could be more appropriate to model future conditions that provide a more representative sensitivity analysis based on the period of time when a new source will begin to operate.

In most cases, the modeled base year is the best representation of current conditions. Note however that the modeled base year is not necessarily the same as modeling a "current" year. In some cases, the base year used for modeling purposes may be several years or more in the past. Therefore, future year baseline modeling may in some cases be more appropriate for attainment plan modeled precursor demonstrations. As such, air agencies should consult the appropriate EPA Regional office to determine the appropriate analysis year(s).

5.3 Modeling Approaches

The simplest sensitivity modeling approach (brute force change to emissions) would be to simulate two sets of conditions, one with all emissions and one with an across the board anthropogenic emissions reduction (or zero precursor emissions in the case of a "zero-out" model run). The difference between these simulations provides an estimate of the air quality change related to the change in emissions from the precursor. Additionally, some photochemical models have been instrumented with source apportionment, which tracks emissions from specific sources, source sectors, and/or source regions through chemical transformation, transport, and deposition processes to estimate the apportionment of predicted $PM_{2.5}$ species concentrations (Kwok et al., 2015; Kwok et al., 2013). Source apportionment has been used to calculate the contribution from multiple states on model predicted ozone and $PM_{2.5}$ as part of several transport related rulemakings (USEPA, 2011; USEPA, 2016c). Air agencies can choose the most efficient modeling technique for their particular situation and should discuss the options with the appropriate EPA Regional office.

5.4 Calculating the Modeled Impact from Precursors

The modeled precursor impact on $PM_{2.5}$ levels can be calculated as either the absolute modeled concentration change, or as the relative concentration change, based on the percent modeled change in $PM_{2.5}$ species, applied to ambient data. The photochemical modeling guidance recommends performing a "relative" attainment test for modeled attainment demonstrations. The recommended test uses model estimates in a "relative" rather than "absolute" sense to estimate future year design values. The fractional changes in air pollutant concentrations between the model future year and model base year are calculated for all valid monitor locations. These ratios are called *relative response factors* (RRF). Future $PM_{2.5}$ design values are estimated at existing monitoring sites by multiplying the modeled relative response factor for each monitor by the monitor-specific base year design value. The resulting estimates of future concentrations are then compared to the NAAQS. The relative attainment test has the benefit of anchoring the projected $PM_{2.5}$ concentrations to measured ambient data, which helps mitigate modeled over or under-predictions, relative to the level of the NAAQS.

In contrast to an attainment demonstration, precursor demonstrations do not examine changes in emissions between a base year and a future year. Instead, the calculation of relative changes in $PM_{2.5}$ concentrations occur between a modeled case with all emissions and a modeled case with reduced precursor emissions.

Even though it may be appropriate to calculate absolute modeled $PM_{2.5}$ concentration changes, there are advantages to calculating relative concentration changes, using the modeling guidance recommended procedures for the modeled attainment test. The recommended procedure involves applying adjustments to the ambient data to reconstruct the measured species components so that they add up to the measured FRM mass. Data analyses (Frank, 2006) have noted that the FRM monitors do not measure the same components and do not retain all of the $PM_{2.5}$ that is measured by routine speciation samplers and, therefore, cannot be directly compared to speciation measurements from the Chemical Speciation Network (CSN).[32] The FRM mass measurement does not retain all ammonium nitrate and other semi-volatile materials (negative sampling artifacts) and includes particle bound water associated with sulfates, nitrates and other hygroscopic species (positive sampling artifacts). This results in FRM measured concentrations (and percent attribution of $PM_{2.5}$ mass) which may be different from the ambient levels of some $PM_{2.5}$ chemical constituents. Using the SANDWICH technique, it is possible to reconstruct $PM_{2.5}$ species so that they more closely match the composition of mass retained by the FRM. This adjustment can be applied to the modeled change in $PM_{2.5}$ species components. This will result in calculated $PM_{2.5}$ species mass, which is anchored to the measured mass, and more closely reflects the species concentrations that are retained on the FRM filters, including an estimate of particle bound water. See the photochemical modeling guidance (USEPA, 2014b; Frank, 2006) for more details on the recommended calculations.

