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Executive Summary

Jeremy Nichols is the Climate and Energy Program Director for WildEarth Guardians, a nonprofit environmental advocacy organization whose missions is to protect wildlife, wild places, wild rivers, and health in the American West. Jeremy has held this position since August 2008. Prior to holding this position, Mr. Nichols founded and directed the clean air advocacy organization, Rocky Mountain Clean Air Action.

In his capacity as Climate and Energy Program Director, Jeremy develops, directs, and leads the implementation of advocacy strategies to protect the climate through the advancement of clean energy, environmental and health safeguards, and policies that reduce greenhouse gas emissions. These efforts frequently entail engaging in air quality issues and advancing policies, actions, and accountability around clean air.

His experience with air quality regulation is extensive and diverse. For over 15 years, Mr. Nichols has been involved in the development of rules, permits, policies, and actions to address air quality concerns in the western United States, at both a federal and state level.

Experience

2008- Present: **WildEarth Guardians, Climate and Energy Program Director**. Developing and leading initiatives to advance action to reduce greenhouse gas emissions and safeguard the climate in the western United States, including initiatives to confront air pollution, drive accountability for public health, and enforce the Clean Air Act. Working from the organization's Denver Office, have developed and managed coalitions and projects to address air quality issues affecting health, the environment, and climate in Colorado, Montana, New Mexico, Utah, Wyoming, and other western states. In collaboration with scientists, attorneys, policymakers, elected officials, and the general public, have helped secure greater accountability to climate and clean air in the American West.

2005-2008: **Rocky Mountain Clean Air Action, Executive Director**. Founded and directed the nonprofit advocacy group in its efforts to address air quality issues in the western United States and ensure compliance with state and federal clean air laws across the region. Working from Denver, Colorado, engaged with constituents across the western United States to promote

greater public involvement in air quality proceedings and used the law, science, and policy to spur the development and implementation of stronger clean air safeguards in states including Colorado, New Mexico, and Wyoming.

2000-2005: **Biodiversity Conservation Alliance, Program Director.** Developed and led conservation program for local grassroots advocacy group located in Laramie, Wyoming. Conservation advocacy work included developing science-based petitions to protect endangered species, working with scientists to develop and advance forest management policies, gathering water quality data and driving action to protect clean water, and working with local attorneys and members of the public to ensure compliance with clean air and water laws at local facilities.

Education

1998-2004: **University of Wyoming**. Completed six years toward a B.S. in Geology, a minor in Chemistry, and additional classes toward a B.A. in Women's Studies. Enrolled in Honors Program.

Examples of Relevant Professional Engagement

2006

On behalf of Rocky Mountain Clean Air Action, engaged rulemaking hearing to update regulations for oil and gas industry emissions in the Denver Metro ozone nonattainment area. Participation included draft and submitting prehearing filings and providing technical testimony during in-person hearing in December 2006.

2007

On behalf of Rocky Mountain Clean Air Action, provided technical testimony to the New Mexico Environmental Improvement Board for rulemaking to adopt mandatory greenhouse gas reporting rules. Testimony specifically addressed issue of oil and gas industry reporting of greenhouse gas emissions. Provided oral testimony to the Environmental Improvement Board during October 2-3, 2007 rulemaking hearing.

2008

On behalf of Rocky Mountain Clean Air Action, drafted and filed "Petition for Objection to Issuance of Operating Permit for Anadarko Petroleum Corporation's Frederick Compressor Station," https://www.epa.gov/sites/production/files/2015-08/documents/anadarko_petition2008.pdf.

On behalf of WildEarth Guardians, filed petition with U.S. Environmental Protection Agency to strengthen regulation of interstate transport of ozone and ozone forming emissions in western United States. Petition was filed in December 2008, http://wg.convio.net/support_docs/petition_final-EPA-ozone-transport.pdf.

2009

Drafted and filed notice of intent to file suit over Clean Air Act violations at coal-fired power plant owned by Xcel Energy north of Denver. Ultimately worked closely with attorneys for several years to advance case, which was ultimately settled, https://pdf.wildearthguardians.org/site/DocServer/WG_vs_XCEL_ENERGY_final_proposed_CD.pdf.

2010

On behalf of WildEarth Guardians, drafted and submitted "Petition for Objection to Issuance of Operating Permit for Public Service Company of New Mexico's San Juan Generating Station," https://www.epa.gov/sites/production/files/2015-08/documents/san_juan_petition2010.pdf

Together with partner organizations, drafted and submitted rulemaking petition to U.S. Environmental Protection Agency to list coal mines as a source category for purposes of regulation under Section 111 of the Clean Air Act, https://www.biologicaldiversity.org/programs/climate_law_institute/global_warming_litigation/clean_air_act/pdfs/Coal_Mine_Petition-06-15-2010.pdf.

2011

Drafted and submitted comments to the U.S. Environmental Protection Agency regarding the State of Nevada's regional haze state implementation plan, https://pdf.wildearthguardians.org/site/DocServer/2011-8-22_Nevada_Regional_Haze_Comments.pdf.

2012

Secured U.S. Environmental Protection Agency response to petition to object to Title V Operating permit issuance for EVRAZ Rocky Mountain Steel Mill in Pueblo, Colorado, https://www.epa.gov/sites/production/files/2015-08/documents/evraz_response2011.pdf.

2013

Working with attorneys, developed and drafted legal complaint over U.S. Environmental Protection Agency failure to take action on Title V Operating Permit application for Bonanza coal-fired power plant in Utah, https://pdf.wildearthguardians.org/site/DocServer/Final_Complaint_12-20-2013.pdf.

2014

Drafted and submitted petition to the U.S. Environmental Protection Agency to designate Uinta Basin of northeast Utah an ozone nonattainment area due to ongoing violations of ambient air quality standards, http://www.riversimulator.org/Resources/farcountry/Air/UIntaBasinOzoneNonattainmentPetitionJan2014.pdf.

2015

Drafted and filed Petition for Review with U.S. Environmental Appeals Board over U.S. Environmental Protection Agency approval of Title V Operating Permit for Bonanza power plant in Utah, https://yosemite.epa.gov/OA/EAB_WEB_Docket.nsf/Filings%20By%20Appeal%20Number/8E7A7CA8B99D57B085257DC700663152/$File/2015-1-7%20WG%20Deseret%20Petition%20for%20Review.pdf.

Drafted and filed notice of intent to file suit over U.S. Environmental Protection Agency failure to promulgate federal implementation plan to address regional haze in the State of Utah, https://www.epa.gov/sites/production/files/2015-05/documents/weg_noi_01212015.pdf.

2016

Working with WildEarth Guardians attorneys, helped negotiate agreement around the Craig coal-fired power plant located in northwest Colorado, https://wildearthguardians.org/press-releases/wildearth-guardians-reaches-western-colorado-clean-air-and-clean-energy-agreement/.

2017

Working with WildEarth Guardians attorneys, drafted notice of intent to file suit over Clean Air Act violations at Colorado Springs coal-fired power plant and legal complaint against Colorado Springs Utilities over violations, https://pdf.wildearthguardians.org/site/DocServer/Complaint_Doc_1__1_.pdf.

2018

Drafted and filed petition for review to U.S. Environmental Appeals Board over Environmental Protection Agency approval of six Title V Operating Permits in the Uinta Basin of northeast Utah, https://yosemite.epa.gov/oa/EAB_Web_Docket.nsf/Filings%20By%20Appeal%20Number/417F3A33696C3725852582C500422870/%24File/2018-7-7%20EAB%20Appeal%20of%20Anadarko%20SMNSR%20Permits.pdf.

2019

Drafted and submitted written testimony and provided expert oral testimony to the Colorado Air Quality Control Commission in December 2019 rulemaking hearing regarding revised regulations to reduce ozone forming emissions from the oil and gas sector in Colorado.

2020

Drafted and submitted written testimony and provided expert oral testimony to the Colorado Air Quality Control Commission in December 2020 rulemaking hearing regarding Colorado's revised state implementation plan for the Denver Metro serious ozone nonattainment area.

2021

Working closely with WildEarth Guardians' attorneys, helped draft legal complaint over the State of Colorado's failure to take action on Title V Operating Permit applications for Denver area oil refinery, https://pdf.wildearthguardians.org/support_docs/Guardians%20Suncor%20Title%20V%20Complaint%20-%20Adams%20County.pdf.

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Article

Making the Environmental Justice Grade: The Relative Burden of Air Pollution Exposure in the United States

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Abstract: This paper assesses whether the Clean Air Act and its Amendments have been equally successful in ensuring the right to healthful air quality in both advantaged and disadvantaged communities in the United States. Using a method to rank air quality established by the American Lung Association in its 2009 State of the Air report along with EPA air quality data, we assess the environmental justice dimensions of air pollution exposure and access to air quality information in the United States. We focus on the race, age, and poverty demographics of communities with differing levels of ozone and particulate matter exposure, as well as communities with and without air quality information. Focusing on $PM_{2.5}$ and ozone, we find that within areas covered by the monitoring networks, non-Hispanic blacks are consistently overrepresented in communities with the poorest air quality. The results for older and younger age as well as poverty vary by the pollution metric under consideration. Rural areas are typically outside the bounds of air quality monitoring networks leaving large segments of the population without information about their ambient air quality. These results suggest that substantial areas of the United States lack monitoring data, and among areas where monitoring data are available, low income and minority communities tend to experience higher ambient pollution levels.

Keywords: environmental justice; air pollution; ozone; particulate matter

1. Introduction

The Clean Air Act of 1970, as amended in 1990, gives the United States Environmental Protection Agency (EPA) the mandate to regulate air pollutant emissions. Under the Clean Air Act, the EPA is required to set National Ambient Air Quality Standards (NAAQS) for pollutants considered harmful to public health and the environment within an "adequate margin of safety" [1]. In response to this mandate, the EPA has established NAAQS for six major pollutants, most commonly called the "criteria air pollutants," including particulate matter (PM_{10} and $PM_{2.5}$) and ozone. In setting NAAQS, the EPA explicitly considers sensitive subpopulations [1]. Because the Clean Air Act establishes an expectation of clean air everywhere through nationally uniform standards, it essentially establishes clean air as a right of all people of the United States. This paper explores whether differential potential exposure to ozone and particulate matter exist between advantaged and disadvantaged populations.

Significant research has been directed toward understanding the potential health effects of air pollution. After major improvements in air quality in the 1970s and 1980s, research now focuses on the impacts of lower level chronic exposure to various pollutants, including fine particulate matter ($PM_{2.5}$) and ozone [2]. Fine particles penetrate deeply into the respiratory system and may have other toxic substances (lead, sulfates, and various metals) adsorbed to their surface [2]. Even at levels lower than the current NAAQS, particulate matter and ozone are linked to mortality and hospital visits [3,4], commonly through their impact on respiratory and cardiovascular disease [2,5]. In addition, exposure to particulate matter and ozone has been linked to poor birth outcomes [6-9].

To assess whether geographic areas are in compliance with the NAAQS, a network of air pollution monitors that measure ambient levels of each of the criteria pollutants has been established across the United States. The number of monitors in a given location typically reflects the population density of the area with a minimum number of monitors prescribed by regulation. For ozone, a minimum of two monitors are required for areas with a population greater than 200,000. If an area has an ozone nonattainment designation of serious, severe, or extreme, up to five monitors are required [10]. For $PM_{2.5}$, the number of required monitors ranges from 1 in metropolitan statistical areas (MSAs) with populations greater than 200,000, to 10 in MSAs with populations greater than 8 million [11]. The monitoring network used for ozone is separate from and uses different equipment than the monitoring network for particulate matter.

The principal objective of the monitoring network is to measure ambient concentrations of various pollutants where people live, work, and play. Ozone monitors are placed to measure the ozone concentration where the highest population density might be exposed to a significant ozone concentration and in areas with maximum downwind concentration [10]. For compliance with the annual $PM_{2.5,}$ standard, monitors are located at sites that represent exposure on an urban or community scale, while sites representing maximum exposure are selected for evaluation against the short-term 24-hour standard [11].

The American Lung Association (ALA) issues an annual report entitled "The State of the Air," which uses data from the U.S. EPA's Air Quality System (AQS) to characterize the ozone and $PM_{2.5}$ concentrations at each monitoring site across the United States [12]. These two pollutant are especially relevant for evaluating human health impacts, as they have been linked to adverse health outcomes, even at low concentration levels [2,6]. The ALA describes trends in the number of sites where air quality has either improved or worsened over the past year and lists America's "cleanest" and "dirtiest" cities with respect to air quality.

This paper uses the air quality ranking approach established by the ALA in its 2009 State of the Air report along with EPA air quality data to assess the environmental justice (EJ) dimensions of air pollution exposure in the United States. The EPA defines environmental justice as:

> "the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. EPA has this goal for all communities and persons across this Nation [13]."

Racial and economic disparity in environmental quality have long been recognized in the United States. The environmental justice movement arose from community concern that toxic waste sites were disproportionally located in poor and minority communities, as described by Robert Bullard in his early work, including "Dumping in Dixie" [14]. A 1987 report by the United Church of Christ Commission for Racial Justice, "Toxic Wastes and Race in the United States" catalyzed national attention when it documented that hazardous waste facilities were sited disproportionately in communities of color [15]. This report was updated in 2007 to use 2000 Census data and more sophisticated spatial analytical techniques, and found that disparities in the location of hazardous waste sites has persisted [16].

Research on environmental justice and equity has investigated whether certain groups have higher exposure to pollution, lower overall environmental quality and amenities, and abnormally high rates of environmentally-driven disease compared to other racial, ethnic, or socioeconomic groups. These studies have been conducted on a variety of pollutants and pollution sources including air pollution, Superfund sites, and manufacturing facilities [17-20]. These analyses have generally demonstrated a correlation with both income and race though there is much variation across regions and amongst these variables that is not well explained [19,21]. Spatially-based approaches are powerful ways to characterize environmental inequity [22,23].

In this paper, we focus on the EJ implications of poor air quality and of monitoring network design by analyzing the race, ethnicity, age, and poverty demographics of communities with differing levels of ozone and particulate matter exposure. The objectives of this paper are to:

- Determine whether counties with sufficient AQS monitoring data are different on key demographic variables compared to those without AQS monitors or with insufficient data (this speaks to the location of the AQS monitors).
- Use the ALA methodology for rating air quality to conduct a national county-level analysis assessing the association between air quality and race, ethnicity, age, and poverty rates.
- Use a buffer analysis to develop a highly resolved geographic analysis of the EJ implications of air quality in the United States.

We are particularly interested in how the implementation of the Clean Air Act and its Amendments has shaped air quality in both advantaged and disadvantaged communities in the United States.

2. Experimental Section

2.1. Air Quality Monitoring Data

We queried the AQS Data Mart [24] for daily 8-hr maximum concentrations of ozone at each monitoring site in the United States in 2005, 2006, and 2007. Consistent with the methodology employed by the ALA, only measurements during the EPA-defined ozone season and only 8-hr ozone concentrations that were based on 6–8 hours of hourly measurements were included in the analysis. The ozone season is designated by EPA on a state-by-state basis, reflecting different seasons of hot weather. Most states in the contiguous United States have an April to September-October ozone season [25].

Daily 24-hour averaged $PM_{2.5}$ concentrations collected using EPA approved reference and equivalent methods during the 2005–2007 period at each monitoring site were also obtained from the AQS database [26]. Annual $PM_{2.5}$ data for 2005–2007 were downloaded as EPA-summarized, annual design values at the county-level [27].

2.2. From Monitoring Data to Air Quality Metrics

We reproduced the ranking methodology for ozone and daily $PM_{2.5}$ previously described in detail in the ALA State of the Air 2009 report [12]. We specifically chose to use the ALA approach because it is highly-regarded and widely cited. The annual report presents a practical and transparent way to condense and present thousands of data points in a manner that is understandable and familiar to the general public and to policymakers. The ALA assigns grades separately for both ozone levels and daily $PM_{2.5}$ levels ranging from "A" to "F" to each county in the United States (where sufficient monitoring data are available for each pollutant). These grades are based on the weighted average of the number of days on which at least one monitor in a county reported a pollution level reaching an air quality designation of orange (unhealthy for sensitive populations, weighting factor = 1), red (unhealthy, weighting factor = 1.5), purple (very unhealthy, weighting factor = 2), or maroon (hazardous, weighting factor = 2.5) [12]. The ALA uses the county-level weighted average number of poor air quality days to assign a letter grade to each county based on the severity of air pollution. This grading was done separately for ozone and daily $PM_{2.5}$ both because the two pollutants are measured by different monitors which may or may not be placed in the same counties, but also because they represent different reasons for concern. Our methodology differed from that of the ALA in that we did not use the letter grade categorization, but instead used the weighted average of the number of days with poor air quality as a direct metric of air quality. In addition to the county-level analysis, we used the same approach to calculate weighted average number of poor air quality days for each individual ozone and daily $PM_{2.5}$ monitor, allowing us to do sub-county analysis.

In addition to metrics based on daily ozone and $PM_{2.5}$ data, attainment of the year-round particulate pollution (annual $PM_{2.5}$) NAAQS is accessed using "design values" that are calculated by EPA. A design value is defined by EPA as a statistic, based on multiple years of monitoring data which

describes the air quality status of a given area relative to the level of the NAAQS [28]. In our analysis, we used the 2005–2007 annual $PM_{2.5}$ design values to rank county-level air quality. Since annual $PM_{2.5}$ design values are available only at the county-level, individual monitoring sites could not be ranked for annual $PM_{2.5}$. Note that the daily ozone and $PM_{2.5}$ metrics provide measures of short term peak exposures, and the annual $PM_{2.5}$ design value metric provides a measure of long term exposure.

We used three air quality metrics—weighted averages of the number of poor air quality days for (1) daily ozone, (2) daily $PM_{2.5}$, and (3) design values for annual $PM_{2.5}$—to rank order all counties with sufficient air quality monitoring data. This allowed us to identify the 20% of counties with the best air quality and the 20% of counties with the worst air quality for each pollution metric. (We note that other comparisons are certainly available and relevant; we chose the top/bottom 20% because it allows us to compare extremes while maintaining a sufficiently large sample size—and is also a familiar metric comparison to the general public.) We first determined the best 20% and worst 20% of counties nationally and then did the same for each of the individual 10 EPA regions. Then, for ozone and daily $PM_{2.5}$, we ranked individual monitoring sites based on the weighted averages of the number of poor air quality days to identify the 20% of monitoring sites with the best and worst air quality. The monitor-level rankings were only done at the national level.

2.3. Demographic Data

Demographic and socioeconomic data were obtained from the 2000 U.S. Census. County and block group level data on age, race, ethnicity, and poverty status were extracted from the Summary Tape File 3 database [29]. Using standard variable definitions from the U.S. Census, we identified percent under 5 years of age, percent 65 years of age and older, percent non-Hispanic black (NHB), percent Hispanic, and percent in poverty as key metrics of environmental justice. While many other demographic variables have been considered in the literature (e.g., percent female-headed households [19]), our selected variables are highly correlated with those of other studies. Recognizing that 2000 Census data may now be outdated and not fully reflect the current composition of communities, we explored using the U.S. Census 2005–2007 American Community Survey (ACS) estimates of key demographic and socioeconomic measures. Although the ACS estimates temporally correspond with the air quality data used in this analysis, ACS data is currently limited to geographic areas with at least 20,000 people [30]. Given the limitations of the ACS, we believe that the advantages of using the Census 2000 data, including the ability to use more geographically refined data and the inclusion of geographic areas with fewer than 20,000 people, outweighed the issue of using older demographic and socioeconomic data in this case. The Census 2000 data will still highlight any systematic differences in the populations affected by different levels of air pollution, and once the 2010 U.S. Census data are available, we plan to run the analyses presented here with updated air quality and demographic data.

2.4. Statistical Analysis

For counties without air quality monitoring data, or less than three years of monitoring data in the 2005–2007 study period, we could not calculate the air quality metrics. In order to determine if there were differences between communities with access to information about their air quality and those lacking such access or information, we compared the Census 2000 county-level rates of key

demographic and socioeconomic indicators for counties with and without monitoring data using population-weighted univariate t-tests. The demographic composition of the communities in monitored *versus* unmonitored counties was compared at both the national and EPA regional level. Because ozone and $PM_{2.5}$ have separate monitoring networks and the data requirements differ between the ALA weighted average number of poor air quality days for short-term $PM_{2.5}$ metric and the EPA-calculated annual design values, the demographic comparisons constitute three separate analyses.

Among those counties with monitoring data in all three years, we compared the communities in the 20% of counties with the best air quality to communities in the 20% of counties with the worst air quality. In order to determine if there were demographic differences between communities with the best and worst air quality, we compared the Census 2000 county-level rates of key demographic and socioeconomic indicators using population-weighted univariate t-tests and multivariate logistic regression controlling for county population. The demographic composition of the communities in best *versus* worst counties was compared across the entire United States and within each EPA region. Because ozone, daily $PM_{2.5}$, and annual $PM_{2.5}$ all have separate monitoring networks, the demographic comparisons constitute three separate analyses.

In addition to county-level analysis, we conducted a more spatially-refined buffer analysis. For monitoring sites active each year from 2005–2007, a site-level weighted average of poor air quality days was calculated for ozone and daily $PM_{2.5}$ per ALA methodology. Site-specific data were not available for annual $PM_{2.5}$, so this air quality metric could not be included in this aspect of the analysis. Monitoring sites were georeferenced using latitude and longitude coordinates provided with the AQS data and a 5 km buffer was constructed around each site. A 5 km buffer was selected to represent a neighborhood scale assessment consistent with dispersion characteristics of PM and ozone. Of note, we constructed 10 and 15 kilometer buffers and obtained similar results. Using the 50% areal containment method [31], in which a geographic unit is considered fully within the buffer zone if at least 50% of the unit's area is captured by the buffer, we identified those Census 2000 block groups within the buffer zone of monitoring sites ranked as being among the 20% of sites with the best or worst air quality. Multiple methods for constructing buffers (e.g., buffer and clip, Census areal unit centroids [32]) exist with no demonstrated superiority of any one method. Similar to the above analysis, population-weighted univariate t-tests and multivariate logistic regression controlling for population within the buffer were used to determine if the rates of the selected demographic and socioeconomic indicators differed between communities around monitoring sites with the best and worst air quality across the United States.

In summary, in all counties in the U.S. as a whole and disaggregated by EPA region, we compared the demographics of monitored *versus* unmonitored counties. In addition, among counties with monitoring data, we compared the demographics of the best and worst air quality counties. To explore the potential importance of geographic scale, we also created buffers around the best and worst monitors (in terms of air quality) across the United States and then compared the demographics within the buffers.

All statistical analysis was undertaken in SAS 9.2 (SAS Institute, Cary, NC, USA). Statistical tests were conducted with an α of 0.05. Since we conducted a large number of weighted t-tests within each set of analyses, we controlled for multiple comparisons by applying Bonferroni's correction within each set of analyses (*i.e.*, county-level national and regional monitored *versus* unmonitored analysis,

county-level national and regional cleanest *versus* dirtiest, and buffer-level national cleanest *versus* dirtiest).

3. Results and Discussion

3.1. Demographic Differences in Communities with and without Air Quality Data

Air pollution metrics were calculated for each county with sufficient monitoring data for ozone, daily $PM_{2.5}$, and annual $PM_{2.5}$ based on the methodology established by the ALA in the 2009 State of the Air report. For ozone and daily $PM_{2.5}$, counties with monitoring data for a particular pollutant in 2005, 2006, and 2007 had sufficient data to apply the ALA methodology, while counties without monitors or with data missing for any or all of the 3 years did not have sufficient monitoring data. For annual $PM_{2.5}$, counties without monitors or without enough monitoring values in each year 2005–2007 for the EPA to calculate a design value were considered not to have sufficient monitoring data. The maps in Figure 1 show the geographic distribution of counties with and without sufficient monitoring data to calculate air pollution metrics. The demographic characteristics of counties with sufficient air quality monitoring data were compared to counties with insufficient or no air quality monitoring data. Table 1 presents the results of this analysis in all counties in the U.S. as a whole and disaggregated by EPA region. In this analysis, U.S. territories were excluded, thus adjusting the geographic coverage of Region 2 (excluded Puerto Rico and the U.S. Virgin Islands) and Region 9 (excluded Guam, Trust Territories, American Samoa, and the Northern Mariana Islands).

Figure 1. County with and without sufficient air quality monitoring in 2005, 2006, and 2007 to calculate each air quality metric.

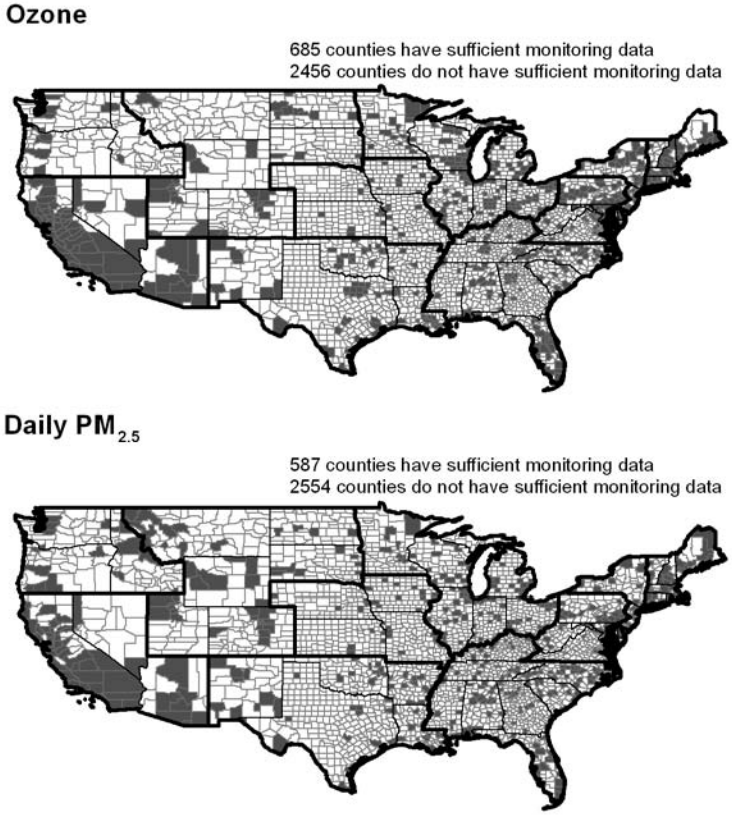


Figure 1. *Cont.*

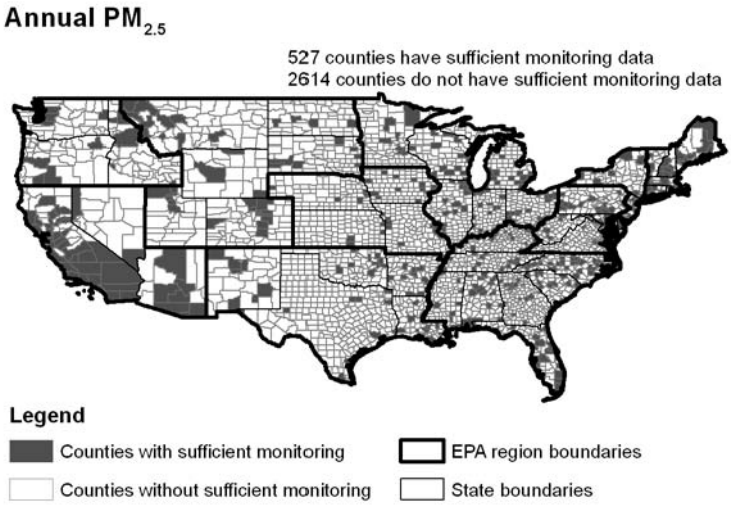


Table 1. Mean demographic composition of U.S. counties with and without sufficient monitoring data to receive an ALA air quality grade.

Demographic	EPA region	Annual $PM_{2.5}$ (design value)			Daily $PM_{2.5}$			Ozone		
		Suff monitoring	Insuff monitoring		Suff monitoring	Insuff monitoring		Suff monitoring	Insuff monitoring	
% non-Hispanic	US	13.7	9.0	*	13.6	8.2	*	12.2	11.4	
Black	1	6.0	2.1		5.6	1.7		5.2	1.8	
	2	17.3	6.2	*	16.4	5.8	*	11.9	18.1	
	3	18.2	14.3		18.9	11.5		15.9	17.4	
	4	22.1	17.8		22.1	17.6		21.0	19.4	
	5	15.6	2.2	*	15.2	2.2	*	14.4	2.9	*
	6	15.6	11.9		16.8	10.0		13.6	13.3	
	7	11.6	2.2	*	11.5	2.1	*	10.7	4.1	
	8	2.7	0.5	*	2.6	0.5	*	2.8	0.5	
	9	6.0	3.9		6.0	1.5	*	5.9	0.9	*
	10	4.0	0.8	*	3.4	0.7	*	3.4	1.1	
% Hispanic	US	15.5	7.4	*	15.1	6.8	*	15.1	6.7	*
	1	7.9	2.7	*	7.4	1.8	*	6.9	1.7	*
	2	18.1	5.4	*	17.3	4.4	*	14.9	13.9	
	3	4.1	3.3		4.6	2.1	*	4.6	1.9	*
	4	9.8	3.3	*	9.5	3.4	*	9.8	3.1	*
	5	6.8	2.1	*	6.7	2.1	*	6.4	2.4	*
	6	27.9	20.1		27.2	19.5		28.6	15.4	*
	7	4.1	3.3		4.2	3.2		3.6	3.8	
	8	12.8	7.1		12.4	7.2		12.8	7.2	
	9	31.5	17.3	*	30.9	17.3	*	30.8	12.7	*
	10	5.7	9.0		5.9	9.7		5.9	9.1	

Table 1. *Cont.*

Demographic	EPA region	Annual $PM_{2.5}$ (design value)			Daily $PM_{2.5}$			Ozone		
		Suff monitoring	Insuff monitoring		Suff monitoring	Insuff monitoring		Suff monitoring	Insuff monitoring	
% under 5 years of age	US	6.9	6.6	*	6.9	6.5	*	6.9	6.5	*
	1	6.3	5.9		6.3	5.7	*	6.2	5.9	
	2	6.6	6.3		6.6	6.2		6.6	6.4	
	3	6.3	6.1		6.3	6.0		6.3	6.0	
	4	6.5	6.5		6.5	6.5		6.5	6.6	
	5	6.9	6.5	*	6.9	6.4	*	6.9	6.4	*
	6	7.8	7.2	*	7.7	7.1	*	7.8	6.9	*
	7	7.0	6.4	*	7.0	6.3	*	6.9	6.5	*
	8	7.6	6.7		7.7	6.5	*	7.8	6.4	*
	9	7.3	6.6	*	7.3	6.4	*	7.3	6.3	*
	10	6.5	7.0		6.7	6.8		6.6	7.0	
% over 64 years of age	US	11.9	13.3	*	11.9	13.5	*	12.0	13.5	*
	1	13.4	13.9		13.4	14.4		13.6	13.4	
	2	13.0	13.0		12.9	13.3		13.1	12.9	
	3	13.1	14.0		13.3	13.9		13.3	14.0	
	4	13.3	13.8		13.3	13.9		13.5	13.4	
	5	12.0	13.6	*	12.0	13.6	*	12.0	13.7	*
	6	9.7	11.9	*	9.8	12.1	*	9.4	13.2	*
	7	12.0	15.5	*	12.1	15.6	*	11.8	15.2	*
	8	9.6	12.3	*	9.4	13.0	*	8.9	13.5	*
	9	10.8	13.0	*	10.8	14.4	*	10.9	14.5	*
	10	10.7	12.0		10.5	12.7		11.1	11.7	
% in poverty	US	12.4	12.4		12.4	12.5		11.8	13.7	*
	1	10.0	7.2		9.5	7.6		9.1	9.1	
	2	14.3	8.7		13.6	9.4		11.5	14.9	
	3	9.6	12.2		10.4	11.6		9.6	13.5	*
	4	13.0	14.9	*	13.0	15.1	*	12.6	15.5	*
	5	10.7	8.8	*	10.6	8.9	*	10.2	9.6	
	6	16.0	16.2		16.5	15.6		15.3	17.4	
	7	9.5	11.5		9.5	11.6		9.1	11.6	
	8	9.9	11.4		9.6	12.1	*	8.8	13.2	*
	9	13.9	14.3		13.9	14.3		13.9	15.6	
	10	10.1	11.8		9.8	12.7	*	10.1	11.9	

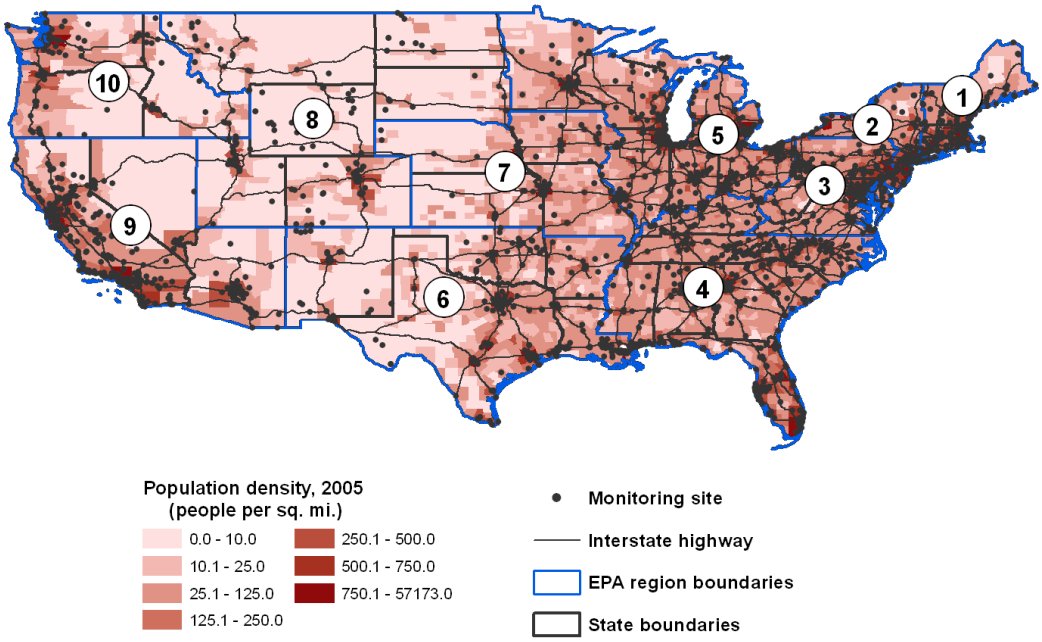
* Population-weighted t-test significant at $\alpha = 0.05$ with Bonferroni correction for multiple comparisons.

Of the 3,141 counties in the United States, 527 had sufficient monitoring data for annual $PM_{2.5}$, 587 had sufficient monitoring data for daily $PM_{2.5}$, and 685 had sufficient monitoring data for ozone. As Table 1 demonstrates, there are clear differences in the demographic characteristics of counties with sufficient air quality data to allow calculation of an air quality metric. At the national level, counties without air quality metrics for annual $PM_{2.5}$, daily $PM_{2.5}$, and ozone are characterized by a lower percent NHB, lower percent Hispanic, lower percent under 5 years of age, and higher percent 65 years

and older. Using population-weighted t-tests and the Bonferroni correction for multiple comparisons, almost all of these differences were significant at an overall α of 0.05. Counties without air quality metrics for annual $PM_{2.5}$ and daily $PM_{2.5}$ exhibit no differences in percent in poverty; however, counties without air quality metrics for ozone are characterized by a higher percent in poverty. These patterns generally held within the 10 EPA regions, although statistical significance under the correction for multiple comparisons varied.

The observed differences in the demographic characteristics of areas for which we could and could not calculate the 3 air quality metrics likely result from the strategies that the EPA pursues in siting monitors. The map in Figure 2 makes it clear that monitoring efforts for ozone and particulate matter are targeted at areas with high population density and along major interstate highways or heavily industrialized areas. While this system for placing air quality monitors captures data where the highest population density is expected to experience significant ozone and $PM_{2.5}$ exposure, it leaves rural areas with generally older, non-Hispanic white populations with limited air quality data.

Figure 2. 2005 United States county-level population density and EPA regions, overlaid with ozone and PM2.5 air quality monitoring sites.



3.2. County Demographics and Air Quality

Among those counties with sufficient data to calculate an air quality metric (see Figure 1), we compared communities with the most extreme air quality based on each pollution metric. Specifically, we employed univariate analysis using population-weighted t-tests to compare the demographic characteristics of the 20% of counties with the best air quality with the 20% of counties with the worst air quality. For all three pollution metrics, the proportion of NHB in those counties with the worst air quality is over twice the corresponding proportion in those counties with the best air quality (significant at $\alpha = 0.05$ with Bonferroni correction). A higher percent Hispanic, higher percent under 5 years of age, and lower percent 65 years and older are characteristic of counties in the worst 20% rather than best 20% of ozone-graded counties (p significant at $\alpha = 0.05$ with Bonferroni correction).

For both annual and daily $PM_{2.5}$, counties with the worst air quality have higher rates of poverty than counties with the best air quality (significant at $\alpha = 0.05$ with Bonferroni correction).

We also used multivariable logistic regression to consider how the various demographic dimensions of communities drive associations with air quality. For each pollution metric, a logistic model estimated the probability of a county being in the worst 20% of counties rather than the best 20% of counties. Models were run using national data, and covariates included all the demographic variables (*i.e.*, percent NHB, percent Hispanic, percent under 5 years of age, percent 65 years and older, and percent in poverty), as well as county population and EPA region. Table 2 presents the odds ratios for a change in each covariate equal to the interquartile range (IQR) of the covariate across all U.S. counties.

Table 2. Multivariable logistic regressions modeling the probability of an ALA-graded U.S. county being in the worst 20% of counties *versus* the best 20% of counties for each air pollution metric [a].

	Annual $PM_{2.5}$	**Daily $PM_{2.5}$**	**Ozone**
% non-Hispanic black	2.73 **	1.58 *	1.36 *
% Hispanic	0.83	1.13	0.89
% under 5 years of age	2.09	1.34	1.68 *
% over 64 years of age	0.25 **	0.51 *	0.71
% in poverty	3.95 ***	1.92 *	0.44 ***
Population in 100,000s	1.01	1.19 ***	1.12 ***
R-squared	0.60	0.51	0.34

[a] Values reported as odds ratios for a change equal to the IQR for each demographic variable based on all U.S. counties. Note: EPA region was also included as a covariate in all models. The Type III p-value for the EPA region covariate was <0.05 in both $PM_{2.5}$ models and 0.052 in the ozone model. *p < 0.1 **p < 0.05 ***p < 0.01.

When controlling for the above-named other demographic variables, we still see a dramatic difference in the percent NHB in counties with the best and worst air quality as measured by all three pollution metrics; moving from the bottom to the top of the IQR on percent NHB is associated with a 36% to 173% increase in the probability of a county being in the worst 20% of graded counties, depending on the air quality metric of interest. Percent in poverty is positively associated with the probability of a county having the worst air quality for both annual and daily $PM_{2.5}$ ($p < 0.01$ and $p < 0.1$, respectively); however, the opposite relationship is seen for ozone ($p < 0.01$). For each pollution metric, one aspect of the age composition is significantly associated with air quality ranking; counties with the worst air quality have a younger age distribution compared to counties with the best air quality.

In each multivariable logistic model, the EPA region covariate was significant ($p < 0.05$ for both $PM_{2.5}$ models and $p = 0.05$ for ozone model), which may indicate that the relationship between county demographics and air quality grades plays out differently in different geographic regions. Although we would like to investigate how the communities with best and worst air quality compare within regions using multivariable analysis parallel to that performed nationally, some regions do not have air quality monitoring data for a sufficient numbers of counties to permit such model-fitting.

We note that the odds ratios between the daily $PM_{2.5}$ model and the annual $PM_{2.5}$ design value model are in the same direction but differ in magnitude. This is reasonable given that the former models short term peak exposures, and the latter measures long term exposures, which do not correlate perfectly.

3.3. Demographic Characteristics of Proximate Communities

The best/worst analysis described above was executed at the county level. To assess demographic differences at a more refined geographic scale, we selected the 20% of monitors reporting the best air quality and the 20% of monitors reporting the worst air quality. We then created a 5 km buffer around each monitoring site. Figure 3 provides a representation of how the buffers were constructed, and Figure 4 shows the distribution of the cleanest *versus* dirtiest monitors using daily $PM_{2.5}$ as an example (*i.e.*, the map of cleanest *versus* dirtiest monitors is different for ozone). Using a previously developed buffering method [31], Census block groups for which 50% of the area was contained within the 5 km buffer were considered to be within the buffer zone and included in the analysis. Buffer analysis could not be undertaken for annual $PM_{2.5}$ as site-specific data are not available.

Figure 3. Representation of the area captured by 5 km buffer of AQS monitor sites.

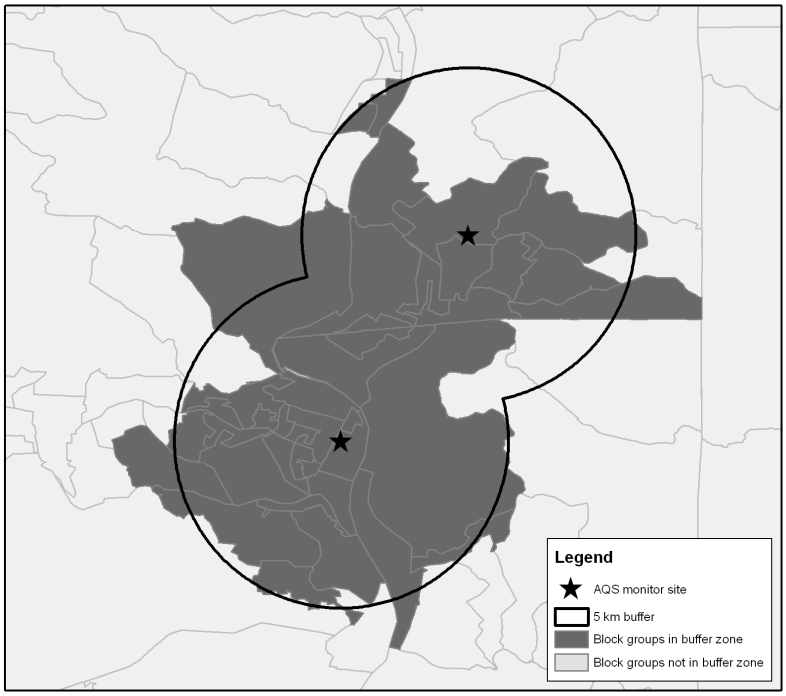
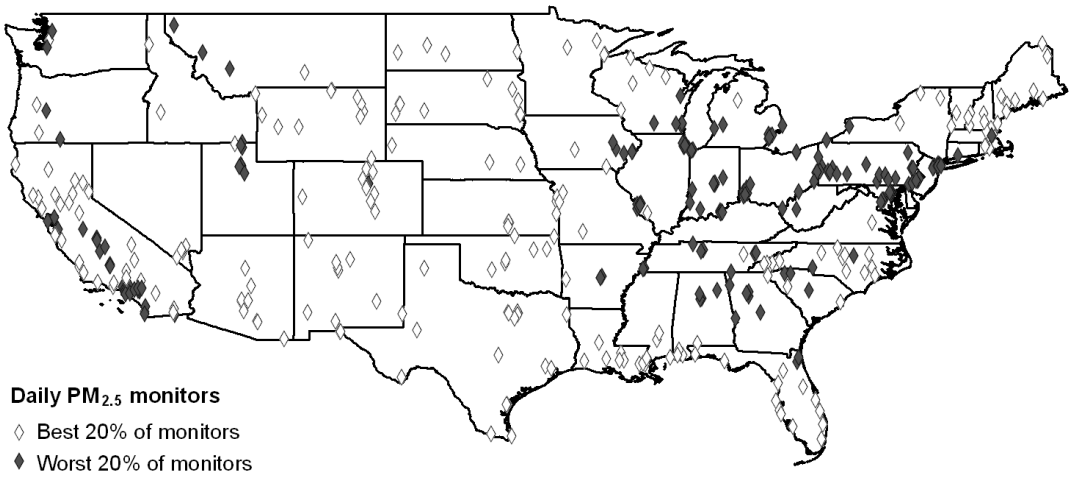


Figure 4. Location of the 20% of monitors with the best air quality and the 20% of monitors with the worst air quality for daily $PM_{2.5}$.



Similar to the county-level analysis, we began by exploring the univariate relationships between demographic composition and air quality for communities within the 5 km buffer zone around monitoring sites. For both daily $PM_{2.5}$ and ozone, compared to communities surrounding monitors with the best air quality, those surrounding monitors with the worst air quality are characterized by a higher percent NHB, higher percent under 5 years of age, and lower percent 65 years and older (significant at $\alpha = 0.05$ with Bonferroni correction). Communities surrounding monitors with the worst air quality in terms of daily $PM_{2.5}$ have higher percent Hispanic and higher percent in poverty than communities around monitors with the best air quality (significant at $\alpha = 0.05$ with Bonferroni correction). In contrast, the communities surrounding monitors with the worst air quality in terms of daily ozone have lower percent Hispanic and lower percent in poverty compared to communities around monitors with the best air quality (significant at $\alpha = 0.05$ with Bonferroni correction).

To supplement the univariate analyses, Table 3 summarizes the results of multivariable logistic models for the probability of a Census block group being within the buffer zone of a site ranking in the worst 20% *versus* the best 20% of monitoring sites for each air pollution metric. The logistic model for each pollution metric was constructed similarly to the county-level analysis above and the results are again presented as the odds ratios for a change in each covariate equal to the IQR of the covariate across all U.S. counties. The exception is population, for which the odds ratio was calculated as an increase of 1,000 individuals in order to more reasonably correspond to a plausible change in block group population.

Table 3 provides interesting contrasts to the univariate analysis. In the multivariable logistic models for $PM_{2.5}$, moving from the bottom to the top of the IQR for percent NHB or percent Hispanic, is associated with a 32% and 9%, respectively, increase in the likelihood of being in the worst air quality areas. Age (whether young or old), percent in poverty, and higher population were associated with a decreased risk of being in areas around the 20% of monitors with the worst air quality. For ozone, moving from the bottom to the top of the IQR for percent NHB is associated with a 6% increase in the likelihood of being in the dirtiest air quality areas. However, moving from the bottom to the top of the IQR for percent Hispanic is associated with a 6% decrease in the likelihood of being in the dirtiest air

quality areas. Moving from the bottom to the top of the IQR for percent under 5 years of age is associated with a 7% increase in the likelihood of being in the worst ozone areas, whereas older age was associated with a decreased risk of being in the worst 20% of areas, as was percent in poverty. Higher population was associated with an increased risk of being in the worst ozone areas (a 24% increase in risk for each additional 1,000 individuals per block group). Unfortunately, we were unable to perform this analysis disaggregated by EPA region due to the uneven representation of monitors with the best and worst air quality across EPA regions.

Table 3. Multivariable logistic regressions modeling the probability of a Census blockgroup being within the 5 km buffer zone of the dirtiest 20% of monitoring sites *versus* cleanest 20% of monitoring sites for each air pollution metric [a].

	Daily $PM_{2.5}$		**Ozone**	
% non-Hispanic black	1.32	***	1.06	***
% Hispanic	1.09	***	0.94	***
% under 5 years of age	0.96	***	1.07	***
% over 64 years of age	0.90	***	0.97	**
% in poverty	0.94	***	0.90	***
Population	0.85	***	1.24	***
R-squared	0.40		0.18	

[a] Values for population reported as odds ratios for an increase in the population of 1,000. All other values reported as odds ratios for a change equal to the IQR for each demographic variable based on all U.S. counties. Note: EPA region was also included as a covariate in both models. The Type III p-value for the EPA region covariate was <0.01 in both models. *p < 0.1 **p < 0.05 ***p < 0.01.

3.4. Summary of Environmental Justice Results

In both univariate and multivariate analyses, NHB are more likely to live in counties where particulate matter and ozone are well-monitored, but, among monitored locations, they are much more likely to live in areas with the worst air quality. In univariate analyses, Hispanics are also more likely to live in counties where particulate matter and ozone are well-monitored and are more likely to live in areas with the worst air quality. The latter result loses significance in the multivariate analyses

Poverty rates do not differ between non-monitored counties for particulate matter *versus* monitored counties. Non-monitored counties for ozone are characterized by higher rates of poverty. In monitored counties, multivariate analysis suggests that counties with the worst particulate matter air quality are characterized by higher rates of poverty. In contrast, counties with the worst ozone air quality are characterized by lower rates of poverty. This may be due to the broader geographic scale at which high ozone levels tend to present.

In areas immediately proximate to the monitors, NHB are more likely to live in areas with the worst daily $PM_{2.5}$ and ozone air quality. Hispanics are more likely to live in areas with the worst daily $PM_{2.5}$ air quality, but less likely to live in areas with the worst ozone levels. The areas proximate monitors recording the worst daily $PM_{2.5}$ and ozone levels are characterized by lower rates of poverty.

Taken together, these results suggest that NHB in the United States suffer worse air quality across multiple metrics, geographic scales, and multiple pollution metrics. Hispanics also suffer worse air

quality with respect to particulate matter, but not necessarily so for ozone. It also appears that environmental justice concerns are more prominent along race/ethnicity lines, rather than measures of poverty.

4. Conclusions

This paper provides an analysis of how the Clean Air Act and its Amendments have shaped air quality in both advantaged and disadvantaged communities in the United States. The results suggest, first, that the placement of monitors across the United States emphasizes more urban and densely populated communities. This means that rural areas, which are generally characterized by older, non-Hispanic white populations, are less likely to be monitored. It also means that non-Hispanic blacks and Hispanics are more likely to have access to monitoring data. Consequently, in areas without monitors, researchers, community members, and policy makers all lack access to information about local air quality. Second, we find that counties with the worst $PM_{2.5}$ air quality are characterized by a statistically significant larger percent of NHB, smaller percent of people over 64 years of age, larger percent of people in poverty, and, for daily $PM_{2.5}$ only, more people per county. We also find that counties with the worst ozone air quality are characterized by a statistically significant larger percent NHB, larger percent children under 5 years of age, smaller percent in poverty, and larger populations. Third, using buffering analysis to analyze at a more refined geographic scale, we found significant relationships between race, age, poverty, and air quality for both $PM_{2.5}$ and ozone. Taken together, these results suggest that air quality is uneven across different demographic groups in the United States.