The EPA provides a software package called the Software for the Modeled Attainment Test (SMAT), which provides default ambient data and performs the relative attainment test calculations. Assuming that the precursor impacts are calculated using base year modeling, a single SMAT run is needed to calculate precursor impacts. SMAT can be run with the base case concentrations as the “base year” and the zero-out/source apportionment or sensitivity model run case(s) as the “future year” (even though the model run does not actually represent a future year). The “future year” $PM_{2.5}$ concentration values are subtracted from the base year values to get the total $PM_{2.5}$ contribution from the precursor. The precursor impact is then compared to the threshold(s) identified in Section 2.2. If the precursor impacts are calculated using future year modeling, two SMAT runs are needed to calculate precursor impacts. The first SMAT run will calculate future year base case $PM_{2.5}$ concentrations using the base case and future year model outputs. The second SMAT run will calculate future year $PM_{2.5}$ concentrations from the zero-out/source apportionment or sensitivity model run(s). The two future year $PM_{2.5}$ concentration values are subtracted from each other to get the total $PM_{2.5}$ impact from the precursor. The precursor impact is then compared to the threshold(s) identified in Section 2.2.

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[32] The information in this section applies to the most common samplers in the CSN. Some networks use alternative special purpose samplers to collect both $PM_{2.5}$ and $PM_{2.5}$ speciation data. The characteristics of the sampler and the analytical procedures used to produce chemical speciation data should be considered in determining which, if any, adjustments are appropriate to make the data useful for comparison to FRM data.

When calculating modeled precursor impacts to $PM_{2.5}$, it is important to consider model performance. This is especially true in cases where air agencies choose to use absolute model results. If the model over predicts $PM_{2.5}$ species concentrations, the absolute modeled concentration changes may be biased high. Similarly, if the model under predicts $PM_{2.5}$ species concentrations, the absolute modeled concentration changes may be biased low. Therefore, model under predictions are a particular concern since this could lead to modeled precursor impacts that may be biased low.

5.4.1 Estimating the Annual $PM_{2.5}$ Impact from Precursors

The first step for estimating annual $PM_{2.5}$ impacts from a precursor is to estimate the annual average $PM_{2.5}$ at each monitor location (the grid cell where the monitor is located) for the baseline scenario. Second, calculate the annual average $PM_{2.5}$ at each monitor for the zero-out/source apportionment or sensitivity scenario. Calculate the difference between the zero-out/source apportionment or sensitivity scenario annual average $PM_{2.5}$ and baseline scenario annual average $PM_{2.5}$ for each monitor location. This difference is the impact from the $PM_{2.5}$ precursor. Based on the recommendation in Section 2.3, the impacts are calculated at monitor locations. When using the relative attainment test, the default recommendation is to average the concentrations at the nine (9) surrounding grid cells (a 3 x 3 matrix of grid cells, with the monitor in the center grid cell).

5.4.2 Estimating the Daily $PM_{2.5}$ Impact from Precursors

The first step for estimating 24-hour $PM_{2.5}$ impacts from a precursor is to estimate the 24-hour average $PM_{2.5}$ mass at each monitor location (the grid cell where the monitor is located) for the baseline scenario. Second, calculate the 24-hour average $PM_{2.5}$ at each monitor for the zero-out/source apportionment or sensitivity scenario. Calculate the difference between the zero-out/source apportionment or sensitivity scenario 24-hr average $PM_{2.5}$ and baseline scenario 24-hour average $PM_{2.5}$ for each day for each monitor location. This difference is the contribution from the $PM_{2.5}$ precursor. Based on the recommendation in Section 2.3, the contributions are calculated at monitor locations. When using the relative attainment test, the default recommendation is to use the single grid cell where the monitor is located to represent the location of the monitor.

When calculating absolute daily impacts, the highest 24-hour average $PM_{2.5}$ impact from the modeled time period should be compared to the daily $PM_{2.5}$ "contribution" threshold at each monitor location. If the highest daily average secondarily-formed $PM_{2.5}$ impact is greater than the level of the threshold, then a second tier analysis may be appropriate to further examine the precursor impacts on the high modeled and/or observed $PM_{2.5}$ days. Air agencies should consult with the appropriate EPA Regional office to discuss the details of the calculations.

Application of the relative attainment test (using SMAT) for the 24-hour NAAQS already takes into consideration the high measured $PM_{2.5}$ days. Therefore, no further (2nd tier) analysis is necessary to calculate the impact on exceedance days. The SMAT 24-hour air quality impact is calculated on high measured $PM_{2.5}$ days in the area.