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Racial isolation and exposure to airborne particulate matter and ozone in understudied US populations: Environmental justice applications of downscaled numerical model output

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ABSTRACT

Background: Researchers and policymakers are increasingly focused on combined exposures to social and environmental stressors, especially given how often these stressors tend to co-locate. Such exposures are equally relevant in urban and rural areas and may accrue disproportionately to particular communities or specific subpopulations.
Objectives: To estimate relationships between racial isolation (RI), a measure of the extent to which minority racial/ethnic group members are exposed to only one another, and long-term particulate matter with an aerodynamic diameter of <2.5 μ ($PM_{2.5}$) and ozone (O_3) levels in urban and nonurban areas of the eastern two-thirds of the US.
Methods: Long-term (5 year average) census tract-level $PM_{2.5}$ and O_3 concentrations were calculated using output from a downscaler model (2002–2006). The downscaler uses a linear regression with additive and multiplicative bias coefficients to relate ambient monitoring data with gridded output from the Community Multi-scale Air Quality (CMAQ) model. A local, spatial measure of RI was calculated at the tract level, and tracts were classified by urbanicity, RI, and geographic region. We examined differences in estimated pollutant exposures by RI, urbanicity, and demographic subgroup (e.g., race/ethnicity, education, socioeconomic status, age), and used linear models to estimate associations between RI and air pollution levels in urban, suburban, and rural tracts.
Results: High RI tracts (≥80th percentile) had higher average $PM_{2.5}$ levels in each category of urbanicity compared to low RI tracts (<20th percentile), with the exception of the rural West. Patterns in O_3 levels by urbanicity and RI differed by region. Linear models indicated that $PM_{2.5}$ concentrations were significantly and positively associated with RI. The largest association between $PM_{2.5}$ and RI was observed in the rural Midwest, where a one quintile increase in RI was associated with a 0.90 μg/m^3 (95% confidence interval: 0.83, 0.99 μg/m^3) increase in $PM_{2.5}$ concentration. Associations between O_3 and RI in the Northeast, Midwest and West were positive and highest in suburban and rural tracts, even after controlling for potential confounders such as percentage in poverty.
Conclusion: RI is associated with higher 5 year estimated $PM_{2.5}$ concentrations in urban, suburban, and rural census tracts, adding to evidence that segregation is broadly associated with disparate air pollution exposures. Disproportionate burdens to adverse exposures such as air pollution may be a pathway to racial/ethnic disparities in health.

1. Introduction

An extensive literature has demonstrated a deleterious relationship between exposure to air pollution and adverse human health outcomes, including poor pregnancy outcomes (Ritz et al., 2002; Miranda et al., 2009; Bell et al., 2010; Miranda et al., 2013; Gray et al., 2014), asthma (McConnell et al., 2002), and cardiovascular- and respiratory-related mortality (Dominici et al., 2003; Bateson and Schwartz, 2004; Laurent et al., 2007) and morbidity (Dominici et al., 2006; Peng et al., 2009; Bell et al., 2014). The close relationship between race/ethnicity and residential location in the US (Gee and Payne-Sturges, 2004) suggests that racial disparities in health (e.g., poor pregnancy outcomes, asthma, etc.) may be partly attributed to systematic differences in adverse exposure burdens, such as exposure to environmental pollution, poor quality built environments, or social stressors. For example, disproportionate air pollution exposure burdens among non-Hispanic blacks (NHB)

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versus non-Hispanic whites (NHW) have been implicated in racial disparities in health outcomes such as asthma (Hill et al., 2011; Nachman and Parker, 2012) and cancer (Apelberg et al., 2005). Racial residential segregation (RRS) of NHB, which refers to the purposeful and systematic geographic separation of NHB into different residential spaces separate from the majority NHW population, may underlie race-based disparities in environmental exposures (Massey and Denton, 1988; Gee and Payne-Sturges, 2004; Morello-Frosch and Lopez, 2006). Through the disinvestment of educational resources and employment opportunities and the concomitant concentration of multiple disadvantages related to such factors as environmental hazards, poor quality built environment, and food insecurity, among others, segregation fosters residential environments inimical to health (Williams and Collins, 2001; Acevedo-Garcia et al., 2003). Indeed, RRS has been associated with a range of adverse health outcomes like infant and adult mortality (Laveist, 1993), poor pregnancy outcomes (Grady, 2006; Osypuk and Acevedo-Garcia, 2008; Anthopolos et al., 2014), and poor cardiovascular health (Kershaw et al., 2011).

RRS is a multidimensional phenomenon with five distinct dimensions, namely, evenness (also called dissimilarity), isolation (or exposure), concentration, centralization, and clustering (Massey and Denton, 1988). Evenness refers to the degree to which racial minority group members may be over or underrepresented across spatial units in a metropolitan area relative to overall group representation. Isolation (exposure) is defined as the extent to which minorities are exposed to majority group members by sharing a residential neighborhood. Concentration, centralization, and clustering capture aspects of the geographic distribution of racial minorities relative to majority group members across a metropolitan area. Historically, RRS developed through the systematic steering of NHB into separate residential spaces through political, economic, and social forces (Williams and Collins, 2001). Despite legal measures to abolish segregation, the consequences of RRS persist today: according to the dimension of evenness, in US metropolitan areas in 2000, on average, two-thirds of the NHB population would need to relocate to another neighborhood to de-segregate a given US city (Gee and Payne-Sturges, 2004). While often overlooked, NHB outside of urban areas in the US also remain segregated. For example, Lichter et al. (2007) find that levels and trends in evenness of NHB in suburban and rural US communities are similar to those observed in urban areas.

In studies examining the role of RRS in racial disparities in air pollution exposures, US metropolitan areas with higher levels of segregation have been shown to have higher overall levels of air pollution (Morello-Frosch and Lopez, 2006). Few in number, these studies have been limited to urban areas (Jones et al., 2014; Rice et al., 2014), and typically measure segregation at a global scale (for example, using city or metropolitan area boundaries) based on the dimension of evenness. In complementary research, a plethora of studies have used racial composition (e.g., percentage NHB) to reveal racial disparities in air pollution exposure, without necessarily intending to proxy segregation (Miranda et al., 2011; Bell and Ebisu, 2012). While important, these studies have not accounted for the relationships among nearby neighborhoods (Brochu et al., 2011); were often limited to areas proximate to air pollution monitors e.g., (Miranda et al., 2011; Bell and Ebisu, 2012); or overlooked potential differences in exposure burdens in urban versus nonurban areas, due to limited ambient monitoring data in less urban areas (Bell and Ebisu, 2012).

We assess the role of one dimension of RRS, racial isolation (RI), in racial differences in exposure to particulate matter with an aerodynamic diameter of $<2.5\ \mu$ ($PM_{2.5}$) and ozone (O_3), in both urban and nonurban tracts across the eastern two-thirds of the US. Ozone and $PM_{2.5}$ are criteria air pollutants that are linked with adverse health outcomes (World Health Organization, 2004) and in nonattainment of the National Ambient Air Quality Standards (NAAQS) in multiple US communities (U.S. Environmental Protection Agency, 2008; U.S. Environmental Protection Agency, 2012a). We choose to focus on RI of NHB because, compared to the commonly employed dimension of evenness, isolation may be more closely linked to health by serving as a proxy for the concentration of multiple disadvantage into a single ecological space (Shihadeh and Flynn, 1996; Acevedo-Garcia et al., 2003). While RRS is standardly conceived as a global construct, we use a previously derived spatial measure of local RI of NHB. At a more resolved geographic scale than the city or metropolitan area level, the local RI index may be more proximally linked to individual health (Anthopolos et al., 2011), and unlike commonly applied aspatial measures of segregation, our spatial index accounts for relationships among nearby geographic units (i.e., census tracts). We use simulated air pollution concentrations to estimate exposure burdens among subpopulations living in areas without air pollution monitors. Although previous work has examined disparities in air pollution exposure for urban and rural populations in selected US cities and states (Yanosky et al., 2008; Brochu et al., 2011; Gray et al., 2013; Jones et al., 2014), the few studies examining disparities based on larger study samples noted that the use of monitoring data precluded assessing exposure in more rural populations (Miranda et al., 2011; Bell and Ebisu, 2012). Furthermore, studies examining other dimensions of RRS and air pollution have done so almost exclusively in metropolitan areas (Lopez, 2002; Morello-Frosch and Jesdale, 2006; Jones et al., 2014; Rice et al., 2014). This study extends the current understanding of racial disparities in air pollution exposures by: 1) estimating ambient air pollutant concentrations in understudied (i.e., rural) populations; and 2) using a spatial measure of local RI to estimate its association with air pollution in urban, suburban, and rural US census tracts.

2. Methods

2.1. Study area

We focus on the eastern two-thirds of the US because this is the area for which the Community Multiscale Air Quality Model (CMAQ) downscaler provides census tract level estimates of $PM_{2.5}$ and O_3 concentrations (census tracts = 53,124).

2.2. Data sources

2.2.1. Demographic data

For each census tract in the study area, we obtained population characteristics from 2000 Census data, including racial composition (U.S. Census Bureau, 2000a), age, educational attainment, poverty, and unemployment (U.S. Census Bureau, 2000b), in addition to tract-level Rural-Urban Commuting Area (RUCA) codes (U.S. Department of Agriculture, 2003). Although 2000 is not the most recent census year, it best matches our study timeframe of 2002–2006, which is determined by the years for which downscaler output are available. According to the US Census Bureau, tracts are small, relatively permanent statistical subdivisions of counties, designed to be fairly homogenous units with respect to socio-demographic characteristics and living conditions, containing on average 4,000 residents (U.S. Census Bureau, 2000c). Consistent with at least one previous study of racial/ethnic disparities in air pollution exposure (Bell and Ebisu, 2012), tracts with population < 100 ($n = 317$, <1%) were excluded from analysis.

2.2.2. Air pollution data

Concentrations of $PM_{2.5}$ and O_3 were obtained for 2002–2006 from two different sources: (1) the CMAQ downscaler (Berrocal et al., 2012; Holland, 2012); and (2) the US EPA Air Quality System (AQS) database (U.S. Environmental Protection Agency, 2012b). The AQS database contains observations from the National Air Monitoring Stations and State and Local Air Monitoring Stations (NAMS/SLAMS) network. Annual averages of 24-h ambient $PM_{2.5}$ and 8-h maximum O_3 concentrations were obtained for each year between 2002 and 2006 for 1215 $PM_{2.5}$ and 1,043 O_3 monitoring locations in the study area.

The downscaler model utilizes a Bayesian space-time modeling framework that relates monitor data and gridded CMAQ model output using a linear regression with additive and multiplicative bias coefficients that can vary in space and time. Input data to the downscaler model include monitoring data obtained from the NAMS/SLAMS network (including stations with some data missingness) and gridded CMAQ numerical output. Output from CMAQ used as input to the downscaler include $PM_{2.5}$ and O_3 concentrations at 12 × 12 km grid cells simulated using CMAQ version 4.6. The CMAQ model is a deterministic regional air quality model using nonlinear partial differential equations to mathematically approximate underlying physical and chemical processes occurring in the atmosphere. Utilizing output from a meteorological model and an emissions inventory, CMAQ simulates chemical and physical atmospheric processes to model pollutant transformation, transport, and fate, producing estimates of pollutant concentrations and deposition fluxes at different horizontal resolutions (e.g., 12 × 12 km) and atmospheric layers (Byun and Schere, 2006). The meteorological inputs to the CMAQ simulations used in the downscaler statistical model are from the 5th generation Mesoscale Model version 3.6.3. The emissions inventory was based on the 2002 National Emissions Inventory version 3 (Houyoux et al., 2000).

The downscaler uses monitoring data and CMAQ output at 12 × 12 km grid cells to predict daily air pollution concentrations at census tract centroids (Berrocal et al., 2010a; Berrocal et al., 2010b). Specifically, downscaler output includes estimates of daily 24-h average $PM_{2.5}$ and 8-h maximum O_3 concentrations at census tract centroids across the eastern two-thirds of the US. We used downscaler output for years 2002–2006, which provide complete coverage of the study area, such that exposures to air pollution can be estimated for all populations within the study area. Downscaler output has been used in other exposure assessment applications, including the publicly available environmental justice screening and mapping tool developed by the US Environmental Protection Agency (U.S. Environmental Protection Agency, 2015). Additional details on the downscaler modeling approach, validation, and performance are provided elsewhere (Berrocal et al., 2012). Archived daily downscaler surfaces are available from the US EPA (Holland, 2012).

2.3. Air pollution exposure assessment

2.3.1. CMAQ downscaler

Tract level estimates of ambient $PM_{2.5}$ and O_3 concentrations obtained from downscaler output were reported at census tract centroids for every day in the study period (2002–2006). Separately for each pollutant, we averaged daily values to generate an annual average concentration estimate for each tract, then averaged annual values to generate 5y average tract level 24-h average $PM_{2.5}$ and 8-h maximum O_3 concentrations. Five-year concentrations were calculated because we were interested in measuring differences in long-term (chronic) exposures. Most O_3 monitors record observations only during O_3 "season," typically April–September, while the downscaler estimates concentrations daily throughout the year. Thus, O_3 exposure estimates were calculated in two ways: (1) 5 year averages calculated from 12 months of daily downscaler-derived concentrations; and (2) 5 year averages calculated from 6 months (April–Sept.) of daily downscaler-derived concentrations.

When using model-derived air pollution concentrations, researchers often compare modeled and observed concentrations as a test of model performance. To assess whether downscaler- and monitor-derived pollution concentrations were similar, we compared monitor- and downscaler-derived 5y tract level exposure estimates. Evaluation metrics of mean bias, normalized mean bias, normalized mean error, root mean square error, and correlation (Boylan and Russell, 2006; Eder and Yu, 2006) were calculated based on tracts with $PM_{2.5}$ and O_3 monitoring data.

2.3.2. Monitoring data

We also obtained annual averages of 24-h $PM_{2.5}$ and 8-h maximum O_3 concentrations reported at monitor locations from the AQS for 2002–2006 (U.S. Environmental Protection Agency, 2012ba). Monitors were matched to tracts based on each monitor's latitude/longitude. If multiple monitors were present for the same pollutant in a single tract, observed concentrations were averaged to create an annual average tract level concentration estimate. We averaged annual $PM_{2.5}$ and O_3 concentrations to generate a 5y average estimate for each pollutant.

Most $PM_{2.5}$ and O_3 monitors do not record observations every day of the year; typically, $PM_{2.5}$ monitors record observations once every three days, while O_3 monitors record daily observations from April–September. We excluded $PM_{2.5}$ and O_3 monitors with observations <50% of days when the monitor should have been operational for ≥3 years (y) during the 5y study period (e.g., a $PM_{2.5}$ monitor with a 1-in-3 day sampling schedule with 100% complete data for a year would have approximately 121 days of data; if it had <61 days of data for 3y or more in the study period, the monitor was excluded). Applying this criterion excluded 133 (~11%) $PM_{2.5}$ monitors and 28 (~3%) O_3 monitors. Monitor locations used in our analysis are shown in Supplemental Material, eFigure 1. Monitor-derived tract level air pollution estimates were calculated only for tracts in the study area containing ambient monitors: 1,053 (2.0%) tracts and 991 (1.9%) tracts for $PM_{2.5}$ and O_3, respectively.

2.4. Urbanicity

Urbanicity was determined using primary and secondary RUCA codes (U.S. Department of Agriculture, 2003), which delineate metropolitan, micropolitan, small town, and rural commuting areas based on the size and direction of the primary (largest) commuting flows. Developed by researchers at the US Department of Agriculture in collaboration with Office of Rural Health Policy and the Rural Health Research Center, RUCA codes use measures of population density, urbanization, and size and direction of primary (largest) daily commuting flows to determine the degree of urbanicity of US census tracts (Hall et al., 2006). RUCA codes were used to classify tracts into one of three mutually exclusive categories: urban, suburban, and rural. RUCA codes and definitions are provided in eTable 1.

2.5. Racial isolation

Using 2000 US Census data on the percentage of tract population self-identifying as NHB, we calculate a local spatial measure of RI. The tract-level spatial measure of this RRS dimension was developed by Anthopolos et al. (2011); they based their index on the regional-scale spatial isolation index developed by Reardon and O'Sullivan (2004). For purposes of consistency, the notation presented here is consistent with Anthopolos et al. (2011).

Let r_i index subregions of a given region R, and $|r_i|$ indicate the area of subregion i. Let m index M mutually exclusive racial groups populating R. Define T^{r_i} as the total population count in tract r_i and $T_m^{r_i}$ to be the same but for subpopulation group m. To specify spatial relationships among tracts, let Γ be a first order adjacency matrix with entries $y_{ij} = 1$ if r_i and r_j share a boundary and 0 otherwise. Since we wish to take into account the fact that individuals can interact within their own tract, we set y_{ii} to equal a constant k, where k is restricted to be greater than or equal to 1.

For any population group m, $\tau\sim_m^{r_i}$ is the weighted average of population intensities at all other locations in R, where weights are assigned based on adjacency to r_i. Formally, $\tau\sim_m^{r_i} = (\sum_{r_j} y_{ij} T_m^{r_j})/(\sum_{r_j} y_{ij}|r_j|)$. The quantity can be similarly defined for the total population: $\tau\sim^{r_i} = (\sum_{r_j} y_{ij} T^{r_j})/(\sum_{r_j} y_{ij}|r_j|)$. By taking the ratio of $\tau\sim_m^{r_i}$ and $\tau\sim^{r_i}$, we have the

RI of group m in tract r_i defined as: ${}_mP \sim_m^{*r_i} = \frac{(\sum_{r_j} y_{ij} T_m^{r_j})}{(\sum_{r_j} y_{ij} T^{r_j})}$.

Note that the double subscripting of m is used to denote that the index is measuring population group m's exposure to itself. This can be interpreted as the average percentage of subpopulation group m in the local environment of r_i, where the local environment is defined in terms of adjacency. We calculated the RI index using weighting scheme of $y_{ij} = 1$. A detailed derivation is available from the authors.

The RI index ranges from 0 (no isolation) to 1 (complete isolation). The RI index was computed for all tracts within the study area to evaluate possible differences in air pollution exposures in tracts with higher versus lower levels of RI. To correct for edge effects in index scores for tracts along the boundary of the study area, we included bordering tracts located outside our study area in the calculation of RI.

2.6. Geography

Relationships between RI, urbanicity, and air pollution exposure were examined throughout the study area and within specific geographic regions. Based on the census classification of states (U.S. Census Bureau, 2014), tracts were classified into one of four geographic regions: Northeast, Midwest, South, or West (eFigure 2).

2.7. Statistical analysis

The RI value for each tract was used to classify tracts into quintiles of RI, which were computed within geographic region. Within each geographic region, we used ANOVA to evaluate whether 5 year average $PM_{2.5}$ and O_3 levels differed by RI quintile and urbanicity category. We assessed whether the assumption of normality in ANOVA was violated by examining histograms of model residuals. Because Levene's test (Levene, 1960) rejected the assumption of homogeneous variance, we applied the Welch correction for unequal variances among groups. Additionally, we evaluated whether results for urbanicity and RI were robust to inclusion of tracts with population < 100.

We also estimated population-level exposures for different demographic subgroups by urbanicity category and by low vs. high RI. We focused on five ways to segment the population:

- Race/ethnicity: population self-identified as NHB, NHW, Hispanic, or other
- Age: persons 0–19, 20–64, or ≥65y of age
- Educational attainment: persons ≥25y with less than a high school degree or equivalent; high school degree/GED or some college; or college degree
- Poverty: percentage in poverty using census-defined poverty levels
- Unemployment: percentage ≥ 16y who are unemployed.

These variables were chosen based on associations between air pollution, race/ethnicity, and socioeconomic status (SES) in previous studies (Gray et al., 2013), and also to explore potential for concentrated disadvantage in more racially isolated (segregated) areas. For each characteristic, we estimated the average exposure to each pollutant for that demographic group in the study area by weighting pollution levels in each tract by the population as:

$$Y_i^k = \frac{\sum_{j=1}^{J} P_{ij} x_j^k}{\sum_{j=1}^{J} P_{ij}}.$$

Where:

Y_i^k is the average estimated exposure across the study area to pollutant k for persons with characteristic i (e.g., high school graduate);

J is the number of census tracts in the study area (n = 52,807);

P_{ij} is the number of persons with characteristic i in census tract j; and

x_j^k is the concentration of pollutant k for census tract j.

This approach produces an estimate of exposure to $PM_{2.5}$ and O_3 during the study period by population group, accounting for population size and estimated pollutant levels. To test for differences in the weighted average air pollution concentrations calculated for each demographic subgroup in a given urbanicity or RI category, we used weighted t-tests. We assessed whether the assumption of normality was violated by examining frequency histograms and boxplots.

We then fit separate linear models of average $PM_{2.5}$ and O_3 concentrations to estimate the association with RI, urbanicity, and region, and computed linear combinations of these variables. RI was measured continuously as quintiles, as exploratory analysis indicated that the association between RI and air pollution was better represented when RI quintiles were used instead of raw RI values. Urbanicity and region were entered as categorical variables. Demographic variables used in the models included percentage of population with less than a high school education, percentage in poverty, and percentage Hispanic. Variables were selected based on associations observed between air pollution, race/ethnicity, and SES observed in previous studies (Miranda et al., 2011; Gray et al., 2013).

All statistical analyses were performed using R version 3.1.2 (R Core Team, 2014). *P*-values from 2-sided 95% confidence intervals were used for statistical inference.

3. Results

Results were based on 52,807 census tracts in the eastern US with a population ≥ 100 in the 2000 Census. The median and mean population in tracts in the study area was 3,937 and 4,257, respectively (standard deviation = 2,114). Tracts vary in land area and shape: median area for tracts in the study area = 6.19 km^2; standard deviation = 396.1km^2; min-max = <1km^2–12,992 km^2.

Metrics of downscaler performance were superior when comparing monitored 5y average O_3 concentrations with downscaler 5y averages based on April–September estimates versus year-round estimates. Henceforth we use 5y O_3 averages based on daily downscaler output from April–Sept. (2002–2006), and 5 year $PM_{2.5}$ averages based on daily downscaler data, year-round. Average pollutant concentrations across the study area and ambient monitoring locations are shown in Fig. 1a–b. The average $PM_{2.5}$ and O_3 downscaler-derived concentrations for the study period across the study area were 12.4 μg/m^3 and 47.7 ppb, respectively. For averages computed for the entire study area, annual average concentrations were all within 1 μg/m^3 for $PM_{2.5}$ and 2 ppb for O_3, that is, there were not clear trends in overall air pollution levels from 2002 to 2006. More detailed model evaluation results can be found in eTable 2 and eFigures 3–4 of the Supplemental Material.

3.1. Air pollution exposures and urbanicity

Higher 5 year $PM_{2.5}$ levels were clearly related to urbanicity: $PM_{2.5}$ concentrations were consistently highest in urban tracts and lowest in rural tracts (eTable 3). Urban $PM_{2.5}$ levels in the West and Northeast were 39% and 29% higher, respectively, than $PM_{2.5}$ in rural tracts within these regions. The South had the smallest differential between urban and rural $PM_{2.5}$ levels, with urban $PM_{2.5}$ levels 7% higher than those in rural tracts. The relationship between urbanicity and O_3 levels varied by region. In the Northeast, Midwest, and South, the highest O_3 levels were observed in suburban tracts. In the West, the highest O_3 levels were observed in urban tracts. For each region, the association between both $PM_{2.5}$ and O_3 and urbanicity was statistically significant (ANOVA with unequal variance correction $p < 0.05$). As a sensitivity analysis, we reproduced this analysis but included all tracts, irrespective of total population (i.e., including the 317 tracts with population <100). Results were not significantly different from those presented here.

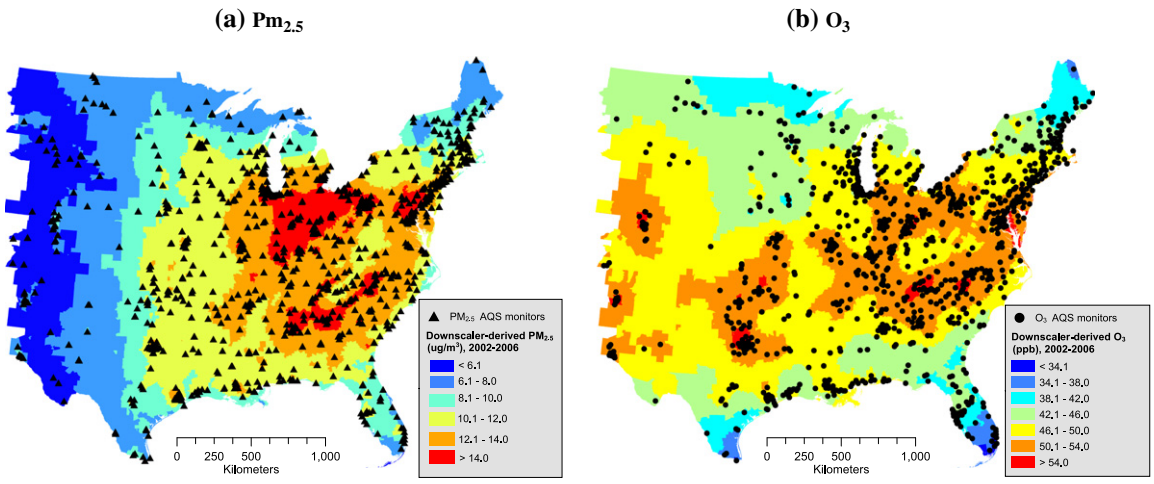

Fig. 1. a, b. Five year average tract level downscaler-derived concentrations.

3.1.1. Urbanicity and demographic subgroup exposures

Exposure estimates by urbanicity for the Northeast are presented in Table 1. For brevity, the corresponding tables for the South, Midwest and West, are presented in eTables 4, 5 and 6, respectively. Weighted *t*-tests with Welch correction for non-homogeneity of variances were used for pairwise comparisons of average pollutant levels estimated for demographic subgroups. For subgroups with more than two categories, a referent category is designated (indicated by *), and weighted *t*-tests are used for pairwise comparisons between the referent category and other categories.

Fig. 2a provides a visual representation of long-term average $PM_{2.5}$ exposures for four racial/ethnic groups by urbanicity and region. Across regions, levels of $PM_{2.5}$ were 0.1–1.1 μg/m^3 higher for NHB compared to other race/ethnicity groups for urban, suburban, and rural tracts. Exposure to $PM_{2.5}$ was higher for less educated (no high school diploma) urban, suburban, and rural populations compared to populations with a college degree, with the exception of the urban South (eTable 4), where college graduates had higher $PM_{2.5}$ exposure. Otherwise, there were not clear patterns in $PM_{2.5}$ exposure by age, education, and SES (e.g., employment, poverty) across the different urbanicity categories in the four regions.

Race/ethnicity-based exposures to O_3 concentrations exhibited marked variation by region and urbanicity (Fig. 2b). The highest O_3 exposures were observed for NHW and NHB in the Northeast and Midwest, respectively; other races in the South; and Hispanics and other races in the West. Ozone exposure gradients by education, age, and SES did not emerge within levels of urbanicity.

3.2. Racial isolation

In each region, there was a clear pattern in which 5 year average $PM_{2.5}$ levels increased with increasing quintile of RI (Table 2). The same pattern of consistently increasing air pollution with increasing RI did not emerge for O_3. Instead, tracts with the highest and lowest RI values tended to have lower O_3 levels than tracts with middle values of RI (e.g., 2nd and 3rd quintiles). Mean $PM_{2.5}$ and O_3 levels differed by quintile of RI within each region ($p < 0.05$).

Table 1
Average downscaler-derived air pollution levels for each population group by urbanicity in the Northeast*.

Variable	Average $PM_{2.5}$ level (standard deviation), μg/m^3				Average O_3 level (standard deviation), parts per billion (ppb)			
	All tracts (n = 13,044)	Urban (n = 11,462)	Suburban (n = 841)	Rural (n = 741)	All tracts (n = 13,044)	Urban (n = 11,462)	Suburban (n = 841)	Rural (n = 741)
Average pollution level	12.8 (1.88)	13.1 (1.66)	11.5 (1.97)	10.2 (1.88)	46.8 (3.56)	46.8 (3.53)	47.4 (3.49)	45.9 (3.86)
Race/ethnicity+								
Non-Hispanic White**	12.5 (1.88)	12.8 (1.70)	11.5 (1.98)	10.2 (1.93)	47.2 (3.32)	47.6 (1.70)	47.2 (3.45)	45.8 (3.85)
Non-Hispanic black	**13.7 (1.27)**	**13.8 (1.22)**	**11.9 (1.78)**	**10.9 (1.59)**	**45.8 (3.46)**	**45.7 (1.22)**	**49.2 (3.40)**	**48.0 (2.47)**
Hispanic	**13.6 (1.40)**	**13.7 (1.34)**	**11.6 (1.67)**	**10.4 (1.48)**	**44.7 (3.68)**	**44.6 (1.34)**	**48.5 (3.52)**	**47.3 (2.86)**
Other	**13.3 (1.64)**	**13.4 (1.63)**	**11.1 (1.82)**	**9.80 (1.73)**	**45.7 (3.64)**	**45.3 (1.42)**	**47.0 (3.68)**	**45.5 (3.95)**
Age (y)								
<20**	12.8 (1.81)	13.0 (1.64)	11.5 (1.95)	10.3 (1.90)	46.9 (3.49)	46.9 (1.63)	47.4 (3.48)	45.9 (3.80)
20–64	12.8 (1.83)	13.1 (1.65)	11.5 (1.98)	10.2 (1.93)	**46.8 (3.55)**	**46.8 (1.65)**	47.4 (3.50)	45.9 (3.84)
≥65	12.8 (1.85)	13.1 (1.66)	11.6 (1.97)	10.2 (1.93)	**47.1 (3.46)**	**47.2 (1.66)**	47.5 (3.39)	45.9 (3.88)
Education								
<High school**	**13.1 (1.80)**	**13.3 (1.60)**	11.7 (1.96)	10.4 (1.99)	46.3 (3.68)	46.3 (1.60)	47.7 (3.33)	46.1 (3.90)
High school	**12.7 (1.86)**	**13.0 (1.67)**	11.6 (1.96)	**10.2 (1.93)**	**47.2 (3.56)**	**47.2 (1.67)**	**47.5 (3.46)**	**45.9 (3.87)**
College	**12.7 (1.76)**	**13.0 (1.61)**	**11.2 (1.98)**	**9.87 (1.77)**	**46.8 (3.51)**	**46.8 (1.61)**	**46.9 (3.62)**	**45.6 (3.64)**
Socioeconomic								
Employed	12.8 (1.82)	13.0 (1.65)	11.5 (1.98)	10.2 (1.92)	46.9 (3.51)	46.9 (1.65)	47.4 (3.49)	45.9 (3.84)
Unemployed	**13.1 (1.80)**	**13.4 (1.58)**	11.5 (1.87)	10.2 (1.95)	**46.2 (3.70)**	**46.1 (1.58)**	**47.6 (3.26)**	46.0 (3.83)
Not in poverty	12.8 (1.82)	13.0 (1.64)	11.5 (1.98)	10.2 (1.91)	47.0 (3.48)	47.0 (1.64)	47.4 (3.29)	45.9 (3.82)
In poverty	**13.1 (1.85)**	**13.4 (1.61)**	11.5 (1.92)	10.2 (1.95)	**45.8 (3.70)**	**45.7 (1.61)**	47.5 (3.35)	45.9 (3.93)

*Values in bold indicate significant differences between categories ($p < 0.05$), assessed using weighted *t*-tests.
**Denotes referent category for comparison in groups with >2 categories.
+Note that race/ethnicity definitions were based on 2000 Census data from Summary File 1, Table P4. Individuals reporting more than one race were classified in the "Other" race category.

3.2.1. Racial isolation and demographic subgroup exposures

Exposure estimates in low vs. high RI tracts in the Northeast are presented in Table 3, while corresponding tables for the three other regions are presented in eTables 7–9. Methods for hypothesis testing correspond to those used for the urbanicity analysis. Without exception across regions, $PM_{2.5}$ exposures estimated for a given demographic subgroup are higher in tracts with the highest RI (≥80th percentile) compared to tracts with the lowest RI (<20th percentile). In high RI tracts, NHB have the highest $PM_{2.5}$ exposure in all regions. In low RI tracts, the racial/ethnic group with the highest exposure differed by region. Race/ethnicity-based exposures to O_3 varied by region and RI: in high RI tracts, NHW had the highest O_3 exposure in the Northeast, Midwest, and South, but in low RI tracts, the race/ethnicity groups with the highest exposure varied by region. There were not clear patterns with respect to age, education, or SES and O_3 exposure.

3.3. Racial isolation, urbanicity, region, and long-term air pollution exposures

Air pollution levels in urban, suburban, and rural tracts were plotted versus region-specific RI quintiles in Fig. 3 ($PM_{2.5}$) and eFigure 5 (O_3); plots suggest an association between $PM_{2.5}$ and RI. We used linear regression to estimate the effect of a one quintile increase in RI by region and urbanicity, holding selected demographic variables at their mean (eTable 10). We report whether associations estimated between RI and air pollution were statistically significant and if associations differed by urbanicity within region.

In the Northeast, Midwest, and South, the association between RI and $PM_{2.5}$ was positive and statistically significant in urban, suburban, and rural tracts. In the Midwest, associations in urban, suburban, and rural tracts were significantly different from one another. The largest association was in the rural Midwest, where a one quintile increase in RI was associated with a 0.90 μg/m^3 (95% confidence interval: 0.83, 0.99 μg/m^3) increase in $PM_{2.5}$ concentration. In the South, the association in urban tracts was significantly higher than that in suburban or rural tracts: a one quintile increase in RI in the urban South was associated with a 0.35 μg/m^3 (0.33, 0.37 μg/m^3) increase in $PM_{2.5}$.

In the Northeast, Midwest, and West, the association between RI and O_3 was positive and statistically significant in urban, suburban, and rural tracts. In the South, the association between RI and O_3 was positive and statistically significant in urban tracts only. A one quintile increase in RI was associated with a 0.56 ppb (0.45, 0.68 ppb) and 0.69 ppb (0.60, 0.79 ppb) decrease in O_3 levels for suburban and rural tracts, respectively. In the Northeast, Midwest, and South, associations in urban tracts differed from those in suburban and rural tracts, while suburban and rural tracts were not significantly different from one another.

4. Discussion

We use a recently developed approach to predicting air pollution levels that allows us to estimate air pollution concentrations in locations without monitoring data and a previously derived local, spatial measure of RI to evaluate relationships among urbanicity, RI, and predicted $PM_{2.5}$ and O_3 in urban, suburban, and rural areas of the US. Concentrations of $PM_{2.5}$ were consistently highest in urban tracts and lowest in rural tracts for all US regions. The highest O_3 levels were found in the suburban Northeast, Midwest, and South, and the urban West. With respect to RI, there was a clear pattern in which 5y average $PM_{2.5}$ levels increased with increasing quintile of RI within each geographic region. For $PM_{2.5}$, high RI tracts had higher average $PM_{2.5}$ levels in each category of urbanicity than low RI tracts, with the exception of rural tracts in the West. Patterns of O_3 levels by urbanicity and low/high RI differed between regions.

Demographic analysis indicated that, without exception, $PM_{2.5}$ exposure estimated for a given demographic subgroup was higher in tracts with high RI vs. low RI. Across all regions, levels of $PM_{2.5}$ were consistently higher for NHB compared to other race/ethnicity groups in urban, suburban, and rural tracts. While the magnitude of differences in $PM_{2.5}$ exposure estimated for different racial/ethnic groups was not large, ranging from approximately 0.1–1.1 μg/m^3, the average difference may be small in magnitude due to averaging over the relatively large study area and regions within. Associations between RI and both $PM_{2.5}$ and O_3 differed by urbanicity, but were positive and statistically significant with exceptions in the South and West. Within each region, associations between RI and predicted $PM_{2.5}$ were highest in rural tracts of the Northeast and Midwest, and in urban tracts of the South and West. For O_3, associations were largest in the rural tracts of all regions except the South.

Previous work has used community-level measures of racial/ethnic composition to evaluate exposure burdens by population subgroup. Findings from our analysis of demographic subgroups are consistent with these studies (Brochu et al., 2011; Miranda et al., 2011; Bell and Ebisu, 2012; Gray et al., 2013; Ard, 2015), which find disproportionate exposure burdens for certain groups. However, a simple measure of

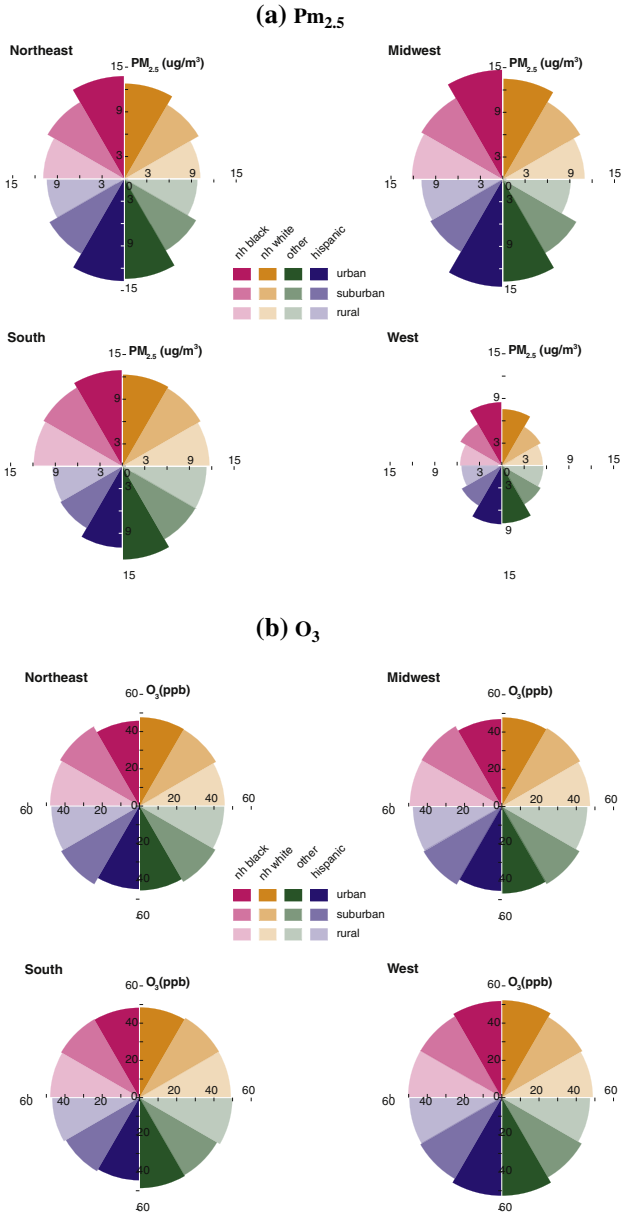

Fig. 2. a, b. Five year average downscaler derived concentrations of (a) $PM_{2.5}$ (b) O_3 for racial/ethnic population subgroups by urbanicity and region.

Table 2
Average downscaler-derived air pollution exposure levels and racial isolation (RI), overall and by region*.

Racial isolation quintile	Average $PM_{2.5}$ level (standard deviation) in μg/m^3				
	All regions (n = 52,807)	Northeast (n = 13,044)	Midwest (n = 16,357)	South (n = 21,776)	West** (n = 1,630)
<20th	11.1 (2.70)	11.5 (2.20)	10.7 (2.52)	11.2 (2.39)	5.91 (1.01)
20–39th	12.2 (2.40)	12.6 (1.80)	12.8 (2.21)	11.8 (2.41)	6.72 (1.26)
40–59th	12.5 (2.24)	12.9 (1.66)	13.2 (1.85)	12.2 (2.17)	7.44 (1.31)
60–79th	12.8 (2.04)	13.2 (1.56)	13.6 (1.62)	12.5 (1.86)	7.40 (1.05)
≥80th	13.5 (1.81)	13.9 (1.16)	14.6 (1.43)	12.9 (1.81)	8.07 (1.15)
	Average O_3 level (standard deviation) in parts per billion (ppb)				
<20th	47.0 (4.12)	46.4 (3.73)	46.6 (3.10)	47.7 (6.03)	42.9 (3.51)
20–39th	48.0 (4.21)	47.4 (3.25)	47.6 (3.26)	48.3 (5.60)	44.1 (2.22)
40–59th	48.0 (4.60)	47. 4 (3.36)	47.8 (3.55)	48.4 (5.22)	43.1 (1.93)
60–79th	48.1 (4.51)	47.2 (3.56)	48.1 (3.35)	48.3 (4.80)	43.7 (2.35)
≥80th	47.3 (4.31)	45.5 (3.52)	47.2 (3.28)	48.1 (4.64)	42.5 (1.88)

*Note that quantiles of RI were calculated for all census tracts (first column), and then separately for each region of census tracts. This is because the distribution of RI values differs between regions, e.g., the 20th percentile RI value for the Northeast region may not be equivalent or even similar to the 20th percentile RIvalue for the South region.
**The West region does not include all tracts in the census-defined West because the downscaler did not estimate air pollution exposures for all tracts in West states for 2002–2006.

racial composition may not be interpretable in the framework of RRS since 1) segregation depends on the relationship among race/ethnicity groups in neighborhoods; and 2) proportions of a given race/ethnicity group should be compared to place-wide racial composition (Morello-Frosch and Jesdale, 2006; Morello-Frosch and Lopez, 2006). Thus, such an approach may provide useful insights but does not account for the racial/ethnic composition of the larger community and thereby provide information as to whether the community's organization reveals broader patterns of racial inequity.

A smaller but growing body of work has examined air pollution exposure and racial segregation. In these studies, residential segregation is conceptualized either as (un)evenness (Lopez, 2002; Morello-Frosch and Jesdale, 2006; Rice et al., 2014), which is evaluated using a dissimilarity index (Sakoda, 1981), or clustering of tracts that significantly deviate from the racial/ethnic composition of the larger spatial unit (Getis and Ord, 1992; Jones et al., 2014). These studies generally find higher exposures and health risks for individuals, specifically NHB (Lopez, 2002; Morello-Frosch and Jesdale, 2006) or Hispanics (Jones et al., 2014), in more segregated areas. A critical limitation of these studies is the exclusion of nonurban populations; without exception, these studies have focused on segregation and pollution only in metropolitan settings. This urban bias is likely due to the dearth of ambient monitoring data in more rural areas, but as a result, air pollution exposure levels, as well as relationships with RI, are uncharacterized for large, primarily rural and suburban swaths of the US population.

Although there is little or no research on segregation and air pollution in nonurban areas, Lichter et al., found patterns of racial unevenness in urban, suburban, and rural US communities (Lichter et al., 2007). Thus, it is not a question of *whether* RI exists outside of urban areas, but whether RI is related to air pollution in these locations. We find that associations between higher $PM_{2.5}$ levels and RI or segregation are not limited to urban areas. Average air pollution levels differ by degree of urbanicity, but at least with respect to $PM_{2.5}$, individuals in high RI urban, suburban, and rural areas were consistently disproportionately exposed compared to their counterparts in low RI areas. Our findings also suggest that, in the Northeast and Midwest, the association between RI and $PM_{2.5}$ is largest for rural tracts, and that the association between RI and O_3 is highest in suburban and rural areas of the Northeast, Midwest, and West. Thus, while overall pollution (e.g., $PM_{2.5}$) levels may be lower in nonurban versus urban areas, racially isolated tracts are disproportionately exposed compared to less racially isolated tracts at similar levels of urbanicity. This finding would seem to strengthen the case for a relationship between segregation and elevated $PM_{2.5}$ exposure burdens.

In contrast, O_3 exposures were not clearly related to RI or consistently higher for particular demographic subgroups. The highest O_3 levels were primarily observed in suburban tracts, while the lowest levels were found in rural tracts, with the exception of the South. Differences in patterning of $PM_{2.5}$ and O_3 exposure by RI, urbanicity, and demographic subgroup are not unexpected: $PM_{2.5}$ is a primary pollutant, while O_3, a secondary pollutant, is formed in light-catalyzed reactions between precursor pollutants, namely nitrogen oxides (NO_x) and volatile organic compounds (VOCs) (Seinfeld and Pandis, 1998). The VOCs may come from anthropogenic or biogenic sources, thus complicating the relationship between urban/suburban/rural category and O_3

Table 3
Average downscaler-derived air pollution levels for each population group by RI in the Northeast*.

Variable	Average $PM_{2.5}$ level (standard deviation) in μg/m^3			Average O_3 level (standard deviation) in parts per billion (ppb)		
	All tracts	Least racially isolated (<20th percentile)	Most racially isolated (>80th percentile RI)	All tracts	Least racially isolated (<20th percentile)	Most racially isolated (>80th percentile RI)
Average pollution level	12.8 (1.88)	11.5 (2.20)	13.9 (1.16)	46.8 (3.56)	46.4 (3.74)	45.5 (3.52)
Race/ethnicity+						
Non-Hispanic White**	12.5 (1.88)	11.3 (2.13)	13.6 (1.29)	47.2 (3.32)	46.7 (3.64)	47.4 (3.28)
Non-Hispanic black	**13.7 (1.27)**	**11.8 (2.07)**	**14.0 (1.03)**	**45.8 (3.46)**	**47.1 (3.39)**	**45.3 (3.29)**
Hispanic	**13.6 (1.40)**	**12.4 (1.95)**	**14.0 (1.04)**	**44.7 (3.68)**	**46.5 (3.38)**	**44.0 (3.47)**
Other	**13.3 (1.64)**	**12.1 (2.15)**	**13.8 (1.08)**	**45.7 (3.64)**	**45.7 (3.32)**	**45.2 (3.28)**
Age (y)						
<20**	12.8 (1.81)	11.5 (2.12)	13.9 (1.11)	46.9 (3.49)	46.5 (3.61)	45.4 (3.51)
20–64	12.8 (1.83)	11.5 (2.13)	13.9 (1.11)	**46.8 (3.55)**	**46.4 (3.64)**	45.5 (3.54)
≥65	12.8 (1.85)	11.5 (2.15)	13.9 (1.16)	**47.1 (3.46)**	46.8 (3.65)	**46.0 (3.52)**
Education						
<High school**	13.1 (1.80)	11.8 (2.27)	13.9 (1.09)	46.3 (3.68)	46.7 (3.75)	45.0 (3.55)
High school	**12.7 (1.86)**	**11.5 (2.14)**	13.8 (1.13)	**47.2 (3.56)**	46.4 (3.69)	**45.8 (3.52)**
College	**12.7 (1.76)**	**11.5 (2.01)**	13.8 (1.13)	**46.8 (3.51)**	**46.4 (3.42)**	**45.5 (3.42)**
Socioeconomic						
Employed	12.8 (1.82)	11.6 (2.13)	13.8 (1.12)	46.9 (3.51)	**46.4 (3.70)**	45.6 (3.52)
Unemployed	**13.1 (1.80)**	**11.4 (2.14)**	**14.0 (1.06)**	**46.2 (3.70)**	46.5 (3.63)	**44.9 (3.50)**
Not in poverty	12.8 (1.82)	11.5 (2.12)	13.8 (1.11)	47.0 (3.48)	46.7 (3.61)	45.8 (3.50)
In poverty	**13.1 (1.85)**	11.4 (2.26)	**14.0 (1.12)**	**45.8 (3.70)**	**46.1 (3.85)**	**44.8 (3.54)**

*Values in bold indicate significant differences between categories ($p < 0.05$), assessed using weighted t-tests.
**Denotes referent category for comparison in groups with >2 categories.
+Note that race/ethnicity definitions were based on 2000 Census data from Summary File 1, Table P4. Individuals reporting more than one race were classified in the "Other" race category.

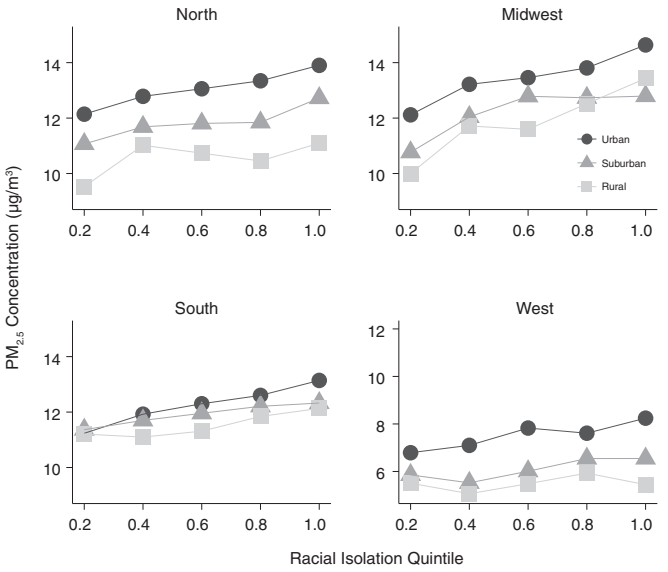

Fig. 3. Quintiles of racial isolation and average $PM_{2.5}$ levels.

concentrations. Ozone concentrations are typically higher where there is a mixture of precursor pollutants in the atmosphere, and O_3 tends to be a "regional" pollutant, that is, it is more homogeneously distributed over larger geographies compared to $PM_{2.5}$ (Bergin et al., 2005).

Several features of this study enhance the health-relevance of our findings. First, exposure burdens were examined as 5y averages, so even small increases in concentration represent elevated exposures that may threaten health over a long period of time. Moreover, because these are long-term averages, it is less likely that they are anomalous; elevated average concentrations observed over one day or week do not provide as convincing evidence of higher overall exposure burdens in the same way as elevated concentrations sustained over multiple years. Further, because we calculate population-level estimates, any differences in exposure apply to a large number of people, and therefore translate into substantial increases in exposure burdens for more racially isolated populations. Unequal exposure burdens, particularly when combined with social, demographic, and neighborhood risk factors, may enhance vulnerability or susceptibility and contribute to the marked disparities that are observed in many health outcomes along racial/ethnic, socioeconomic, urban/rural, neighborhood, or geographic lines (Gee and Payne-Sturges, 2004). Consequently, the association observed between air pollution exposure and RI represents an important and far-reaching public health issue.

This study has several limitations. We use downscaler predictions of air pollution concentrations for 2002–2006, and 2000 Census data to estimate demographic characteristics of tracts for those years. However, 2000 Census data may not accurately reflect population characteristics either for 2002–2006 or for present-day. This analysis may not capture finer scale patterns in RI, SES, or racial/ethnic composition related to long-term $PM_{2.5}$ or O_3 concentrations, as the spatial resolution can impact the presence, magnitude, and extent of estimated exposure disparities (Dolinoy and Miranda, 2004). Tracts are population-based, such that tracts in densely settled urban areas are systematically smaller in size (area) than tracts in less densely populated areas. Thus, spatial "smoothing" of air pollution and RI differ in urban, suburban, and rural settings, which could affect relationships observed between RI and air pollution by urbanicity. Downscaler estimates are not equivalent to monitoring data, and we are less confident in the accuracy of exposures estimated using downscaler output in areas with less monitoring data. Further, downscaler output were only available for the eastern two-thirds of the US for 2002–2006, and entirely exclude multiple states in the western US, including Arizona, California, Idaho, Oregon, Nevada, Utah, and Washington. Finally, ambient air pollution concentrations are not direct measures of exposure and do not capture individual-level exposures due to indoor air pollution, activity patterns, or occupation.