6.0 Nonattainment New Source Review (NNSR) Precursor Demonstration

The $PM_{2.5}$ SIP Requirements Rule identifies a specific type of precursor demonstration that air agencies may use to demonstrate that sources of a particular precursor do not need to be controlled with respect to that precursor under the NNSR program for a particular $PM_{2.5}$ nonattainment area.[33] As detailed in the $PM_{2.5}$ SIP Requirements Rule, the NNSR precursor demonstration is based on the premise that the sensitivity of a particular nonattainment area to precursor emissions from future new major stationary sources and major modifications is best indicated by an emissions *increase* test. The sensitivity of an area to precursor increases may be different from the sensitivity of that same area to decreases (for example, where there is currently very little of the precursor). Therefore, for NNSR, the rule allows an air agency to undertake a sensitivity-based *increase* test in order to demonstrate that increases in emissions of a particular precursor would not contribute significantly to $PM_{2.5}$ levels that exceed the standard, and that sources of such precursor therefore may be exempted from $PM_{2.5}$ controls for that precursor(s) under the NNSR permitting requirements. Note that the NNSR precursor demonstration is optional and an air agency may satisfactorily demonstrate that a precursor is insignificant for all other control requirements other than NNSR, using the analyses previously described in this guidance or other appropriate analyses, without analyzing whether the precursor significantly contributes to $PM_{2.5}$ levels for the purposes of NNSR. In such cases, the nonattainment planning requirements would not apply to existing sources of that precursor, but the NNSR requirements would apply in the event that a new major source or major modification in that area triggers NNSR permitting. Such an approach may be efficient for air agencies who do not want to expend the resources necessary to complete an NNSR precursor demonstration because they expect few or no new or modified major sources of the precursor in question.

The NNSR precursor demonstration differs from the other two demonstrations (comprehensive and major source precursor demonstrations), which are attainment plan tests, in that the latter two demonstrations examine air quality changes resulting from emissions reductions from existing sources. By its nature, an attainment demonstration deals with existing emissions sources and how emissions reductions

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[33] *See* 40 CFR 51.1006(a)(3).

from those sources can help a nonattainment area reach attainment of the NAAQS. In contrast, the statutorily required NNSR program addresses the management of major source growth (new major stationary sources and major modifications) in the nonattainment area. Thus, by its nature, NNSR deals with *increases* of emissions in the nonattainment area. This is true even for an area that currently has no existing major stationary sources. In that case, it would be meaningless to examine decreases in emissions from "existing" major sources (because there are none). Nevertheless, $PM_{2.5}$ precursors from *new* major source growth occurring in the nonattainment area could still contribute significantly to $PM_{2.5}$ levels in the area. Therefore, the $PM_{2.5}$ SIP Requirements Rule mandates that NNSR precursor demonstrations be based on a sensitivity analysis involving potential increases of emissions in the nonattainment area.[34]

Similar to the questions described in Section 4.1, in performing a sensitivity analysis for NNSR, there are several questions that need to be addressed:

1) What amount of emissions increase should be examined as part of the NNSR sensitivity analysis?
2) What location(s) should be used to model the precursor emissions increases resulting from potential major source growth?
3) What air quality concentration threshold should be used to determine if the modeled air quality change from the precursor is insignificant?

The EPA recognizes that there may be a number of factors inherent to a particular nonattainment area that could influence the potential emissions increase from new major stationary sources and major modifications. The following section addresses these factors and sets forth guidance for air agencies to consider in completing the NNSR precursor demonstration.

6.1 NNSR Demonstrations

The purpose of the NNSR precursor demonstration is to determine if the nonattainment area is sensitive to $PM_{2.5}$ precursor emissions increases that may occur in a particular area from new major stationary sources and/or major source modifications. It would be appropriate for the air agency to base estimates of any potential emissions increases in part on the types and size of new major stationary sources that are most likely to locate within the nonattainment area and/or existing sources most likely to undergo a major modification. To help determine the size and types of potential sources, the EPA also recommends an examination of recent (*e.g.*, the last 5 years) major source permits in the region. In order to gather enough information on recently permitted emissions sources, it will likely be necessary to examine a broad region encompassing the

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[34] *See* 40 CFR 51.1005(a)(3)(i).

nonattainment area. For example, an air agency may want to examine permits issued within the entire Northeast, Southeast, or Midwest region. The importance of gathering information concerning permitted major sources that have located elsewhere is that the air agency can utilize information (magnitude of emissions, stack parameters, etc.) from those permits that will make the modeling of precursor emissions more realistic.