To our knowledge, this study is the first to examine associations between air pollution exposure burdens and RI in nonurban settings. We use a local, spatial measure of RI of NHB (Anthopolos et al., 2011) derived from a global spatial measure of isolation (Reardon and O'Sullivan, 2004). This local measure of RI of NHB accounts for the underlying spatial relationships among spatial units, and in effect, the relationships among race/ethnicity groups in different tracts. We contend, as have others, that RRS is a multilevel construct that may manifest in different ways depending on the geographic scale of measurement (Acevedo-Garcia et al., 2003). Further, characterizing exposures in nonurban settings is important, independently of RI or demographic subgroup: pollutant mixtures, concentration, and chemical composition (in the case of $PM_{2.5}$) may differ between urban and rural areas (Krall et al., 2013). Urban and rural populations may also differ systematically in ways that impact exposure levels or health outcomes at a given level of exposure (i.e., effect modification) (Vanasse et al., 2010). Using downscaler-predicted air pollution levels allowed us to include a diverse population that is a larger, more representative sample of the US population than that obtained from examining exclusively urban populations.

Although this work and previous studies differ with respect to study area, segregation/isolation measures, and geographic scale, results consistently indicate that greater NHB segregation is associated with disparities in air pollution exposures (Lopez, 2002; Morello-Frosch and Jesdale, 2006; Jones et al., 2014; Rice et al., 2014). The current study uses a finer scale spatial measure of RI that can identify specific tracts with elevated air pollution levels. Such local information may more readily translate into state/tribal or county initiatives targeted at particular communities to mitigate exposure levels or pre-empt poor health outcomes among residents. Findings from this study contribute to a more comprehensive understanding of air pollution exposure and segregation, which can be used to inform policy-making and better identify and protect sensitive, susceptible, and vulnerable subpopulations.

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Competing interests/conflicts of interest

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.envint.2016.04.008.

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Technical Support Document (TSD)

Additional Updates to Emissions Inventories for the Version 6.3,

2011 Emissions Modeling Platform for the Year 2023

October, 2017

U.S. Environmental Protection Agency
Office of Air and Radiation
Office of Air Quality Planning and Standards
Air Quality Assessment Division

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Note: this document has been updated from its original version to correct internal bookmarks in Sections 3.2.1.3 and 3.2.2

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Acronyms

AE5	CMAQ Aerosol Module, version 5, introduced in CMAQ v4.7
AE6	CMAQ Aerosol Module, version 6, introduced in CMAQ v5.0
AEO	Annual Energy Outlook
BAFM	Benzene, Acetaldehyde, Formaldehyde and Methanol
BEIS	Biogenic Emissions Inventory System
BELD	Biogenic Emissions Landuse Database
Bgal	Billion gallons
BPS	Bulk Plant Storage
BTP	Bulk Terminal (Plant) to Pump
C1/C2	Category 1 and 2 commercial marine vessels
C3	Category 3 (commercial marine vessels)
CAEP	Committee on Aviation Environmental Protection
CAIR	Clean Air Interstate Rule
CAMD	EPA's Clean Air Markets Division
CAMx	Comprehensive Air Quality Model with Extensions
CAP	Criteria Air Pollutant
CARB	California Air Resources Board
CB05	Carbon Bond 2005 chemical mechanism
CBM	Coal-bed methane
CEC	North American Commission for Environmental Cooperation
CEMS	Continuous Emissions Monitoring System
CEPAM	California Emissions Projection Analysis Model
CISWI	Commercial and Industrial Solid Waste Incinerators
Cl	Chlorine
CMAQ	Community Multiscale Air Quality
CMV	Commercial Marine Vessel
CO	Carbon monoxide
CSAPR	Cross-State Air Pollution Rule
CWFIS	Canadian Wildland Fire Information System
E0, E10, E85	0%, 10% and 85% Ethanol blend gasoline, respectively
EBAFM	Ethanol, Benzene, Acetaldehyde, Formaldehyde and Methanol
ECA	Emissions Control Area
EEZ	Exclusive Economic Zone
EF	Emission Factor
EGU	Electric Generating Units
EIS	Emissions Inventory System
EISA	Energy Independence and Security Act of 2007
EPA	Environmental Protection Agency
EMFAC	Emission Factor (California's onroad mobile model)
FAA	Federal Aviation Administration
FAPRI	Food and Agriculture Policy and Research Institute
FASOM	Forest and Agricultural Section Optimization Model
FCCS	Fuel Characteristic Classification System
FEPS	Fire Emission Production Simulator
FF10	Flat File 2010
FINN	Fire INventory from NCAR
FIPS	Federal Information Processing Standards

FHWA	Federal Highway Administration
HAP	Hazardous Air Pollutant
HCl	Hydrochloric acid
HDGHG	Heavy-Duty Vehicle Greenhouse Gas
Hg	Mercury
HMS	Hazard Mapping System
HPMS	Highway Performance Monitoring System
HWC	Hazardous Waste Combustion
HWI	Hazardous Waste Incineration
ICAO	International Civil Aviation Organization
ICI	Industrial/Commercial/Institutional (boilers and process heaters)
ICR	Information Collection Request
IDA	Inventory Data Analyzer
I/M	Inspection and Maintenance
IMO	International Marine Organization
IPAMS	Independent Petroleum Association of Mountain States
IPM	Integrated Planning Model
ITN	Itinerant
LADCO	Lake Michigan Air Directors Consortium
LDGHG	Light-Duty Vehicle Greenhouse Gas
LPG	Liquefied Petroleum Gas
MACT	Maximum Achievable Control Technology
MARAMA	Mid-Atlantic Regional Air Management Association
MATS	Mercury and Air Toxics Standards
MCIP	Meteorology-Chemistry Interface Processor
Mgal	Million gallons
MMS	Minerals Management Service (now known as the Bureau of Energy Management, Regulation and Enforcement (BOEMRE)
MOVES	Motor Vehicle Emissions Simulator
MSA	Metropolitan Statistical Area
MSAT2	Mobile Source Air Toxics Rule
MTBE	Methyl tert-butyl ether
MWRPO	Mid-west Regional Planning Organization
NCD	National County Database
NEEDS	National Electric Energy Database System
NEI	National Emission Inventory
NESCAUM	Northeast States for Coordinated Air Use Management
NESHAP	National Emission Standards for Hazardous Air Pollutants
NH_3	Ammonia
NIF	NEI Input Format
NLCD	National Land Cover Database
NLEV	National Low Emission Vehicle program
nm	nautical mile
NMIM	National Mobile Inventory Model
NOAA	National Oceanic and Atmospheric Administration
NODA	Notice of Data Availability
NONROAD	EPA model for estimation of nonroad mobile emissions
NO_X	Nitrogen oxides
NSPS	New Source Performance Standards
NSR	New Source Review

OAQPS	EPA's Office of Air Quality Planning and Standards
OHH	Outdoor Hydronic Heater
OTAQ	EPA's Office of Transportation and Air Quality
ORIS	Office of Regulatory Information System
ORD	EPA's Office of Research and Development
ORL	One Record per Line
OTC	Ozone Transport Commission
PADD	Petroleum Administration for Defense Districts
PF	Projection Factor, can account for growth and/or controls
PFC	Portable Fuel Container
$PM_{2.5}$	Particulate matter less than or equal to 2.5 microns
PM_{10}	Particulate matter less than or equal to 10 microns
ppb, ppm	Parts per billion, parts per million
RBT	Refinery to Bulk Terminal
RFS2	Renewable Fuel Standard
RIA	Regulatory Impact Analysis
RICE	Reciprocating Internal Combustion Engine
RRF	Relative Response Factor
RWC	Residential Wood Combustion
RPO	Regional Planning Organization
RVP	Reid Vapor Pressure
SCC	Source Classification Code
SESQ	Sesquiterpenes
SMARTFIRE	Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation
SMOKE	Sparse Matrix Operator Kernel Emissions
SO_2	Sulfur dioxide
SOA	Secondary Organic Aerosol
SI	Spark-ignition
SIP	State Implementation Plan
SPDPRO	Hourly Speed Profiles for weekday versus weekend
SPPD	Sector Policies and Programs Division
TAF	Terminal Area Forecast
TCEQ	Texas Commission on Environmental Quality
TOG	Total Organic Gas
TSD	Technical support document
ULSD	Ultra Low Sulfur Diesel
USDA	U. S. Department of Agriculture
VOC	Volatile organic compound
VMT	Vehicle miles traveled
VPOP	Vehicle Population
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting Model

1 Introduction

In support of an analysis of the transport of ozone as it relates to the 2008 Ozone National Ambient Air Quality Standards (NAAQS), the U.S. Environmental Protection Agency (EPA) developed an air quality modeling platform based on the 2011 National Emissions Inventory (NEI), version 2 (2011NEIv2) with updates. The air quality modeling platform consists of all the emissions inventories and ancillary data files used for emissions modeling, as well as the meteorological, initial condition, and boundary condition files needed to run the air quality model. The emissions modeling component of the modeling platform includes the emission inventories, the ancillary data files, and the approaches used to transform inventories for use in air quality modeling. The emissions modeling platform that corresponded to the air quality modeling platform for ozone transport related to the 2008 ozone NAAQS is known as the 2011v6.3 platform.

This document focuses on the ***updates made*** to the 2011v6.3 platform to support analyses of transport of zone related to the 2008 Ozone NAAQS. Much of the year 2011 data from the 2011v6.3 platform was unchanged for this updated platform and therefore the platform was not given a new number, although the future year of 2023 was used for this analysis as compared to 2017 for the original 2011v6.3 platform. For more information on the *original* 2011v6.3 platform and on any sectors or modeling techniques unchanged in this analysis, see the technical support document (TSD) *Preparation of Emission Inventories for the version 6.3, 2011 Emissions Modeling Platform* (EPA, 2016a), from August, 2016 available from EPA's Air Emissions Modeling web page for the version 6.3 platform: https://www.epa.gov/air-emissions-modeling/2011-version-63-platform. This web page also includes a link to the TSD *Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the Year 2023* (EPA, 2016b) that describes an earlier iteration of 2011 and 2023 emission cases that were released for public comment in January, 2017 (https://www.regulations.gov/document?D=EPA-HQ-OAR-2016-0751-0001). The updated platform described in *this document* includes additional updates as compared to the previously released and documented versions of the 2011v6.3 platform.

This 2011-based modeling platform includes all criteria air pollutants (CAPs) and precursors and the following hazardous air pollutants (HAPs): chlorine (Cl), hydrogen chloride (HCl), benzene, acetaldehyde, formaldehyde and methanol. The latter four HAPs are also abbreviated as BAFM. The air quality model used for this study is the Comprehensive Air Quality Model with Extensions (CAMx) model (http://www.camx.com/), version 6.40. However, emissions are first processed into a format compatible with for the Community Multiscale Air Quality (CMAQ) model (https://www.epa.gov/cmaq), version 5.0.2, and those emissions are converted into CAMx-ready formats.

Both CAMx and CMAQ support modeling ozone (O_3) and particulate matter (PM), and require as input hourly and gridded emissions of chemical species that correspond to CAPs and specific HAPs. The chemical mechanism used by CAMx for this platform is called Carbon Bond version 6 revision 4 (CB6r4). This version includes updated reactions, but the emissions species needed to drive this version are unchanged from the Carbon Bond version 6 revision 2 (CB6r2), which includes important reactions for simulating ozone formation, nitrogen oxides (NOx) cycling, and formation of secondary aerosol species (Hildebrant Ruiz and Yarwood, 2013). CB6 provides several revisions to the previous carbon bond version (CB05) through inclusion of four new explicit organic species: benzene, propane, acetylene and acetone, along with updates to reaction chemistry for those species and several other volatile organic chemicals (VOCs).

This update to the 2011v6.3 platform consists of two 'complete' emissions cases: the 2011 base case (i.e., 2011en_cb6v2_v6), and the 2023 base case (i.e., 2023en_cb6v2_v6), plus a source apportionment case

with the same emissions as the 2023 base case but processed for ozone source apportionment. In the case abbreviations, 2011 and 2023 are the years represented by the emissions; the "e" stands for evaluation, meaning that year-specific data for fires and electric generating units (EGUs) are used; and the "n" represents that an iteration of emissions for the 2011-based modeling platform (i.e., the first case for the 2011 platform was 2011ea, the second was 2011eb, and so on). The purpose of the 2011 base case is to represent the year 2011 in a manner consistent with the methods used in corresponding future-year cases, including the 2023 future year base case, as well as any additional future year control and source apportionment cases. Table 1-1 provides more information on these emissions cases. This document describes any changes made since the original 2011v6.3 platform that included the cases 2011ek and 2017ek, thus any changes included in the cases 2011el and 2023el are described in addition to changes made for 2011en and 2023en.

For this application, the outputs from the 2011 base case are used in conjunction with the outputs from the 2023 base case in the relative response factor (RRF) calculations to identify future areas of nonattainment. For more information on the use of RRFs and air quality modeling, see "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, PM 2.5, and Regional Haze," available from http://www.epa.gov/ttn/scram/guidance/guide/final-03-pm-rh-guidance.pdf.

Table 1-1. List of cases in this update to the 2011 Version 6.3 Emissions Modeling Platform for 2023

Case Name	Abbreviation	Description
2011 base case	2011en_cb6v2_v6	2011 case relevant for air quality model evaluation purposes and for computing relative response factors with 2023 scenario(s). Uses 2011NEIv2 along with some other inventory data, with hourly 2011 continuous emissions monitoring system (CEMS) data for electric generating units (EGUs), hourly onroad mobile emissions, and 2011 day-specific wild and prescribed fire data. Wildfire inventories for Canada and Mexico were also included.
2023 base case	2023en_cb6v2_v6	2023 "base case" scenario, representing the best estimate for 2023 that incorporates estimates of the impact of current "on-the-books" regulations.
2023 source apportionment case	2023en_ussa_cb6v2_v6_11g	2023 emissions equivalent to those in the 2023el_cb6v2_v6 case, except that the emission sources are tagged according to their origin by state or sector.

All of the above cases use the same version of the 2011 meteorology and the cases are sometimes referred to with "_11g" after the emissions portion of the case name where "g" corresponds to the 7th configuration of the meteorological modeling platform, although the configuration is not exclusive to modeling of the year 2011. A special version of the 2023en_cb6v2_v6 case called 2023en_ussa_cb6v2_v6_11g was prepared for use with the CAMx OSAT/APCA feature that allowed the contribution of 2023 base case NOx and VOC emissions from all sources in each state to projected 2023 ozone concentrations at air quality monitoring sites to be quantified. The emissions for the case are equivalent to those in the 2023el_cb6v2_v6 case, except that the emission sources are tagged according to their origin by state or sector. The steps for setting up the 2023el_ussa_cb6v2_v6 source apportionment case include:

1) prepare files for the source groups to track (e.g., anthropogenic emissions from each state, non-geographic sector-specific tags for biogenic, fugitive dust, fire, and non-U.S. emissions);

2) run all sectors in Sparse Matrix Operator Kernel Emissions (SMOKE) using the specified source groups (note that emissions for both source apportionment and for a regular CAMx run can be developed simultaneously);
3) create CAMx point source files for source groups tracked only by sector;
4) convert SMOKE outputs to CAMx point source files using the tags assigned by SMOKE; and
5) merge all of the point source files together into a single CAMx mrgpt file for each day.

More information on processing for source apportionment is available with the scripts provided for the 2011v6.3 platform at ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/.

The emissions data in this platform are primarily based on the 2011NEIv2 for point sources, nonpoint sources, commercial marine vessels (CMV), nonroad mobile sources and fires. The onroad mobile source emissions are similar to those in the 2011NEIv2, but were generated using the released 2014a version of the Motor Vehicle Emissions Simulator (MOVES2014a) (http://www.epa.gov/otaq/models/moves/).

The primary emissions modeling tool used to create the air quality model-ready emissions was the SMOKE modeling system (https://www.cmascenter.org/smoke/). SMOKE version 3.7 was used to create emissions files for a 12-km national grid that includes all of the contiguous states "12US2," shown in Figure 3-1. Electronic copies of the data used as input to SMOKE for the cases for this update to the 2011v6.3 platform are available from the corresponding section of the EPA Air Emissions Modeling website, https://www.epa.gov/air-emissions-modeling/2011-version-63-platform.

The gridded meteorological model used for the emissions modeling was developed using the Weather Research and Forecasting Model (WRF, https://www.mmm.ucar.edu/weather-research-and-forecasting-model) version 3.4, Advanced Research WRF core (Skamarock, et al., 2008). The WRF Model is a mesoscale numerical weather prediction system developed for both operational forecasting and atmospheric research applications. The WRF model was run for 2011 over a domain covering the continental U.S. at a 12km resolution with 35 vertical layers. The data output from WRF were collapsed to 25 layers prior to running the emissions and air quality models. The run for this platform included high resolution sea surface temperature data from the Group for High Resolution Sea Surface Temperature (GHRSST) (see https://www.ghrsst.org/) and is given the EPA meteorological case label "11g" and are consistent with those used for the original 2011v6.3 platform cases.

This document contains five sections. Section 2 describes the changes made to the 2011 inventories input to SMOKE in this update to the 2011v6.3 platform. Section 3 describes the updates to emissions modeling and the ancillary files used to convert the emission inventories into air quality model-ready formats. Section 4, describes the development of the 2023 inventory (projected from 2011). Data summaries comparing the 2011 and 2023 base cases are provided in Section 5. Section 6 provides references.

2 2011 Emission Inventories and Approaches

This section describes the updates to the 2011 emissions data as compared to the 2011 case known as 2011ek_cb6v2_v6 in the 2011v6.3 platform (EPA, 2016a). Table 2-1 presents the sectors in this update to the 2011 platform that differ from the original 2011v6.3 plaform. The platform sector abbreviations are provided in italics. These sector abbreviations are used in the SMOKE modeling scripts, inventory file names, and throughout the remainder of this document. The remaining sectors for which 2011 emissions are unchanged from those in the 2011ek case are listed below in Table 2-2. Documentation for these sectors, plus additional information on the updated sectors, can be found in the original 2011v6.3 TSD (EPA, 2016a).

Table 2-1. Platform sectors updated since the original 2011v6.3 emissions modeling platform

Platform Sector: ***abbreviation***	**Description and resolution of the data input to SMOKE**
Biogenics: ***beis***	Emissions from natural vegetative sources. Minor corrections made to BELD4.1 landuse data used as input to BEIS3.61 (*updated in 2011en).*
Category 1 and 2 CMV: ***cmv_c1c2***	*New sector in 2011en:* Category 1 (C1) and category 2 (C2) commercial marine vessel (CMV) emissions sources using diesel fuel from the 2011NEIv2 nonpoint inventory. County and annual resolution; (*2011el included updated CMV emissions for California; emissions unchanged in 2011en but improved spatial surrogate is used)*
Category 3 CMV: ***cmv***	*New sector in 2011en:* Category 3 (C3) commercial marine vessel (CMV) emissions sources using residual fuel from the 2011NEIv2 nonpoint inventory including emissions in state and federal waters. In 2011en, this sector includes the ECA inventory for non-US, non-Canada waters that was formerly part of the othpt sector. County and annual resolution *(emissions totals unchanged from 2011el but new sector allows for plume rise treatment in 2011en).*
Non-point: ***nonpt***	Nonpoint sources not included in other sectors. 2011en includes a minor reduction to VOC emissions in New York state for Commercial/Industrial and Residential Natural Gas: Boilers and IC Engines (*updated in 2011en).*
Nonroad: ***Nonroad***	Nonroad mobile source emissions based on 2011NEIv2. Inventory data consistent in 2011el and 2011en. In 2011en, temporal profiles for construction, lawn/garden (residential and commercial), and agriculture sources were updated (*temporal profiles updated in 2011en).*
Onroad: ***onroad***	Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles. Includes exhaust, extended idle, auxiliary power units, evaporative, permeation, refueling, and brake and tire wear. For all states, except California and Texas, based on monthly MOVES emissions tables produced by MOVES2014a. California emissions are based on Emission Factor (EMFAC) *and were updated in 2011el from the original 2011v6.3platform*. MOVES emissions for Texas provided by TCEQ for year 2012 were backcast to year 2011. MOVES-based emissions computed for each hour and model grid cell using monthly and annual activity data (e.g., VMT, vehicle population). *In 2011el, ethanol-85 usage in 2011 VMT was reduced to reflect actual percentage of E-85 used (changes in 2011el but none in 2011en).*

Platform Sector: ***abbreviation***	**Description and resolution of the data input to SMOKE**
EGU point sources: ***ptegu***	Point sources for electric generating units. In 2011en, minor changes were made to stack parameters, locations, and Continuous Emissions Monitoring System (CEMS) matching were made based on comments. Some sources moved into this sector from ptnonipm and out of the sector to ptnonipm also based on comments (*inventory and temporal profiles updated in 2011en).*
Non-US. fires: ***ptfire_mxca***	*New Sector added in 2011el:* Point source day-specific wildfires and prescribed fires for 2011 provided by Environment Canada with data for missing months and for Mexico filled in using fires from the Fire INventory from NCAR (FINN) fires (*emissions unchanged in 2011en).*
Non-EGU point sources: ***ptnonipm***	Point sources other than EGU and oil and gas production-related sources form 2011NEIv2. *In 2011en*, minor changes were made to stack parameters, locations, and CEMS matching were made based on comments. Some sources moved into this sector from ptegu and out of the sector to ptegu also based on comments (*updates specific to 2011en).*
Other point sources not from the 2011 NEI: ***othpt***	Offshore U.S. oil platforms from 2011NEIv2, plus point sources from Canada's **2013** inventory and Mexico's 2008 inventory *projected to 2011*, annual resolution. The *othpt* section was processed as a monthly sector because the 2013 Canadian airport point source inventory was at the monthly resolution. Also, for 2011en the ECA C3 for non-US/non-Canada CMV was moved into *cmv_c3 (2013 inventory for Canada is new in 2011en).*
Other area-fugitive dust not from 2011 NEI: ***othafdust***	Annual fugitive dust sources from Canada's **2013** inventory at province resolution. Export fraction and precipitation adjustments applied to this inventory to produce hourly, gridded emissions (*2013 for Canada is new in 2011en).*
Other non-NEI nonpoint and nonroad: ***othar***	Monthly year **2013** Canada (province resolution) and Mexico's 2008 nonpoint and nonroad mobile inventories *projected to 2011* (municipio resolution). Updated Canadian spatial surrogates along with population surrogate for Mexico (*new surrogates in 2011en and 2013 for Canada).*
Other non-NEI onroad sources: ***othon***	Monthly year **2013** Canada (province / annual resolution) onroad mobile inventories and *MOVES-Mexico emissions for 2011* (municipio / monthly resolution). Updated Canadian spatial surrogates and population surrogate for Mexico used (*new surrogates in 2011en and 2013 for Canada).*

Table 2-2. Platform sectors for which 2011 emissions are unchanged since the original 2011v6.3 emissions modeling platform

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Area fugitive dust: *afdust*	Nonpoint	PM_{10} and $PM_{2.5}$ fugitive dust sources from the 2011NEIv2 nonpoint inventory; including building construction, road construction, agricultural dust, and road dust. However, unpaved and paved road dust emissions differ from the NEI in that they do not have a precipitation adjustment. Instead, the emissions modeling adjustment applies a transport fraction and a meteorology-based (precipitation and snow/ice cover) zero-out. County and annual resolution. *Note: 2011 afdust emissions are unchanged from 2011ek and 2023 afdust emissions are unchanged from 2023el.*
Agricultural: *ag*	Nonpoint	NH_3 emissions from 2011NEIv2 nonpoint livestock and fertilizer application, county and annual resolution. *Note: 2011 ag emissions are unchanged from 2011ek and 2023 ag emissions are unchanged from 2023el.*
Agricultural fires: *agfire*	Nonpoint	2011NEIv2 agricultural fire sources, except for Missouri, which reverted to 2011NEIv1 based on comments. County and monthly resolution. *Note: agfire emissions are constant in the base and future years and unchanged from 2011ek.*
Nonpoint source oil and gas: *np_oilgas*	Nonpoint	2011NEIv2 nonpoint sources from oil and gas-related processes with specific adjustments based on comments. County and annual resolution. Includes updates in Utah, and corrects sources in WRAP areas so that they are no-integrate and use WRAP speciation profiles. Additionally, new Texas inventory supplied by TCEQ, and modifications to Oklahoma (VOC-only changes) and West Virginia (SO2-only changes) inventories due to NODA comments. *Note: 2011 np_oilgas emissions are unchanged from 2011ek, but 2023 emissions have been updated in 2023en based on comments.*
Point source fires: *ptfire*	Fires	Point source day-specific wildfires and prescribed fires for 2011 computed using SMARTFIRE2, except for Georgia and Florida-submitted emissions. Consistent with 2011NEIv2. *Note: ptfire emissions are constant in the base and future years and unchanged from 2011ek.*
Point source oil and gas: *pt_oilgas*	Point	2011NEIv2 point sources that include oil and gas production emissions processes with specific updates to emissions and stack parameters based on comments and updates to control program order of precedence. Annual resolution. *Note: 2011pt_oilgas emissions are unchanged from 2011ek, but 2023 emissions have been updated in 2023en based on comments.*
Locomotives: *rail*	Nonpoint	Rail locomotives emissions from the 2011NEIv2 with specific adjustments based on comments. *Note: 2011 rail emissions are unchanged from 2011ek and 2023 rail emissions are unchanged from 2023el.*
Residential Wood Combustion: *rwc*	Nonpoint	2011NEIv2 NEI nonpoint sources with Residential Wood Combustion (RWC) processes. County and annual resolution. *Note: 2011 rwc emissions are unchanged from 2011ek and 2023 emissions are unchanged from 2023el.*

The emission inventories in SMOKE input format for the 2011 base case are available from the EPA's Air Emissions Modeling website for the version 6.3 platform, https://www.epa.gov/air-emissions-modeling/2011-version-63-platform. The README_2011en_2023en_package.txt file indicates the particular zipped files associated with each platform sector. The specific updated inventories for this platform can be found in the directories ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/2011en_update/ and ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/2023en_update/. Files in the ancillary_data directory and the 12km spatial surrogates have been updated to include all of the files for this update of the platform.

A number of reports (i.e., summaries) are available with the data files for the updated 2011v6.3 platform in ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/reports/2011en_and_2023en/. The types of reports include state summaries of inventory pollutants and model species by modeling platform sector, county annual totals by modeling platform sector, daily NOx and VOC emissions by sector and total, and state-SCC-sector summaries. A comparison of the complete list of inventory files, ancillary files, and parameter settings with those for the 2011v6.3 platform is also available in *2011v6.3_ek_el_en_case_inputs.xlsx*.

The remainder of Section 2 provides details about the data contained in each of the 2011 platform sectors that were modified from the original 2011v6.3 platform.

2.1 2011 point sources (ptegu, ptnonipm, pt_oilgas)

Point sources are sources of emissions for which specific geographic coordinates (e.g., latitude/longitude) are specified, as in the case of an individual facility. A facility may have multiple emission release points that may be characterized as units such as boilers, reactors, spray booths, kilns, etc. A unit may have multiple processes (e.g., a boiler that sometimes burns residual oil and sometimes burns natural gas). With a couple of minor exceptions, this section describes only NEI point sources within the contiguous U.S. The NEI is split into three point sectors: the EGU sector for non-peaking units (ptegu), point source oil and gas extraction-related emissions (pt_oilgas) – including off-shore oil platforms, and the remaining non-EGU sector (ptnonipm) sector. The EGU emissions are split out from the other sources to facilitate the use of distinct SMOKE temporal processing and future-year projection techniques. The oil and gas sector emissions (pt_oilgas) were processed separately for summary tracking purposes and distinct future-year projection techniques from the remaining non-EGU emissions (ptnonipm).

The ptnonipm and pt_oilgas sector emissions were provided to SMOKE as annual emissions. For those ptegu sources with CEMS data (that could be matched to the 2011NEIv2), 2011 hourly CEMS NO_X and SO_2 emissions were used rather than NEI emissions, and for all other pollutants, annual emissions were used as-is from the NEI, but were allocated to hourly values using heat input CEMS data. EGUs without CEMS are allocated to hourly data base on IPM region- and pollutant-specific temporal profiles as discussed in Section 3.3.3.

The inventory pollutants processed through SMOKE for all point source sectors were: CO, NO_X, VOC, SO_2, ammonia (NH_3), PM_{10}, and $PM_{2.5}$ and the following HAPs: HCl (pollutant code = 7647010), and Cl (code = 7782505). The inventory BAFM from these sectors was not used, instead VOC was speciated to these pollutants without any use (i.e., integration) of the VOC HAP pollutants from the inventory.

Minor updates were made to some sources in the ptnonipm sector to address comments on the January, 2017 Notice of Data Availability (NODA) as follows:

1. Added four Connecticut municipal waste combustor (MWC) units to ptnonipm from ptegu, and removed two Wheelabrator Bridgeport units to be moved to ptegu. For the new ptnonipm sources, blanked out the ORIS IDs and NEEDS_ID fields.
2. NC closures from pre2011_nc_ptnonipm_closures.xlsx were applied to ptnonipm. We confirmed that all of those facilities/units listed were in ptnonipm, and not ptegu/pt_oilgas.

Updates were made to some sources in the ptegu sector to address comments on the NODA and other updated data updates as follows:

1. Updated some FIPS codes and latitudes/longitudes based on the information in the CEMS reporting data.
2. Updated stack parameters as specified in Kansas NODA comments.
3. For Unit 21257713 in Texas (IPM_YN = 7097_B_BLR1; former ORIS facility 7097, ORIS boiler **1), blanked out ORIS IDs to make that unit a non-CEM source so that inventory emissions are used instead of CEMs, in particular for SO2.
4. Moved four Connecticut MWCs to ptnonipm, and added two Wheelabrator Bridgeport units from ptnonipm.

2.1.1 EGU sector (ptegu)

The ptegu sector contains emissions from EGUs in the 2011NEIv2 point inventory that could be matched to units found in the NEEDS v5.16 database that includes the units for which the Integrated Planning Model (IPM) predicts emissions. The ptegu sector indication is used in this modeling even though IPM was not used to derive the future year emissions. In the SMOKE point flat file, emission records for sources that have been matched to the NEEDS database have a value filled into the IPM_YN column. Many of these matches are stored within the Emission Inventory System (EIS) that is used to create the NEI. In some cases, it was difficult to match the sources between the databases due to different facility names in the two data systems and due to differences in how the units are defined, thereby resulting in matches that are not always one-to-one. Some additional matches were made in the modeling platform to accommodate some of these situations as described later in this section.

Some units in the ptegu sector are matched to CEMS data via ORIS facility codes and boiler ID. For matched units, SMOKE replaces the 2011 emissions of NO_X and SO_2 with the CEMS emissions, thereby ignoring the annual values specified in the NEI. For other pollutants, the hourly CEMS heat input data are used to allocate the NEI annual emissions to hourly values. All stack parameters, stack locations, and SCC codes for these sources come from the NEI. Because these attributes are obtained from the NEI, the chemical speciation of VOC and $PM_{2.5}$ for the sources is selected based on the SCC or in some cases, based on unit-specific data. If CEMS data exists for a unit, but the unit is not matched to the NEI, the CEMS data for that unit is not used in the modeling platform. However, if the source exists in the NEI and is not matched to a CEMS unit, the emissions from that source are still modeled using the annual emission value in the NEI. The EIS stores many matches from EIS units to the ORIS facility codes and boiler IDs used to reference the CEMS data. Some additional matches were made in the modeling platform as described later in this section.

In the SMOKE point flat file, emission records for point sources matched to CEMS data have values filled into the ORIS_FACILITY_CODE and ORIS_BOILER_ID columns. The CEMS data in SMOKE-ready format is available at http://ampd.epa.gov/ampd/ near the bottom of the "Prepackaged Data" tab. Many smaller emitters in the CEMS program are not identified with ORIS facility or boiler IDs that can be matched to the NEI due to inconsistencies in the way a unit is defined between the NEI and CAMD datasets, or due to uncertainties in source identification such as inconsistent plant names in the two data systems. Also, the NEEDS database of units modeled by IPM includes many smaller emitting EGUs that are not included in the CAMD hourly CEMS programs. Therefore, there will be more units in the NEEDS database than have CEMS data. The temporalization of EGU units matched to CEMS is based on the CEMS data in the base and future years are based on the base year CEMS data for those units, whereas regional profiles are used for the remaining units. More detail can be found in Section 3.3.3.

Matches between the NEI and NEEDS were identified by identifying units in IPM outputs that were not yet matched to NEI data, and by looking for units identified in the NEI with facility type codes identifying them as EGUs or facility names that indicated they were EGUs. In each case, priority was given to units with larger emissions (e.g., > 300TPY of NO_x or SO_2). The units in each data set that did not yet have matches within the same county were compared to one another on the basis of their plant names and locations. In some cases, IDs were similar but were mismatched only due to a missing leading zero in one of the databases. In other cases, a facility level match was specified, but a unit/boiler level match was not yet identified and, therefore, the units at the facility were compared to one another on the basis of design capacity and naming. For any new matches that were found, values that represented the NEEDS IDs were filled in to the IPM_YN in the modeling platform flat files. When possible, these matches were loaded into EIS. When new matches were identified, EGUs that otherwise would have remained in the ptnonipm sector were moved to the ptegu sector.

A similar process was used to identify additional matches between the 2011NEIv2 and CEMS data. To determine whether a NEI unit matched a CEMS unit, the CEMS units were compared to facilities in the NEI that were not yet identified as a CEMS unit on the basis of their county FIPS codes, locations, and total emissions of NO_x and SO_2. Additional CEMS matches that were found were applied to the FF10 file by specifying values for ORIS_FACILITY_CODE, ORIS_BOILER_ID. Because IPM uses a concatenation of the ORIS facility code and boiler ID, values were also filled in to the IPM_YN field for these units. Many new CEMS assignments were loaded into EIS for use in future inventories. Note that SMOKE can perform matches of CEMS data down to the stack or release point-level, which is finer than unit-level.

2.1.2 Point source oil and gas sector (pt_oilgas)

The pt_oilgas sector was separated from the ptnonipm sector by selecting sources with specific NAICS codes shown in Table 2-3. The emissions and other source characteristics in the pt_oilgas sector are submitted by states, while the EPA developed a dataset of nonpoint oil and gas emissions for each county in the U.S. with oil and gas activity that was available for states to use. Nonpoint oil and gas emissions can be found in the np_oilgas sector. More information on the development of the 2011 oil and gas emissions can be found in Section 3.20 of the 2011NEIv2 TSD.

Table 2-3. Point source oil and gas sector NAICS Codes

NAICS	NAICS description
2111	Oil and Gas Extraction
2212	Natural Gas Distribution

NAICS	NAICS description
4862	Pipeline Transportation of Natural Gas
21111	Oil and Gas Extraction
22121	Natural Gas Distribution
48611	Pipeline Transportation of Crude Oil
48621	Pipeline Transportation of Natural Gas
211111	Crude Petroleum and Natural Gas Extraction
211112	Natural Gas Liquid Extraction
213111	Drilling Oil and Gas Wells
213112	Support Activities for Oil and Gas Operations
221210	Natural Gas Distribution
486110	Pipeline Transportation of Crude Oil
486210	Pipeline Transportation of Natural Gas

2.1.3 Non-IPM sector (ptnonipm)

Except for some minor exceptions, the non-IPM (ptnonipm) sector contains the 2011NEIv2 point sources that are not in the ptegu or pt_oilgas sectors. For the most part, the ptnonipm sector reflects the non-EGU sources of the NEI point inventory; however, it is likely that some small low-emitting EGUs not matched to the NEEDS database or to CEMS data are present in the ptnonipm sector. The sector includes some ethanol plants that have been identified by EPA and require special treatment in the future cases as they are impacted by mobile source rules.

The ptnonipm sector contains a small amount of fugitive dust PM emissions from vehicular traffic on paved or unpaved roads at industrial facilities, coal handling at coal mines, and grain elevators. Sources with state/county FIPS code ending with "777" are in the 2011NEIv2 but are not included in any modeling sectors. These sources typically represent mobile (temporary) asphalt plants that are only reported for some states, and are generally in a fixed location for only a part of the year and are, therefore, difficult to allocate to specific places and days as is needed for modeling. Therefore, these sources are dropped from the point-based sectors in the modeling platform.

EPA estimates for ethanol facilities

As ethanol plants are important facilities for mobile source rules that have impact development work, the EPA developed a list of corn ethanol facilities for 2011. Ethanol facilities that were not in 2011NEIv1 were added into 2011NEIv2. Some adjustments were made to these based on comments. Locations and FIPS codes for these ethanol plants were verified using web searches and Google Earth. The EPA believes that some of these sources were not originally included in the NEI as point sources because they do not meet the 100 ton/year potential-to-emit threshold for NEI point sources. Emission rates for the ethanol plants were obtained from EPA's updated spreadsheet model for upstream impacts developed for the Renewable Fuel Standard (RFS2) rule (EPA, 2010a). Plant emission rates for criteria pollutants used to estimate impacts for years 2011 (and are assumed to be the same in the future) are given in Table 2-4.

Table 2-4. Corn Ethanol Plant Criteria Pollutant Emission Factors (grams per gallon produced)

Corn Ethanol Plant Type	VOC	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	NH_3
Dry Mill Natural Gas (NG)	2.29	0.58	0.99	0.94	0.23	0.01	0.00

Corn Ethanol Plant Type	VOC	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	NH_3
Dry Mill NG (wet distillers grains with solubles (DGS))	2.27	0.37	0.63	0.91	0.20	0.00	0.00
Dry Mill Biogas	2.29	0.62	1.05	0.94	0.23	0.01	0.00
Dry Mill Biogas (wet DGS)	2.27	0.39	0.67	0.91	0.20	0.00	0.00
Dry Mill Coal	2.31	2.65	4.17	3.81	1.71	4.52	0.00
Dry Mill Coal (wet DGS)	2.31	2.65	2.65	2.74	1.14	2.87	0.00
Dry Mill Biomass	2.42	2.55	3.65	1.28	0.36	0.14	0.00
Dry Mill Biomass (wet DGS)	2.35	1.62	2.32	1.12	0.28	0.09	0.00
Wet Mill NG	2.35	1.62	1.77	1.12	0.28	0.09	0.00
Wet Mill Coal	2.33	1.04	5.51	4.76	2.21	5.97	0.00

Air toxic emission rates were estimated by applying toxic to VOC ratios in Table 2-5, and were multiplied by facility production estimates for 2011 and 2018 based on analyses performed for the industry characterization described in Chapter 1 of the RFS2 final rule regulatory impact analysis. For air toxics, except ethanol, the toxic-to-VOC ratios were developed using emission inventory data from the 2005 NEI (EPA, 2009a).

Table 2-5. Toxic-to-VOC Ratios for Corn Ethanol Plants

	Acetaldehyde	Acrolein	Benzene	1,3-Butadiene	Formaldehyde
Wet Mill NG	0.02580	0.00131	0.00060	2.82371E-08	0.00127
Wet Mill Coal	0.08242	0.00015	0.00048	2.82371E-08	0.00108
Dry Mill NG	0.01089	0.00131	0.00060	2.82371E-08	0.00127
Dry Mill Coal	0.02328	0.00102	0.00017	2.82371E-08	0.00119

2.2 2011 nonpoint sources (afdust, ag, agfire, np_oilgas, rwc, nonpt)

Several modeling platform sectors were created from the 2011NEIv2 nonpoint inventory. This section describes the *stationary* nonpoint sources. Locomotives, C1 and C2 CMV, and C3 CMV are also included the 2011NEIv2 nonpoint data category, but are mobile sources that are described in Sections 2.4.1 and 2.4.2 as the CMV and rail sectors, respectively. The 2011NEIv2 TSD available from https://www.epa.gov/air-emissions-inventories/2011-national-emissions-inventory-nei-documentation includes documentation for the nonpoint sector of the 2011NEIv2 Stationary nonpoint sources that were not subdivided into the afdust, ag, np_oilgas, or rwc sectors were assigned to the "nonpt" sector.

The nonpoint tribal-submitted emissions are dropped during spatial processing with SMOKE due to the configuration of the spatial surrogates. Part of the reason for this is to prevent possible double-counting with county-level emissions and also because spatial surrogates for tribal data are not currently available. These omissions are not expected to have an impact on the results of the air quality modeling at the 12-km scales used for this platform.

For the 2011en case, the only change in the nonpt sector was based on a comment from MARAMA regarding natural gas combustion SCCs in the state of New York. The *Commercial/Residential* (SCC=2103006000) and *Residential* (SCC=2104006010) *Natural Gas; Total Boilers and IC Engines* VOC emissions were both reduced by about 25% in New York state. This resulted in about a 575-ton reduction in VOC emissions.

The following subsections describe how the sources in the 2011NEIv2 nonpoint inventory were separated into 2011 modeling platform sectors, along with any data that were updated replaced with non-NEI data.

2.2.1 Area fugitive dust sector (afdust)

The area-source fugitive dust (afdust) sector contains PM_{10} and $PM_{2.5}$ emission estimates for nonpoint SCCs identified by EPA staff as dust sources. Categories included in the afdust sector are paved roads, unpaved roads and airstrips, construction (residential, industrial, road and total), agriculture production, and mining and quarrying. It does not include fugitive dust from grain elevators, coal handling at coal mines, or vehicular traffic on paved or unpaved roads at industrial facilities because these are treated as point sources so they are properly located.

The afdust sector is separated from other nonpoint sectors to allow for the application of a "transport fraction," and meteorological/precipitation reductions. These adjustments are applied with a script that applies land use-based gridded transport fractions followed by another script that zeroes out emissions for days on which at least 0.01 inches of precipitation occurs or there is snow cover on the ground. The land use data used to reduce the NEI emissions determines the amount of emissions that are subject to transport. This methodology is discussed in (Pouliot, et al., 2010), and in "Fugitive Dust Modeling for the 2008 Emissions Modeling Platform" (Adelman, 2012). Both the transport fraction and meteorological adjustments are based on the gridded resolution of the platform (e.g., 12km grid cells); therefore, different emissions will result if the process were applied to different grid resolutions. A limitation of the transport fraction approach is the lack of monthly variability that would be expected with seasonal changes in vegetative cover. While wind speed and direction are not accounted for in the emissions processing, the hourly variability due to soil moisture, snow cover and precipitation is accounted for in the subsequent meteorological adjustment.

The sources in the afdust sector are for SCCs and pollutant codes (i.e., PM_{10} and $PM_{2.5}$) that are considered to be "fugitive" dust sources. These SCCs are provided in Table 2-6.

Table 2-6. SCCs in the afdust platform sector

SCC	SCC Description
2275085000	Mobile Sources;Aircraft;Unpaved Airstrips;Total
2294000000	Mobile Sources;Paved Roads;All Paved Roads;Total: Fugitives
2294000002	Mobile Sources;Paved Roads;All Paved Roads;Total: Sanding/Salting - Fugitives
2296000000	Mobile Sources;Unpaved Roads;All Unpaved Roads;Total: Fugitives
2296005000	Mobile Sources;Unpaved Roads;Public Unpaved Roads;Total: Fugitives
2296010000	Mobile Sources;Unpaved Roads;Industrial Unpaved Roads;Total: Fugitives
2311000000	Industrial Processes;Construction: SIC 15 - 17;All Processes;Total
2311010000	Industrial Processes;Construction: SIC 15 - 17;Residential;Total
2311020000	Industrial Processes;Construction: SIC 15 - 17;Industrial/Commercial/Institutional;Total
2311030000	Industrial Processes;Construction: SIC 15 - 17;Road Construction;Total
2311040000	Industrial Processes;Construction: SIC 15 - 17;Special Trade Construction;Total
2325000000	Industrial Processes;Mining and Quarrying: SIC 14;All Processes;Total
2325020000	Industrial Processes;Mining and Quarrying: SIC 14;Crushed and Broken Stone;Total
2325030000	Industrial Processes;Mining and Quarrying: SIC 14;Sand and Gravel;Total

SCC	SCC Description
2801000000	Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Total
2801000002	Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Planting
2801000003	Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Tilling
2801000005	Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Harvesting
2801000008	Miscellaneous Area Sources;Agriculture Production - Crops;Agriculture - Crops;Transport
2805001000	Miscellaneous Area Sources;Agriculture Production - Livestock;Beef cattle - finishing operations on feedlots (drylots);Dust Kicked-up by Hooves (use 28-05-020, -001, -002, or -003 for Waste

The dust emissions in the modeling platform are not the same as the 2011NEIv2 emissions because the NEI paved and unpaved road dust emissions include a built-in precipitation reduction that is based on average meteorological data, which is at a coarser temporal and spatial resolution than the modeling platform meteorological adjustment. Due to this, in the platform the paved and unpaved road emissions, data used did not include any precipitation-based reduction. This allows the entire sector to be processed consistently so that the same grid-specific transport fractions and meteorological adjustments can be applied. Where states submitted afdust data, it was assumed that the state-submitted data were not met-adjusted and therefore the meteorological adjustments were still applied. Thus, it is possible that these sources may have been adjusted twice. Even with that possibility, air quality modeling shows that in general, dust is frequently overestimated in the air quality modeling results.

The total impacts of the transport fraction and meteorological adjustments for the 2011NEIv2 are shown in Table 2-7, where the starting inventory numbers include unadjusted paved and unpaved road dust, so they do not match the NEI values because those include a different type of adjustment. The amount of the reduction ranges from about 93% in New Hampshire to about 29% in Nevada.

Figure 2-1 shows the impact of each step of the adjustment for 2011. The reductions due to the transport fraction adjustments alone are shown at the top of Figure 2-1. The reductions due to the precipitation adjustments are shown in the middle of Figure 2-1. The cumulative emission reductions after both transport fraction and meteorological adjustments are shown at the bottom of Figure 2-1. The top plot shows how the transport fraction has a larger reduction effect in the east, where forested areas are more effective at reducing PM transport than in many western areas. The middle plot shows how the meteorological impacts of precipitation, along with snow cover in the north, further reduce the dust emissions.

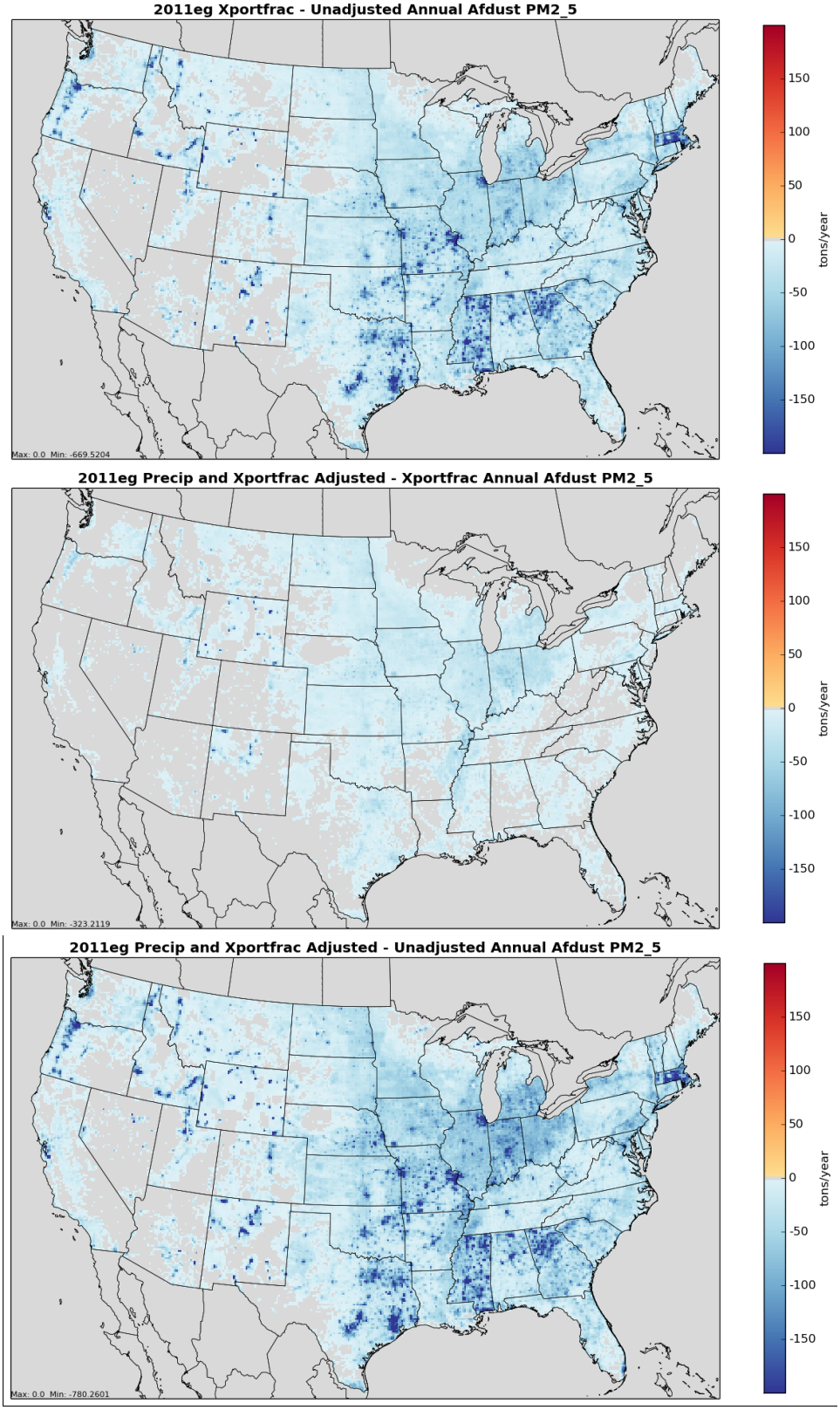
Table 2-7. Total Impact of Fugitive Dust Adjustments to Unadjusted 2011 Inventory

State	Unadjusted PM10	Unadjusted PM2_5	Change in PM10	Change in PM2_5	PM10 Reduction	PM2_5 Reduction
Alabama	378,874	47,158	-310,750	-38,597	82%	82%
Arizona	237,361	30,015	-78,519	-9,778	33%	33%
Arkansas	421,958	58,648	-305,611	-40,757	72%	69%
California	255,889	38,664	-119,035	-17,930	47%	46%
Colorado	244,630	40,421	-130,598	-20,991	53%	52%

State	Unadjusted PM10	Unadjusted PM2_5	Change in PM10	Change in PM2_5	PM10 Reduction	PM2_5 Reduction
Connecticut	29,067	4,393	-25,877	-3,912	89%	89%
Delaware	11,548	1,968	-8,219	-1,396	71%	71%
D.C.	2,115	337	-1,596	-254	75%	75%
Florida	292,797	39,637	-181,017	-24,333	62%	61%
Georgia	733,478	90,041	-593,644	-72,028	81%	80%
Idaho	432,116	49,294	-291,880	-32,897	68%	67%
Illinois	763,665	123,680	-472,806	-76,086	62%	62%
Indiana	603,152	85,151	-435,027	-60,660	72%	72%
Iowa	590,528	96,070	-339,349	-54,855	57%	57%
Kansas	747,242	118,726	-352,559	-54,760	47%	46%
Kentucky	199,744	29,496	-160,640	-23,511	80%	80%
Louisiana	236,787	35,730	-162,780	-24,086	69%	67%
Maine	50,547	7,016	-43,643	-6,078	86%	87%
Maryland	65,701	10,215	-49,481	-7,691	75%	75%
Massachusetts	205,561	22,444	-177,808	-19,370	86%	86%
Michigan	462,324	61,969	-353,225	-47,137	76%	76%
Minnesota	336,791	64,253	-217,036	-41,145	64%	64%
Mississippi	956,702	107,965	-782,249	-86,685	82%	80%
Missouri	1,063,992	130,995	-780,488	-94,576	73%	72%
Montana	385,541	50,583	-266,046	-33,521	69%	66%
Nebraska	591,457	85,206	-316,918	-45,198	54%	53%
Nevada	160,699	20,477	-47,147	-5,688	29%	28%
New Hampshire	25,540	3,766	-23,836	-3,515	93%	93%
New Jersey	24,273	5,412	-19,215	-4,255	79%	79%
New Mexico	924,497	95,871	-352,117	-36,344	38%	38%
New York	274,114	37,493	-236,431	-31,990	86%	85%
North Carolina	186,650	33,409	-146,918	-26,184	79%	78%
North Dakota	354,107	59,113	-218,630	-36,286	62%	61%
Ohio	414,902	64,609	-319,831	-49,298	77%	76%
Oklahoma	733,750	87,864	-385,344	-44,585	53%	51%
Oregon	348,093	40,596	-268,605	-30,516	77%	75%
Pennsylvania	208,246	30,344	-179,991	-26,158	86%	86%
Rhode Island	4,765	731	-3,628	-564	76%	77%
South Carolina	259,350	31,494	-198,175	-24,002	76%	76%
South Dakota	262,935	44,587	-155,938	-26,215	59%	59%
Tennessee	139,731	25,357	-107,964	-19,514	77%	77%
Texas	2,573,687	304,551	-1,278,053	-146,122	50%	48%

State	Unadjusted PM10	Unadjusted PM2_5	Change in PM10	Change in PM2_5	PM10 Reduction	PM2_5 Reduction
Utah	196,551	21,589	-113,837	-12,464	58%	58%
Vermont	67,690	7,563	-61,423	-6,855	91%	91%
Virginia	131,798	19,374	-108,700	-15,895	82%	82%
Washington	174,969	27,999	-99,720	-15,425	57%	55%
West Virginia	85,956	10,652	-79,745	-9,888	93%	93%
Wisconsin	239,851	41,669	-164,113	-28,542	68%	68%
Wyoming	434,090	45,350	-264,580	-27,467	61%	61%
Domain Total	**18,525,814**	**2,489,943**	**-11,790,743**	**-1,566,004**	**64%**	**63%**

Figure 2-1. Impact of adjustments to fugitive dust emissions due to transport fraction, precipitation, and cumulative



2.2.2 Agricultural ammonia sector (ag)

The agricultural NH_3 (ag) sector includes livestock and agricultural fertilizer application emissions from the 2011NEIv2 nonpoint inventory. The livestock and fertilizer emissions in this sector are based only on the SCCs listed in Table 2-8 and Table 2-9. The "ag" sector includes all of the NH_3 emissions from fertilizer from the NEI. However, the "ag" sector does not include all of the livestock NH_3 emissions, as there are also a small amount of NH_3 emissions from livestock feedlots in the ptnonipm inventory (as point sources) in California (175 tons) and Wisconsin (125 tons).