The identified range of emissions from recently permitted major sources may vary widely among $PM_{2.5}$ precursors. SO_2, NOx and VOC are $PM_{2.5}$ precursors that are also regulated as pollutants associated with other NAAQS, while ammonia is not nationally regulated under any NAAQS. All new major sources and major modifications of SO_2, NOx and VOC must already meet Best Available Control Technology (BACT) level controls and all other NSR program requirements (and Lowest Achievable Emissions Rate [LAER] controls if they are located in nonattainment areas). The treatment of SO_2, NOx and VOC under the NSR program for other NAAQS pollutants (besides $PM_{2.5}$) has an impact on the potential increase of $PM_{2.5}$ precursor emissions from new sources even absent controls as a $PM_{2.5}$ precursor. Therefore, how the particular precursor is treated as a result of regulation pursuant to other NAAQS is an important consideration when determining the potential emissions increases that should be modeled for a $PM_{2.5}$ NNSR precursor demonstration.

Other important considerations for determining the amount of emissions increase that should be analyzed in the NNSR precursor demonstration include but are not limited to: the size of the nonattainment area, the number of existing major stationary sources (from which major modifications could occur), natural resources available to support new sources, economic focus of the area and associated potential growth (conducive to a particular industry/source category).

Upon the EPA's approval of a NNSR precursor demonstration, the air agency would not need to apply the $PM_{2.5}$ control requirements to new major stationary sources and major modifications with respect to that precursor under the NNSR program for $PM_{2.5}$ (for the current SIP). Therefore, the NNSR demonstration should include a conservative representation of potential emissions increases from new and modified major sources. For example, the modeled size of sources (in tons per year of emissions) and the number and location of sources should be adequately conservative to analyze more than what is merely "likely" to occur in the area. The goal of the NNSR demonstration is not simply to determine the $PM_{2.5}$ air quality impact of likely new sources. Instead, it is to examine whether the nonattainment area is sensitive to increases of precursor emissions and whether the resulting $PM_{2.5}$ air quality change that could result from potential major source growth would be a significant contribution to $PM_{2.5}$ levels that exceed the NAAQS in a $PM_{2.5}$ nonattainment area. It is, however, important to consider the potential size and number of new sources of $PM_{2.5}$ precursors that may possibly locate in the nonattainment area (using conservative assumptions) when planning the analysis.

6.2 Modeling for NNSR Demonstrations

The fundamental approach for analyzing changes in emissions pursuant to the NNSR precursor demonstration involves the use of a photochemical model to project the air quality changes associated with various potential emissions increases from hypothetical new major stationary sources or major modifications. In most cases, it will not be sufficient to model emissions increases from existing major sources in the area. Some nonattainment areas may only have one or, in some cases, no existing major sources. Moreover, it is important to examine the area's sensitivity to emissions increases from potential source locations across the entire nonattainment area because a new source may locate in any part of the nonattainment area. New and/or modified sources could contribute significantly to existing monitored locations within the nonattainment area or cause new exceedances of the standard in other parts of the nonattainment area. Therefore, in most cases it will be necessary to model a number of hypothetical new sources, placed in various locations across the nonattainment area. The location of existing major sources and the stack parameters of those sources can be used to help design the NNSR modeling demonstration. The existing major source information can be the starting point of the analysis, with additional hypothetical new sources (that may or may not resemble existing sources) placed in other parts of the area, as necessary.

The EPA also recommends modeling multiple hypothetical sources with emission rates and stack release characteristics typical of existing sources in the area or region. The overall approach for hypothetical source impact assessment would be generally similar to the analysis documented in "Estimating ozone and secondary $PM_{2.5}$ impacts from hypothetical single source emissions in the central and eastern United States" (Baker, 2015). Choices made for these hypothetical sources should be done in consultation with the appropriate EPA Regional office.

Due to the unique sensitivity levels of nonattainment areas to air quality impacts from individual $PM_{2.5}$ precursors, the EPA is not making default recommendations on the size and number of hypothetical new and/or existing sources to model in a NNSR demonstration. The details of the analysis, including a modeling protocol, should be discussed in advance with the appropriate EPA Regional office.

6.2.1 Types of Models

Quantifying secondary pollutant formation requires simulating chemical reactions and thermodynamic gas-particle partitioning in a realistic chemical and physical environment. Therefore, in most cases, the EPA believes it will be necessary to employ a CTM for NNSR precursor demonstrations. CTMs treat atmospheric chemical and physical processes such as deposition and transport. In some limited cases, a simplified box model that employs chemistry may be sufficient. Below, we describe additional details for the purposes of estimating the magnitude of secondarily-formed $PM_{2.5}$ from $PM_{2.5}$ precursor emissions associated from major source growth.

6.2.2 Modeling for Major Point Sources

A variety of Lagrangian and Eulerian modeling systems exist that could potentially be used to estimate point source impacts from major sources on secondarily-formed pollution such as $PM_{2.5}$. These modeling systems represent varying levels of complexity in the treatment of plume chemistry and the chemical and physical environment in which the plume exists. It is important that any Lagrangian or Eulerian modeling system be appropriately applied for assessing the effects of major stationary sources on secondarily-formed pollutants such as $PM_{2.5}$ for the purposes of a precursor demonstration (USEPA, 2005).

Lagrangian modeling systems that have been used to assess single source impacts in North America include CALPUFF, HYSPLIT, FLEXPART, SCIPUFF, and SCICHEM. Some Lagrangian models treat in-plume gas and particulate chemistry. These models require time and space varying oxidant concentrations and, in the case of $PM_{2.5}$, also neutralizing agents (such as ammonia) as important secondary impacts happen when plume edges start to interact with the surrounding chemical environment (Baker and Kelly, 2014; ENVIRON, 2012). These oxidant and neutralizing agents are not routinely measured, but can be generated with a three dimensional photochemical transport model and subsequently input to a Lagrangian modeling system.

It is therefore possible to use a Lagrangian model to support an NNSR precursor demonstration but, since it is likely that multiple hypothetical sources will need to be modeled and the Lagrangian model requires realistic background oxidant information (which can be supplied from a photochemical model), it will be easier in most cases to use a photochemical grid model for the demonstration. See Section 5 for more details on photochemical grid models.

It is important that modeling systems used for these assessments be fit for this purpose and evaluated for skill in replicating meteorology and atmospheric chemical and physical processes that result in secondary pollutant formation and deposition. A candidate model for use in estimating the effects of precursors emitted from potential major point sources on secondarily-formed $PM_{2.5}$ for the purposes of a NNSR precursor demonstration should meet the general criteria for an “alternative model” outlined in 40 CFR part 51, Appendix W, Section 3.2 (USEPA, 2005). The determination of acceptability of a particular model and approach for that model application is an EPA Regional office responsibility.

6.2.3 Modeling Approaches for NNSR Demonstrations

The simplest modeling approach to calculate impacts for a NNSR precursor demonstration (brute force change to emissions) is to simulate two sets of conditions: one with all existing emissions and one that includes an increase in emissions of the precursor that could result from major source growth (new major stationary sources and major modifications) (Baker and Kelly, 2014; Bergin et al., 2008; Kelly et al., 2015; Zhou et al., 2012). The difference between these simulations provides an estimate of the air quality change related to the increase in emissions from the precursor. Additionally, some photochemical models have been instrumented with source apportionment, which tracks emissions from specific sources, source sectors, and/or source regions through chemical transformation, transport and deposition processes to estimate an impact to predicted air quality (Kwok et al., 2015; Kwok et al., 2013). Source apportionment has been used to differentiate the impact from single sources on model predicted ozone and $PM_{2.5}$ (Baker and Foley, 2011; Baker and Kelly, 2014; Baker et al., 2015).

Alternatively, the Direct Decoupled Method (DDM) source sensitivity technique has also been used to estimate ozone and $PM_{2.5}$ impacts from specific sources (Baker and Kelly, 2014; Bergin et al., 2008; Cohan et al., 2005; Cohan et al., 2006; Kelly et al., 2015).

Since a NNSR precursor demonstration may require modeling multiple sources in multiple locations, an advanced technique such as source apportionment may save resources compared to numerous brute force model runs. Air agencies can choose the most efficient modeling technique for their particular situation; discussing the options in advance with the appropriate EPA Regional office is strongly advised.