Table 2-8. Livestock SCCs extracted from the NEI to create the ag sector

SCC	SCC Description*
2805001100	Beef cattle - finishing operations on feedlots (drylots);Confinement
2805001200	Beef cattle - finishing operations on feedlots (drylots);Manure handling and storage
2805001300	Beef cattle - finishing operations on feedlots (drylots);Land application of manure
2805002000	Beef cattle production composite; Not Elsewhere Classified
2805003100	Beef cattle - finishing operations on pasture/range; Confinement
2805007100	Poultry production - layers with dry manure management systems;Confinement
2805007300	Poultry production - layers with dry manure management systems;Land application of manure
2805008100	Poultry production - layers with wet manure management systems;Confinement
2805008200	Poultry production - layers with wet manure management systems;Manure handling and storage
2805008300	Poultry production - layers with wet manure management systems;Land application of manure
2805009100	Poultry production - broilers;Confinement
2805009200	Poultry production - broilers;Manure handling and storage
2805009300	Poultry production - broilers;Land application of manure
2805010100	Poultry production - turkeys;Confinement
2805010200	Poultry production - turkeys;Manure handling and storage
2805010300	Poultry production - turkeys;Land application of manure
2805018000	Dairy cattle composite;Not Elsewhere Classified
2805019100	Dairy cattle - flush dairy;Confinement
2805019200	Dairy cattle - flush dairy;Manure handling and storage
2805019300	Dairy cattle - flush dairy;Land application of manure
2805020000	Cattle and Calves Waste Emissions;Milk Total
2805020002	Cattle and Calves Waste Emissions:Beef Cows
2805021100	Dairy cattle - scrape dairy;Confinement
2805021200	Dairy cattle - scrape dairy;Manure handling and storage
2805021300	Dairy cattle - scrape dairy;Land application of manure
2805022100	Dairy cattle - deep pit dairy;Confinement
2805022200	Dairy cattle - deep pit dairy;Manure handling and storage
2805022300	Dairy cattle - deep pit dairy;Land application of manure
2805023100	Dairy cattle - drylot/pasture dairy;Confinement
2805023200	Dairy cattle - drylot/pasture dairy;Manure handling and storage
2805023300	Dairy cattle - drylot/pasture dairy;Land application of manure
2805025000	Swine production composite;Not Elsewhere Classified (see also 28-05-039, -047, -053)
2805030000	Poultry Waste Emissions;Not Elsewhere Classified (see also 28-05-007, -008, -009)
2805030003	Poultry Waste Emissions;Layers
2805030004	Poultry Waste Emissions;Broilers
2805030007	Poultry Waste Emissions;Ducks
2805030008	Poultry Waste Emissions;Geese
2805030009	Poultry Waste Emissions;Turkeys

SCC	SCC Description*
2805035000	Horses and Ponies Waste Emissions;Not Elsewhere Classified
2805039100	Swine production - operations with lagoons (unspecified animal age);Confinement
2805039200	Swine production - operations with lagoons (unspecified animal age);Manure handling and storage
2805039300	Swine production - operations with lagoons (unspecified animal age);Land application of manure
2805040000	Sheep and Lambs Waste Emissions;Total
2805045000	Goats Waste Emissions;Not Elsewhere Classified
2805045002	Goats Waste Emissions;Angora Goats
2805045003	Goats Waste Emissions;Milk Goats
2805047100	Swine production - deep-pit house operations (unspecified animal age);Confinement
2805047300	Swine production - deep-pit house operations (unspecified animal age);Land application of manure
2805053100	Swine production - outdoor operations (unspecified animal age);Confinement

* All SCC Descriptions begin "Miscellaneous Area Sources;Agriculture Production – Livestock"

Table 2-9. Fertilizer SCCs extracted from the NEI for inclusion in the "ag" sector

SCC	SCC Description*
2801700001	Anhydrous Ammonia
2801700002	Aqueous Ammonia
2801700003	Nitrogen Solutions
2801700004	Urea
2801700005	Ammonium Nitrate
2801700006	Ammonium Sulfate
2801700007	Ammonium Thiosulfate
2801700008	Other Straight Nitrate
2801700009	Ammonium Phosphates
2801700010	N-P-K (multi-grade nutrient fertilizers)
2801700011	Calcium Ammonium Nitrate
2801700012	Potassium Nitrate
2801700013	Diammonium Phosphate
2801700014	Monoammonium Phosphate
2801700015	Liquid Ammonium Polyphosphate
2801700099	Miscellaneous Fertilizers

* All descriptions include "Miscellaneous Area Sources; Agriculture Production – Crops; Fertilizer Application" as the beginning of the description.

2.2.3 Agricultural fires (agfire)

The agricultural fire (agfire) sector contains emissions from agricultural fires. These emissions were placed into the sector based on their SCC code. All SCCs starting with 28015 are included. The first three levels of descriptions for these SCCs are: 1) Fires - Agricultural Field Burning; Miscellaneous Area Sources; 2) Agriculture Production - Crops - as nonpoint; and 3) Agricultural Field Burning - whole field set on fire. The SCC 2801500000 does not specify the crop type or burn method, while the more specific SCCs specify field or orchard crops and, in some cases, the specific crop being grown. For more information on how emissions for agricultural fires were developed in the 2011NEIv2, see Section 5.2 of the 2011NEIv2 TSD.

2.2.4 Nonpoint source oil and gas sector (np_oilgas)

The nonpoint oil and gas (np_oilgas) sector contains onshore and offshore oil and gas emissions. The EPA estimated emissions for all counties with 2011 oil and gas activity data with the Oil and Gas Tool, and many S/L/T agencies also submitted nonpoint oil and gas data. The types of sources covered include drill rigs, workover rigs, artificial lift, hydraulic fracturing engines, pneumatic pumps and other devices, storage tanks, flares, truck loading, compressor engines, and dehydrators. Nonpoint oil and gas emissions for most states in the 2011v6.3 platform are consistent with those in the 2011NEIv2. For more information on the development of the oil and gas emissions in the 2011NEIv2, see Section 3.20 of the 2011NEIv2 TSD. The S/L/T agencies that submitted data used in 2011v6.3 include Texas, Oklahoma and Utah.

2.2.5 Residential wood combustion sector (rwc)

The residential wood combustion (rwc) sector includes residential wood burning devices such as fireplaces, fireplaces with inserts (inserts), free standing woodstoves, pellet stoves, outdoor hydronic heaters (also known as outdoor wood boilers), indoor furnaces, and outdoor burning in firepots and chimneas. Free standing woodstoves and inserts are further differentiated into three categories: 1) conventional (not EPA certified); 2) EPA certified, catalytic; and 3) EPA certified, noncatalytic. Generally speaking, the conventional units were constructed prior to 1988. Units constructed after 1988 had to meet EPA emission standards and they are either catalytic or non-catalytic. For more information on the development of the residential wood combustion emissions, see Section 3.14 of the 2011NEIv2 TSD. The SCCs in the rwc sector are shown in Table 2-10.

Table 2-10. SCCs in the Residential Wood Combustion Sector (rwc)*

SCC	SCC Description
2104008100	SSFC;Residential;Wood;Fireplace: general
2104008210	SSFC;Residential;Wood;Woodstove: fireplace inserts; non-EPA certified
2104008220	SSFC;Residential;Wood;Woodstove: fireplace inserts; EPA certified; non-catalytic
2104008230	SSFC;Residential;Wood;Woodstove: fireplace inserts; EPA certified; catalytic
2104008300	SSFC;Residential;Wood;Woodstove: freestanding, general
2104008310	SSFC;Residential;Wood;Woodstove: freestanding, non-EPA certified
2104008320	SSFC;Residential;Wood;Woodstove: freestanding, EPA certified, non-catalytic
2104008330	SSFC;Residential;Wood;Woodstove: freestanding, EPA certified, catalytic
2104008400	SSFC;Residential;Wood;Woodstove: pellet-fired, general (freestanding or FP insert)
2104008420	SSFC;Residential;Wood;Woodstove: pellet-fired, EPA certified (freestanding or FP insert)
2104008510	SSFC;Residential;Wood;Furnace: Indoor, cordwood-fired, non-EPA certified
2104008610	SSFC;Residential;Wood;Hydronic heater: outdoor
2104008700	SSFC;Residential;Wood;Outdoor wood burning device, NEC (fire-pits, chimeas, etc)
2104009000	SSFC;Residential;Firelog;Total: All Combustor Types

* SSFC=Stationary Source Fuel Combustion

2.2.6 Other nonpoint sources sector (nonpt)

Stationary nonpoint sources that were not subdivided into the afdust, ag, np_oilgas, or rwc sectors were assigned to the "nonpt" sector. Locomotives and CMV mobile sources from the 2011NEIv2 nonpoint inventory are described in Section 2.4.1. There are too many SCCs in the nonpt sector to list all of them individually, but the types of sources in the nonpt sector include:

- stationary source fuel combustion, including industrial, commercial, and residential;
- chemical manufacturing;
- industrial processes such as commercial cooking, metal production, mineral processes, petroleum refining, wood products, fabricated metals, and refrigeration;
- solvent utilization for surface coatings such as architectural coatings, auto refinishing, traffic marking, textile production, furniture finishing, and coating of paper, plastic, metal, appliances, and motor vehicles;
- solvent utilization for degreasing of furniture, metals, auto repair, electronics, and manufacturing;
- solvent utilization for dry cleaning, graphic arts, plastics, industrial processes, personal care products, household products, adhesives and sealants;
- solvent utilization for asphalt application and roofing, and pesticide application;
- storage and transport of petroleum for uses such as portable gas cans, bulk terminals, gasoline service stations, aviation, and marine vessels;
- storage and transport of chemicals;
- waste disposal, treatment, and recovery via incineration, open burning, landfills, and composting;
- agricultural burning and orchard heating;
- miscellaneous area sources such as cremation, hospitals, lamp breakage, and automotive repair shops.

2.3 2011 onroad mobile sources (onroad)

Onroad mobile sources include emissions from motorized vehicles that are normally operated on public roadways. These include passenger cars, motorcycles, minivans, sport-utility vehicles, light-duty trucks, heavy-duty trucks, and buses. The sources are further divided between diesel, gasoline, E-85, and compressed natural gas (CNG) vehicles. The sector characterizes emissions from parked vehicle processes (e.g., starts, hot soak, and extended idle) as well as from on-network processes (i.e., from vehicles moving along the roads). Except for California and Texas, all onroad emissions are generated using the SMOKE-MOVES emissions modeling framework that leverages MOVES-generated outputs (https://www.epa.gov/moves) and hourly meteorological data. For more information on the preparation of onroad mobile source emissions with SMOKE-MOVES, see the 2011v6.3 platform TSD.

There were no changes to onroad emissions or how they were processed for 2011en as compared to 2011el. The primary change to the onroad mobile source sector that were made for the *2011el* case concerns the penetration of E-85 fuels. Specifically, the percentage of E-85 in the activity data used to compute the EPA-default emissions for the 2011el case was updated to reflect actual usage of E-85 fuel, instead of reflecting activity from all "flex-fuel" vehicles which *could* use E-85. In the 2011ek case, 5.14 percent of all passenger vehicle VMT activity was allocated to E-85. That percentage reflects all flex-fuel vehicles on the road, whether or not those vehicles are actually using E-85. In the 2011el case, only 0.016 percent of total passenger vehicle VMT was allocated to E-85 fuel, reflecting the actual amount of E-85 fuel consumed. Table 2-11 shows the total onroad U.S. CAP emissions in the 2011v6.3 and updated platforms, rounded to the nearest thousand tons. The slight increase in some pollutants is due to the fact the E-85 emission factors are somewhat cleaner than those of regular gasoline. Thus, with the percent of E-85 reduced, the emissions increase slightly.

Table 2-11. Onroad CAP emissions in the 2011v6.3 and updated platforms (tons)

Pollutant	2011ek	2011el	% change
CO	25,380,000	25,992,000	2%
NH3	112,000	121,000	8%
NOX	5,609,000	5,708,000	2%
PM10	326,000	327,000	0%
PM2_5	188,000	189,000	1%
SO2	27,000	28,000	3%
VOC	2,657,000	2,713,000	2%

California onroad emissions were also updated for the *2023el* platform. The California onroad inventory includes updated vehicle type and road type distribution, so that they are estimated in a consistent way with the state-provided 2023 emissions. The vehicle type and road type distribution is based on the latest mapping between EMFAC Emissions Inventory Codes (EICs) and EPA source classification codes (SCCs), and unlike prior EIC-to-SCC mappings, distinguishes on-network emissions from off-network emissions.

2.3.1 Onroad (onroad)

For the continental U.S., EPA used a modeling framework that took into account the temperature sensitivity of the on-road emissions. Specifically, EPA used MOVES inputs for representative counties, vehicle miles traveled (VMT), vehicle population (VPOP), and hoteling data for all counties, along with tools that integrated the MOVES model with SMOKE. In this way, it was possible to take advantage of the gridded hourly temperature information available from meteorology modeling used for air quality modeling. The "SMOKE-MOVES" integration tool was developed by EPA in 2010 and is used for regional air quality modeling of onroad mobile sources.

SMOKE-MOVES requires that emission rate "lookup" tables be generated by MOVES which differentiate emissions by process (i.e., running, start, vapor venting, etc.), vehicle type, road type, temperature, speed, hour of day, etc. To generate the MOVES emission rates that could be applied across the U.S., EPA used an automated process to run MOVES to produce emission factors by temperature and speed for a series of "representative counties," to which every other county is mapped. Representative counties are used because it is impractical to generate a full suite of emission factors for the more than 3,000 counties in the United States. Representative counties, for which emission factors are generated are selected according to their state, elevation, fuels, age distribution, ramp fraction, and inspection & maintenance programs. Each county is then mapped to a representative county based on its similarity with the representative county with respect to those attributes. For the 2011v6.3 platform, there are 285 representative counties.

Once representative counties have been identified, emission factors are generated with MOVES for each representative county and for each "fuel month" – typically a summer month and a winter month. Using the MOVES emission rates, SMOKE selects appropriate emissions rates for each county, hourly temperature, SCC, and speed bin and multiplies the emission rate by activity: VMT (vehicle miles travelled), VPOP (vehicle population)), or HOTELING (hours of extended idle) to produce emissions. These calculations were done for every county and grid cell in the continental U.S. for each hour of the year.

The SMOKE-MOVES process for creating the model-ready emissions consists of the following steps:

1) Determine which counties will be used to represent other counties in the MOVES runs.
2) Determine which months will be used to represent other month's fuel characteristics.
3) Create MOVES inputs needed only by MOVES. MOVES requires county-specific information on vehicle populations, age distributions, and inspection-maintenance programs for each of the representative counties.
4) Create inputs needed both by MOVES and by SMOKE, including temperatures and activity data.
5) Run MOVES to create emission factor tables for the temperatures found in each county.
6) Run SMOKE to apply the emission factors to activity data (VMT, VPOP, and HOTELING) to calculate emissions based on the gridded hourly temperatures in the meteorological data.
7) Aggregate the results to the county-SCC level for summaries and quality assurance.

The onroad emissions are processed in four processing streams that are merged together into the onroad sector emissions after processing:

- rate-per-distance (RPD) uses VMT as the activity data plus speed and speed profile information to compute on-network emissions from exhaust, evaporative, permeation, refueling, and brake and tire wear processes;
- rate-per-vehicle (RPV) uses vehicle population (VPOP) activity data to compute off-network emissions from exhaust, evaporative, permeation, and refueling processes;
- rate-per-profile (RPP) uses VPOP activity data to compute off-network emissions from evaporative fuel vaper venting including hot soak (immediately after a trip) and diurnal (vehicle parked for a long period) emissions; and
- rate-per-hour (RPH) uses hoteling hours activity data to compute off-network emissions for idling of long-haul trucks from extended idling and auxiliary power unit process.

The onroad emissions inputs are similar to the emissions in the onroad data category of the 2011NEIv2, described in more detail in Section 4.6 of the 2011NEIv2 TSD. Specifically, the 2011v6.3 platform and the 2011NEIv2 have nearly identical:

- MOVES County databases (CDBs) including Low Emission Vehicle table dated 20140903
- Representative counties (i.e., 285RepCos2011_M2014_20151208)
- Fuel months
- Meteorology
- Activity data (VMT, VPOP, speed, HOTELING)

SMOKE-MOVES are both run using a detailed set of processes, but in the NEI emissions were aggregated into two modes: refueling and all other modes. In addition, the NEI SCCs were aggregated over roads to all parking and all road emissions. The list of modes (or aggregate processes) used in the v6.2 platform and the corresponding MOVES processes mapped to them are listed in Table 2-12.

Table 2-12. Onroad emission aggregate processes

Aggregate process	Description	MOVES process IDs
40	All brake and tire wear	9;10
53	All extended idle exhaust	17;90
62	All refueling	18;19
72	All exhaust and evaporative except refueling and hoteling	1;2;11;12;13;15;16
91	Auxiliary Power Units	91

One reason that brake and tire wear was split out from the other processes was to allow for better modeling of the impacts of electric vehicles in future years, since these vehicles still have brake and tire wear emissions, but do not have exhaust, evaporative, or refueling emissions. For more detailed information on methods used to develop the onroad emissions and input data sets and on running SMOKE-MOVES, see the 2011NEIv2 TSD.

The California and Texas onroad emissions were created through a hybrid approach of combining state-supplied annual emissions with EPA-developed SMOKE-MOVES runs. Through this approach, the platform was able to reflect the unique rules in California and Texas, while leveraging the more detailed SCCs and the highly resolved spatial patterns, temporal patterns, and speciation from SMOKE-MOVES. The basic steps involved in temporally allocating onroad emissions from California and Texas based on SMOKE-MOVES results were:

1) Run CA and TX using EPA inputs through SMOKE-MOVES to produce hourly 2011 emissions hereafter known as "EPA estimates." These EPA estimates for CA and TX are run in a separate sector called "onroad_catx."
2) Calculate ratios between state-supplied emissions and EPA estimates[2]. For California, these were calculated for each county/SCC/pollutant combination, except with all road types summed together because California's emissions did not provide data by road type, and with E-85 emissions combined with gasoline because separate emissions were not provided for E-85. For Texas, the ratios were calculated for each county/SCC/pollutant combination, including by road type, but also with E-85 combined with gasoline.
3) Create an adjustment factor file (CFPRO) that includes EPA-to-state estimate ratios.
4) Rerun CA and TX through SMOKE-MOVES using EPA inputs and the new adjustment factor file.

Through this process, adjusted model-ready files were created that sum to annual totals from California and Texas, but have the temporal and spatial patterns reflecting the highly resolved meteorology and SMOKE-MOVES. After adjusting the emissions, this sector is called "onroad_catx_adj." Note that in emission summaries, the emissions from the "onroad" and "onroad_catx_adj" sectors are summed and designated as the emissions for the onroad sector.

An additional step was taken for the refueling emissions. Colorado submitted point emissions for gasoline refueling for some counties[3]. For these counties, the EPA zeroed out the onroad estimates of gasoline refueling (SCC 2201*62) so that the states' point emissions would take precedence. The onroad refueling emissions were zeroed out using the adjustment factor file (CFPRO) and Movesmrg.

[2] These ratios were created for all matching pollutants. These ratios were duplicated for all appropriate modeling species. For example, EPA used the NO_X ratio for NO, NO_2, HONO and used the $PM_{2.5}$ ratio for PEC, PNO_3, POC, PSO_4, etc. (For more details on NO_X and PM speciation, see Sections 3.2.2, and 3.2.3. For VOC model-species, if there was an exact match (e.g., BENZENE), the EPA used that HAP pollutant ratio. For other VOC-based model-species that didn't exist in the NEI inventory, the EPA used VOC ratios.

[3] There were 53 counties in Colorado that had point emissions for gasoline refueling. Outside Colorado, it was determined that refueling emissions in the 2011 NEIv2 point did not significantly overlap the refueling emissions in onroad.

2.4 2011 nonroad mobile sources (cmv_c1c2, cmv_c3, rail, nonroad)

The nonroad mobile source emission modeling sectors consist of nonroad equipment emissions (nonroad), locomotive (rail) and CMV emissions.

2.4.1 Category 1, Category 2, Category 3 Commercial Marine Vessels (cmv_c1c2, cmv_c3)

In the 2011el case, the cmv sector contained all Category 1, 2 and 3 CMV emissions in U.S. waters. In the 2011en case, the CMV emissions are split between the cmv_c1c2 and the cmv_c3 sectors but the total emissions are essentially unchanged. In the NEI emissions in these sectors are annual and at the county-SCC resolution and based on the 2011NEIv2. The NEI CMV emissions use state-submitted values and EPA-developed emissions in areas where states did not submit. The emissions include the offshore portion of the C1 and C2 commercial marine sources, including fishing vessels and oil rig support vessels in the Gulf of Mexico. Emissions that occur outside of state waters are not assigned to states. For more information on CMV sources in the NEI, see Section 4.3 of the 2011NEIv2 TSD.

Table 2-13. 2011NEIv2 SCCs extracted for the cmv sector

SCC	Sector	Description: Mobile Sources prefix for all
2280002100	cmv	Marine Vessels; Commercial; Diesel; Port
2280002200	cmv	Marine Vessels; Commercial; Diesel; Underway
2280003100	cmv	Marine Vessels, Commercial;Residual;Port emissions
2280003200	cmv	Marine Vessels, Commercial;Residual;Underway emissions
2280004000	cmv	Marine Vessels, Commercial;Gasoline;Total, All Vessel Types

In 2011el, the cmv sector was updated to incorporate updated CMV emissions in California so that they are estimated in a consistent way with the state-provided 2023 emissions. A comparison of the 2011NEIv2 and the updated emissions for California is shown in Table 2-14. In 2011en, these updated emissions are found in the cmv_c1c2 sector because in California, the ships are required to use cleaner diesel fuel in state waters instead of the residual fuel assumed for C3 ships in most areas.