6.2.4 Horizontal Grid Resolution for NNSR Demonstrations

Major stationary source assessments for nonattainment areas should be conducted at horizontal grid resolutions between ~1 kilometer (km) up to ~12 km. Photochemical grid model application up to 12 km has been shown to capture similar changes in air quality due to changes in emissions from a specific source on secondary pollutants in an urban area estimated with finer grid resolution (Cohan et al., 2006). In instances where sources may be modeled at coarser resolutions or at resolutions finer than 1 km, consultation with the appropriate EPA Regional office is advised.

Even though single source emissions are averaged into a grid volume, photochemical transport models have been shown to adequately capture single source impacts when compared with downwind in-plume measurements (Baker and Kelly, 2014; Zhou et al., 2012). Where set up appropriately for the purposes of assessing the impact of single sources on secondarily-formed pollutants, photochemical grid models could be used with a variety of approaches to estimate these impacts (see Section 6.2.3, above).

In some instances, where the source and key receptors are in very close proximity, the source and receptor may be located in the same photochemical grid model cell. Since physical and chemical processes represent a volume average, this may not adequately represent the gradients of pollution possible between the source and receptor when they are located in such proximity. The preferred approach to better represent the spatial gradient in source-receptor relationships when they are in close proximity is to use smaller sized grid cells. In such cases, grid resolution should be defined such that the source and receptor are no longer in the same grid cell. Ideally, there should also be several grid cells between the source and receptor to resolve best near-source pollution gradients.

In situations of close proximity between the source and receptor, a photochemical model instrumented with sub-grid plume treatment and sampling could potentially represent these relationships. Sub-grid plume treatment extensions in photochemical models typically solve for in-plume chemistry and use a set of physical and chemical criteria for a determination of when puff mass is merged back into the host model grid. A notable limitation of sub-grid plume treatments is that these implementations do not have more refined information related to meteorology or terrain than the host grid cell. In addition to tracking puffs at sub-grid scale, the host modeling systems must be able to track and output surface layer sub-grid puff concentrations, "sub-grid plume sampling," to best represent receptor concentrations that are in close proximity to the source (Baker et al., 2014). Another important reason sub-grid plume sampling is necessary is that inherently in this type of system (sub-grid plume treatment in a photochemical grid model) some of the source's impacts on air quality are resolved in puffs at the sub-grid scale and some have been resolved in the 3-dimensional grid space. Just extracting sub-grid plume information or just 3-dimensional model output would miss some of the source's impacts on air quality, which means that accounting for both is necessary either with sub-grid sampling or options that integrate puffs within a grid cell with grid cell concentrations. Sub-grid plume treatments in photochemical grid models do not track grid-resolved source impacts separately from other sources in the model simulation. When either sub-grid treatment is applied for a NNSR precursor demonstration, source apportionment or source sensitivity is necessary to track the grid-resolved source impact in addition to sub-grid plume treatment to fully capture source impact.

6.3 Location of Potential Major Source Growth

Air agencies should consult with the appropriate EPA Regional office to determine the appropriate number and location of potential major sources in a NNSR precursor demonstration. Enough locations should be included in the demonstration such that new sources are placed in a variety of chemical regimes to provide full coverage over the nonattainment area. "Estimating ozone and secondary $PM_{2.5}$ impacts from hypothetical single source emissions in the central and eastern United States" (Baker,

2015) provides examples of different types of hypothetical sources, modeled to examine secondary $PM_{2.5}$ impacts. The journal article examined the $PM_{2.5}$ concentration impacts from several different size sources with different stack parameters. For example, hypothetical sources were modeled in different areas across the country using stack parameters that represented both elevated sources and near ground level sources. The techniques applied in that study may be useful for designing future major sources for sensitivity modeling in NNSR precursor demonstrations. In addition, the air agency may demonstrate that certain locations are clearly unsuitable for major source growth (*e.g.*, agricultural, residential and resort areas) so that they can be eliminated as potential growth sites for the modeling analysis.

6.4 Significant Impact Thresholds

The EPA recommends that the sensitivity analysis for NNSR, which involves potential future emissions increases associated with new major stationary sources and major modifications, rely on the same recommended thresholds that were described earlier in Section 2.2 of this guidance.

6.5 Base Year and Future Year Model Assessments

Modeled attainment demonstrations typically include modeling for both a base year (used to evaluate model performance) and a future year, which typically corresponds to the attainment date. Meteorological fields are developed for the base year and held constant in the future year modeling. Future year emissions fields are used to simulate the impact of emissions controls (including growth) on future air quality concentrations. Attainment demonstrations use the future year modeled air quality concentrations to determine if attainment is likely to be reached by the applicable attainment deadline. Accordingly, air agencies should evaluate emissions controls in the context of achieving needed air quality improvements in the attainment year. On the other hand, air agencies should account for the fact that new major stationary sources could locate in the nonattainment area at any time between the nonattainment designation date and the date when the area is eventually redesignated to attainment. Since NNSR provisions are effective immediately after the area is designated as nonattainment, there is some basis for using base case modeling for a NNSR precursor demonstration. However, in some situations, particularly where no new major source permit applications have yet been filed and any new major sources would, therefore, not be in operation for a number of years, air agencies may find that future year modeling could more accurately reflect atmospheric conditions for secondary $PM_{2.5}$ formation when precursor emissions increases from potential major source growth may occur. Air agencies should consult the appropriate EPA Regional office to determine the appropriate analysis years.

6.6 Calculating the Modeled Impact from Precursors

The modeled precursor impacts on $PM_{2.5}$ concentrations can be calculated either as the absolute modeled concentration changes or as relative concentration changes, based on the percent modeled change in $PM_{2.5}$ species, applied to ambient data. The photochemical modeling guidance recommends performing a "relative" attainment test for modeled attainment demonstrations. However, modeling for PSD analyses of single point sources typically uses absolute model results (USEPA, 2005 and USEPA, 2014a). Since the modeled emissions and stack parameters from major sources are well characterized and known, the use of absolute concentration change estimates from those sources in a photochemical model is in most cases appropriate. Adjusting the single source impacts up or down based on overall modeled concentrations of species (using the relative attainment test procedures) may in some cases inappropriately adjust the absolute modeled concentration change. Additionally, it is necessary to estimate source impacts throughout the area potentially impacted by major sources, not just at locations where monitors exist. Therefore, the EPA recommends using absolute model outputs to calculate major source impacts for NNSR precursor demonstrations. There may be some cases where relative impacts for a NNSR precursor demonstration may be appropriate. However, air agencies should consult with the appropriate EPA Regional office to determine the most appropriate post-processing procedures for the area.

6.6.1 Estimating the Annual $PM_{2.5}$ Impact from Precursors - NNSR Demonstration

The first step for estimating annual $PM_{2.5}$ impacts from a precursor is to estimate the annual average $PM_{2.5}$ at each receptor in the nonattainment area (if using a grid model, each grid cell is a receptor) for the baseline scenario. The second step is to calculate the annual average $PM_{2.5}$ at each receptor for the sensitivity scenario. The final step is to calculate the difference between the sensitivity scenario annual average $PM_{2.5}$ and baseline scenario annual average $PM_{2.5}$ for each receptor. This difference yields the impact from the $PM_{2.5}$ precursor. Based on the recommendation in Section 2.3, the impacts are calculated for all locations (grid cells) within the nonattainment area and should be compared to the thresholds recommended in Section 2.2.

6.6.2 Estimating the Daily $PM_{2.5}$ Impact from Precursors

The first step for estimating 24-hour $PM_{2.5}$ impacts from a precursor is to estimate the 24-hour average $PM_{2.5}$ at each receptor in the nonattainment area (if using a grid model, each grid cell is a receptor) for the baseline scenario. The second step is to calculate the 24-hour average $PM_{2.5}$ at each receptor for the sensitivity scenario. The final step is to calculate the difference between the sensitivity scenario 24-hour average $PM_{2.5}$ and baseline scenario 24-hour average $PM_{2.5}$ for each day for each receptor. This difference yields the impact from the $PM_{2.5}$ precursor. Based on the recommendation in Section

2.3, the contributions are calculated for all locations (grid cells) within the nonattainment area.

When calculating absolute daily impacts, the highest 24-hour average $PM_{2.5}$ impact from the modeled time period should be compared to the daily $PM_{2.5}$ threshold at each grid cell. If the highest daily average secondarily-formed $PM_{2.5}$ contribution is greater than the level of the threshold, then a second tier analysis may be appropriate to further examine the precursor impacts on the highest modeled $PM_{2.5}$ days. Air agencies should consult with the appropriate EPA Regional office to discuss the details of the calculations.

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