Table 2-14. California CMV CAP emissions in the original and updated 2011v6.3 platforms (tons)

Pollutant	2011ek	2011el
CO	6,572	5,082
NH3	8	6
NOX	21,622	21,055
PM10	495	808
PM2_5	462	752
SO2	255	1,827
VOC	1,675	1,375

Category 3 (C3) CMV sources run on residual oil, are consistent with those in the 2011NEIv2, and use the SCCs 2280003100 and 2280003200 for port and underway emissions, respectively. In 2011en, the Category 3 (C3) CMV emissions were reallocated from area to point sources so that emissions could be assigned to layers higher than layer 1, but the emissions totals are the same as those in 2011el. The point sources in the cmv_c3 inventory align with the point sources in the Emissions Control Area (ECA) inventory (EPA, 2015b). A set of fixed stack parameters were assigned to every CMV point source

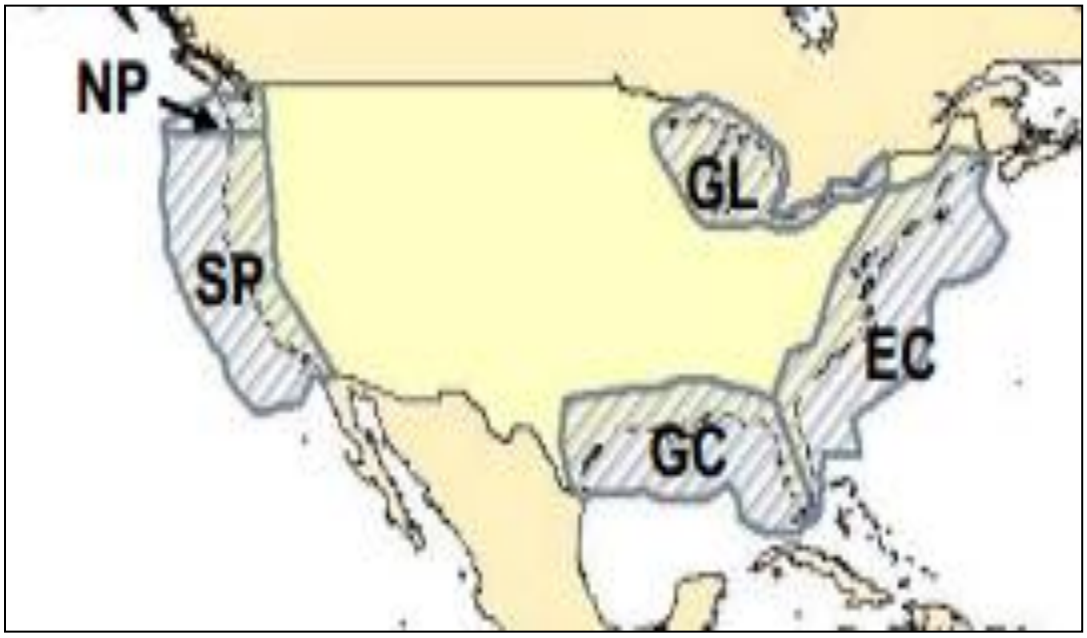
created in this process: stack height of 20 m, stack diameter of 0.8 m, stack velocity of 25 m/s, and a stack temperature of 282°C.

The base-year ECA inventory is 2002 and consists of these CAPs: PM_{10}, $PM_{2.5}$, CO, CO_2, NH_3, NO_X, SO_X (assumed to be SO_2), and hydrocarbons (assumed to be VOC). The EPA developed regional growth (activity-based) factors that were applied to create the 2011 inventory from the 2002 data. These growth factors are provided in Table 2-15. The geographic regions listed in the table are shown in Figure 2-2. * The East Coast and Gulf Coast regions were divided along a line roughly through Key Largo (longitude 80° 26' West). Technically, the Exclusive Economic Zone (EEZ) FIPS are not really "FIPS" state-county codes, but are treated as such in the inventory and emissions processing.

Table 2-15. Growth factors to project the 2002 ECA-IMO inventory to 2011

Region	EEZ FIPS	NO_X	PM_{10}	$PM_{2.5}$	VOC	CO	SO_2
East Coast (EC)	85004	1.301	0.500	0.496	1.501	1.501	0.536
Gulf Coast (GC)	85003	1.114	0.428	0.423	1.288	1.288	0.461
North Pacific (NP)	85001	1.183	0.467	0.458	1.353	1.353	0.524
South Pacific (SP)	85002	1.367	0.525	0.521	1.565	1.562	0.611
Great Lakes (GL)	n/a	1.072	0.394	0.390	1.177	1.176	0.415
Outside ECA	98001	1.341	1.457	1.457	1.457	1.457	1.457

Figure 2-2. Illustration of regional modeling domains in ECA-IMO study



The emissions were converted to SMOKE point source inventory format allowing for the emissions to be allocated to modeling layers above the surface layer. As described in the paper, the ASCII raster dataset was converted to latitude-longitude, mapped to state/county FIPS codes that extended up to 200 nautical miles (nm) from the coast, assigned stack parameters, and monthly ASCII raster dataset emissions were used to create monthly temporal profiles. All non-US, non-EEZ emissions (i.e., in waters considered outside of the 200 nm EEZ and, hence, out of the U.S. and Canadian ECA-IMO

controllable domain) were simply assigned a dummy state/county FIPS code=98001, and were projected to year 2011 using the "Outside ECA" factors in Table 2-15.

The assignment of U.S. state/county FIPS codes was restricted to state-federal water boundaries data from the Mineral Management Service (MMS) that extend approximately 3 to 10 nm off shore. Emissions outside the 3 to 10 mile MMS boundary, but within the approximately 200 nm EEZ boundaries in Figure 2-2, were projected to year 2011 using the same regional adjustment factors as the U.S. emissions; however, the state/county FIPS codes were assigned as "EEZ" codes and those emissions processed in the "othpt" sector (see Section 2.5.1). Note that state boundaries in the Great Lakes are an exception, extending through the middle of each lake such that all emissions in the Great Lakes are assigned to a U.S. county or Ontario. This holds true for Midwest states and other states such as Pennsylvania and New York. The classification of emissions to U.S. and Canadian FIPS codes is needed to avoid double-counting of C3 CMV U.S. emissions in the Great Lakes because, as discussed in the previous section, all CMV emissions in the Midwest RPO are processed in the "cmv" sector.

The SMOKE-ready data have been cropped from the original ECA-IMO entire northwestern quarter of the globe to cover only the large continental U.S. 36-km "36US1" air quality model domain, the largest domain used by EPA in recent years[4]. The original ECA-IMO inventory did not delineate between ports and underway emissions (or other C3 modes such as hoteling, maneuvering, reduced-speed zone, and idling). However, a U.S. ports spatial surrogate dataset was used to assign the ECA-IMO emissions to ports and underway SCCs 2280003100 and 2280003200, respectively.

To prepare the cmv_c3 inventory for 2011en, in cases where counties and SCCs overlap between the 2011NEIv2 cmv_c3 inventory and the 2011 ECA point inventory, county to point allocation fractions by county and SCC were derived from the 2011 ECA point inventory. The county allocation fractions were calculated by dividing the 2011 ECA annual $PM_{2.5}$ emissions for each point source within a county by the total 2011 ECA $PM_{2.5}$ emissions for that county. These fractions were then applied to the cmv_c3 area county level 2011NEIv2 inventory emissions by associated county and SCC to get cmv_c3 emissions by county, SCC, and point source in point FF10 inventory format. The locations of the ECA point sources were carried forward into the cmv_c3 point inventory for each source that was allocated to a 2011NEIv2 cmv_c3 county.

Where the cmv_c3 area county-level inventory had emissions in counties not contained in the 2011 ECA point inventory, fallback factors by source type, port and underway, were applied to spatially allocate the emissions. These fallback methods produce cmv_c3 point sources at a 12km resolution based on polygons or surrogates. The fallback port point allocations were calculated based on the 2014 NATA v1 port polygons. Port activity was estimated by county using the fraction of PM2_5 emissions (SCC 2280003100) assigned to each port within a county. To get a total emissions allocation fraction from county to a 12US2 (see Figure 3-1) grid cell centroid the county activity fraction was multiplied by the fraction of area that a 12US2 grid cell overlaps each county port shape. Surrogate 801 was used as a tertiary fallback when port polygons were not available for a county with cmv_c3 port emissions. The underway point fallbacks were calculated from surrogate 806. County emissions (SCC 2280003200) were assigned to 12US2 grid cell centroids based on the county to grid cell surrogate fractions in surrogate 806. The underway surrogate fallback methodology is comparable to the surrogate 801 fallback used for port emissions.

[4] The extent of the "36US1" domain is similar to the full geographic region shown in Figure 3-1. Note that this domain is not specifically used in this 2011 platform, although spatial surrogates that can be used with it are provided.

2.4.2 Railroad sources: (rail)

The rail sector includes all locomotives except for railway maintenance locomotives. Railway maintenance emissions are included in the nonroad sector. The yard locomotives are included in the ptnonipm sector. For more information on locomotive sources in the NEI, see Section 4.4 of the 2011NEIv2 TSD.

Table 2-16. 2011NEIv2 SCCs extracted for the starting point in rail development

SCC	Sector	Description: Mobile Sources prefix for all
2285002007	rail	Railroad Equipment;Diesel;Line Haul Locomotives: Class II / III Operations
2285002008	rail	Railroad Equipment;Diesel;Line Haul Locomotives: Passenger Trains (Amtrak)
2285002009	rail	Railroad Equipment;Diesel;Line Haul Locomotives: Commuter Lines
2285002010	rail	Railroad Equipment;Diesel;Yard Locomotives

2.4.3 Nonroad mobile equipment sources: (nonroad)

The nonroad equipment emissions are equivalent to the emissions in the nonroad data category of the 2011NEIv2, with the exception that the modeling platform emissions also include monthly totals. All nonroad emissions are compiled at the county/SCC level. NMIM (EPA, 2005) creates the nonroad emissions on a month-specific basis that accounts for temperature, fuel types, and other variables that vary by month. The nonroad sector includes monthly exhaust, evaporative and refueling emissions from nonroad engines (not including commercial marine, aircraft, and locomotives) that EPA derived from NMIM for all states except California and Texas. Additional details on the development of the 2011NEIv2 nonroad emissions are available in Section 4.5 the 2011NEIv2 TSD.

California year 2011 nonroad emissions were submitted to the 2011NEIv2 and are also documented in a staff report (ARB, 2010a). The nonroad sector emissions in California were developed using a modular approach and include all rulemakings and updates in place by December 2010. These emissions were developed using Version 1 of the CEPAM, which supports various California off-road regulations such as in-use diesel retrofits (ARB, 2007), Diesel Risk-Reduction Plan (ARB, 2000) and 2007 State Implementation Plans (SIPs) for the South Coast and San Joaquin Valley air basins (ARB, 2010b).

The CARB-supplied nonroad annual inventory emissions values were converted to monthly values by using the aforementioned EPA NMIM monthly inventories to compute monthly ratios by county, SCC7 (fuel, engine type, and equipment type group), mode, and pollutant. The SCC7 ratios were used because the SCCs in the CARB inventory did not align with many of the SCCs in EPA NMIM inventory. By aggregating up to SCC7, the two inventories had a more consistent coverage of sources. Some VOC emissions were added to California to account for situations when VOC HAP emissions were included in the inventory, but there were no VOC emissions. These additional VOC emissions were computed by summing benzene, acetaldehyde, and formaldehyde for the specific sources.

Texas year 2011 nonroad emissions were also submitted to the NEI. The 2011NEIv2 nonroad annual inventory emissions values were converted to monthly values by using EPA's NMIM monthly inventories to compute monthly ratios by county, SCC7, mode, and poll[5].

2.5 "Other Emissions": Emissions from Non-U.S. sources

The emissions from Canada, Mexico, and U.S. offshore drilling platforms are included as part of four emissions modeling sectors: othpt, othar, othafdust, and othon. The "oth" refers to the fact that these emissions are usually "other" than those that exist in areas that use the U.S. state-county geographic Federal Information Processing Standards (FIPS) for county locations, while the remaining characters provide the SMOKE source types: "pt" for point; "ar" for "area and nonroad mobile;" and "on" for onroad mobile. The changes in the 2011el case for emissions in the entire country of Mexico for each sector are shown in Table 2-17 and Table 2-18 shows the changes for Canada. The reasons for the changes are explained in the sub-sections that follow.

Table 2-17. Mexico CAP emissions in the 2011v6.3 and updated platforms (tons)

	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
2011ek othpt	694,173	31,569	606,442	233,158	160,911	2,393,790	290,676
2011el othpt	683,482	32,773	651,521	241,496	168,144	2,276,770	303,905
2011ek othar	3,081,442	852,041	721,690	628,158	454,385	47,290	3,488,075
2011el othar	2,579,614	875,696	706,612	574,293	404,291	44,083	3,564,949
2011ek othon	23,220,743	53,309	1,650,448	16,582	12,002	25,449	2,159,346
2011el othon	5,887,937	9,170	1,411,830	57,782	43,576	22,470	541,390

Table 2-18. Canada CAP emissions in 2011el vs 2011en (tons)

Case and Sector	CO	NH3	NOx	PM10	PM2.5	SO2	VOC
2011el othafdust				6,018,802	938,015		
2011en othafdust				8,573,732	1,643,832		
2011el othar	4,151,170	468,863	667,282	244,765	199,352	156,765	1,285,976
2011en othar	3,265,982	509,752	768,873	301,445	259,832	86,284	1,243,806
2011el othon	4,262,403	24,226	506,407	23,572	18,019	2,381	262,908
2011en othon	2,259,190	8,884	505,059	29,840	22,772	1,673	205,535
2011el othpt	1,329,036	20,987	958,229	165,389	69,195	1,347,075	979,932
2011en othpt	1,405,817	19,240	833,998	133,709	57,660	1,235,619	963,504

2.5.1 Point Sources from Offshore C3 CMV, Drilling platforms, Canada and Mexico (othpt)

The othpt sectors includes offshore oil and gas drilling platforms that are beyond U.S. state-county boundaries in the Gulf of Mexico and point sources for Canada and Mexico. Point sources in Mexico were compiled based on the Inventario Nacional de Emisiones de Mexico, 2008 (ERG, 2014a). The 2011ek case used 2008 estimates, but in 2011el, the emissions were projected to the year 2011 by

[5] If there was no match at county/SCC7/mode/poll, the allocation would fall back to state/SCC7/mode/poll. If that did not find a match, then state/SCC7 was used. For a few situations, that would also fail to match and the monthly emissions were allocated with a similar SCC7.

interpolating between 2008 emissions and projected 2014 emissions (ERG, 2016). The point source emissions in the 2008 inventory were converted to English units and into the FF10 format that could be read by SMOKE, missing stack parameters were gapfilled using SCC-based defaults, and latitude and longitude coordinates were verified and adjusted if they were not consistent with the reported municipality. Note that there are no explicit HAP emissions in this inventory.

The point source offshore oil and gas drilling platforms from the 2011NEIv2 were used. For Canadian point sources, 2013 emissions provided by Environment Canada were used. Temporal profiles and speciated emissions were also provided. Note that Canadian CMV emissions are in the othar sector and are not processed as point sources.

C3 CMV emissions assigned to either the Exclusive Economic Zone (EEZ) (defined as those emissions beyond the U.S. Federal waters approximately 3-10 miles offshore, and extending to about 200 nautical miles from the U.S. coastline) or to outlying waters beyond the EEZ, which were part of the othpt sector in the 2011el case, were moved to the *cmv_c3* sector for the 2011en case.

2.5.2 Area and Nonroad Mobile Sources from Canada and Mexico (othar, othafdust)

The othar sector includes nonpoint and nonroad mobile source emissions in Canada and Mexico. The Canadian sources were updated to month-specific year-2013 emissions provided by Environment Canada, including the Canadian C3 CMV emissions.

For the original 2011ek case, area and nonroad mobile sources in Mexico for 2008 were compiled the Inventario Nacional de Emisiones de Mexico, 2008 (ERG, 2014a). The 2008 emissions were quality assured for completeness, SCC assignments were made when needed, the pollutants expected for the various processes were reviewed, and adjustments were made to ensure that PM_{10} was greater than or equal to $PM_{2.5}$. The resulting inventory was written using English units to the nonpoint FF10 format that could be read by SMOKE and projected to the year 2014 (ERG, 2016). For the 2011el case, the area and nonroad emissions were linearly interpolated to represent the year 2011. Also in 2011el, wildfire and agricultural fire emissions were removed from the Mexico nonpoint inventory to prevent double counting emissions with the new ptfire_mxca sector. Note that unlike the U.S. inventories, there are no explicit HAPs in the nonpoint or nonroad inventories for Canada and Mexico and, therefore, all HAPs are created from speciation. For the 2011en case, an updated population surrogate was added to spatially allocate Mexican area and nonroad sources in the 2023en case.

The othafdust sector includes nonpoint fugitive dust source emissions for Canada only. For 2011en, Environment Canada provided an updated year 2013 inventory for the othafdust sector for this updated modeling platform. The othafdust inventory consisted of an annual inventory at the province resolution that was adjusted using export fraction and precipitation data to generate hourly, gridded emissions for this sector.

2.5.3 Onroad Mobile Sources from Canada and Mexico (othon)

The othon sector includes onroad mobile source emissions in Canada and Mexico. The Canadian sources were updated in the 2023en case using month-specific year-2013 emissions provided by Environment Canada. Note that unlike the U.S. inventories, there are no explicit HAPs in the onroad inventories for Canada and therefore all HAPs are created from speciation.

For the 2011en case, an updated population surrogate was used to spatially allocate onroad sources in Mexico. For the earlier 2011el case, the onroad mobile sources in Mexico were updated to 2011 levels based on a run of MOVES-Mexico for 2011. The development of the 2011 onroad inventory for Mexico is described in Development of Mexico Emission Inventories for the 2014 Modeling Platform (ERG, 2016). The following information on how the 2011 onroad inventory was developed is from that document which also includes a comparison of the updated emissions with other recent inventories or onroad mobile sources in Mexico:

> "Under the sponsorship of USAID, through the Mexico Low Emissions Development Program (MLED), in early 2016 ERG adapted MOVES2014a (https://www.epa.gov/moves) to Mexico (USAID, 2016). As with the U.S. version of the model, "MOVES-Mexico" has the capability to produce comprehensive national vehicle emission inventories, and to provide a framework for users to create detailed regional emission inventories and microscale emission assessments. The approach for adapting MOVES was determined based on Mexico's available vehicle fleet and activity data, and to account for significant differences in vehicle emissions standards between Mexico and the U.S. To aid this, the Mexican government agency National Institute of Ecology and Climate Change (*Instituto Nacional de Ecología y Cambio Climático* or INECC) provided data for fundamental model inputs such as vehicle kilometers travelled, vehicle population, age distribution, and emission standards. INECC also provided data on over 250,000 roadside remote sensing device (RSD) measurements across 24 Mexican cities, which were analyzed to help calibrate MOVES-Mexico emission rates. The data from INECC and other government sources have been synthesized to create a national Mexico-specific MOVES database that can be used directly with MOVES2014a as an alternate default database, replacing the U.S. default database that comes with the U.S. model download. MOVES-Mexico can estimate vehicle emissions for calendar years 1990 through 2050 at the nation, state or municipio (county-equivalent) level."
> …
> "[The 2011] on-road mobile source emissions inventory was developed using output from MOVES-Mexico. Emissions were generated for each municipio; for a typical weekday and typical weekend by month; for the pollutant set used for the U.S. NEI. Total annual emissions were compiled into a single Flat File 10 (FF10) format file. MOVES-Mexico was run in default mode, which reflects Mexico-specific data for key inputs such as vehicle population, VMT, fuels, inspection and maintenance (I/M) programs and Mexico's emission standards."
> …
> "The outputs of the MOVES-Mexico runs were processed to obtain total annual emissions by pollutant and EPA Source Classification Code (SCC) and compiled into a single FF10 format file. This involved looping through the output databases for all the individual municipios; extracting the emissions for a particular pollutant from both the evaporative and non-evaporative output databases; and summing the emissions across all hours to obtain total emissions by day type (weekend and weekday) for each month. The total monthly emissions were then calculated as the product of the daily weekend (weekday) emissions and the number of weekends (weekdays) in each month. The monthly emissions were then summed to obtain annual emissions and converted to U.S. short tons."

2.6 U.S. Fires (ptfire)

In the 2011v6.3 platform, both the wildfires and prescribed burning emissions are contained in the ptfire sector. Fire emissions are specified at geographic coordinates (point locations) and have daily emissions values. The ptfire sectors exclude agricultural burning and other open burning sources that are included in the nonpt sector. Emissions are day-specific and include satellite-derived latitude/longitude of the

fire's origin and other parameters associated with the emissions such as acres burned and fuel load, which allow estimation of plume rise. Emissions for the SCCs listed in Table 2-21 are treated as point sources and are consistent with the fires stored in the Events data category of the 2011NEIv2. For more information on the development of the 2011NEIv2 fire inventory, see Section 5.1 of the 2011NEIv2 TSD.

Table 2-19. 2011 Platform SCCs representing emissions in the ptfire modeling sectors

SCC	SCC Description*
2810001000	Other Combustion; Forest Wildfires; Total
2810001001	Other Combustion; Forest Wildfires; Wildland fire use
2811015000	Other Combustion-as Event; Prescribed Burning for Forest Management; Total

* The first tier level of the SCC Description is "Miscellaneous Area Sources"

The point source day-specific emission estimates for 2011 fires rely on SMARTFIRE 2 (Sullivan, et al., 2008), which uses the National Oceanic and Atmospheric Administration's (NOAA's) Hazard Mapping System (HMS) fire location information as input. Additional inputs include the CONSUMEv3.0 software and the Fuel Characteristic Classification System (FCCS) fuel-loading database to estimate fire emissions from wildfires and prescribed burns on a daily basis. The method involves the reconciliation of ICS-209 reports (Incident Status Summary Reports) with satellite-based fire detections to determine spatial and temporal information about the fires. A functional diagram of the SMARTFIRE 2 process of reconciling fires with ICS-209 reports is available in the documentation (Raffuse, et al., 2007). Once the fire reconciliation process is completed, the emissions are calculated using the U.S. Forest Service's CONSUMEv3.0 fuel consumption model and the FCCS fuel-loading database in the BlueSky Framework (Ottmar, et al., 2007).http://www.fs.fed.us/pnw/fera/research/smoke/consume/index.shtml

SMARTFIRE 2 estimates were used directly for all states except Georgia and Florida. For Georgia, the satellite-derived emissions were removed from the ptfire inventory and replaced with a separate state-supplied ptfire inventory. Adjustments were also made to Florida as described in Section 5.1.4 of the 2011NEIv2 TSD. These changes made the data in the ptfire inventory consistent with the data in the 2011NEIv2.

An update originally incorporated in the 2011v6.2 platform was to split fires over 20,000 acres into the respective grid cells that they overlapped. The idea of this was to prevent all emissions from going into a single grid cell when, in reality, the fire was more dispersed than a single point. The large fires were each projected as a circle over the area centered on the specified latitude and longitude, and then apportioned into the grid cells they overlapped. The area of each of the "subfires" was computed in proportion to the overlap with that grid cell. These "subfires" were given new names that were the same as the original, but with "_a", "_b", "_c", and "_d" appended as needed. The FIPS state and county codes and fire IDs for the fifteen fires apportioned to multiple grid cells are shown in Table 2-20.

Table 2-20. Large fires apportioned to multiple grid cells

County FIPS	Fire ID
32007	SF11C1774898
32007	SF11C1775252
32013	SF11C1774993
35027	SF11C1760072
35027	SF11C1760460

County FIPS	Fire ID
46065	SF11C1503125
48003	SF11C1718109
48081	SF11C1742329
48125	SF11C1749358
48243	SF11C1738273
48243	SF11C1747162
48353	SF11C1759082
48371	SF11C1750272
48415	SF11C1742358
56013	SF11C1791126

2.7 Non-U.S. Fires (ptfire_mxca)

The development of the U.S. fires in the ptfire sector is described in the 2011v6.3 TSD (EPA, 2016a). The SCCs for this sector are listed in Table 2-21. In the 2011el case update to the 2011v6.3 platform, a new sector of fire emissions in Mexico and Canada was added. Note that unlike the other sectors, the ptfire_mxca sector emissions were processed with SMOKE 4.0 because it has better support for processing FF10-formatted fire inventories. Fire emissions are specified at geographic coordinates (point locations) and have daily emissions values. Emissions are day-specific and include satellite-derived latitude/longitude of the fire's origin and other parameters associated with the emissions such as acres burned and fuel load, which allow estimation of plume rise.

Table 2-21. 2011 Platform SCCs representing emissions in the ptfire modeling sectors

SCC	**SCC Description***
2810001000	Other Combustion; Forest Wildfires; Total
2810001001	Other Combustion; Forest Wildfires; Wildland fire use
2811015000	Other Combustion-as Event; Prescribed Burning for Forest Management; Total

* The first tier level of the SCC Description is "Miscellaneous Area Sources."

The 2011 fire inventory for Canada was obtained from Environment Canada. This point source fire inventory was generated using the Canadian Wildland Fire Information System (CWFIS) (http://cwfis.cfs.nrcan.gc.ca). Area burned and daily fire spread estimates are derived from satellite products. CWFIS integrates multi-source data for national-level products. These data include a fuels database, fire weather, topography, moisture content, and fire type and duration information. CWFIS also uses the BlueSky module Fire Emission Production Simulator (FEPS) (Anderson, 2004) to generate day-specific SMOKE-ready emissions data. The CWFIS fire inventory can also include agricultural burns, however all CWFIS fires are labeled with SCC 2810001000. The output format from CWFIS currently only supports older versions of SMOKE. The CWFIS data were converted to SMOKE FF10 format for use in this modeling effort.

The Fire INventory from NCAR (FINN) (Wiedinmyer, 2011) version 1.5 was used to supply a fire inventory for Mexico. FINN (https://www2.acom.ucar.edu/modeling/finn-fire-inventory-ncar) provides daily, 1 km resolution, global estimates of the trace gas and particle emissions from open burning of biomass, which includes wildfire, agricultural fires, and prescribed burning and does not include biofuel

use and trash burning. This day-specific FINN data was downloaded from http://bai.acom.ucar.edu/Data/fire/ and was converted to SMOKE FF10 format for this modeling effort.

2.8 Biogenic emissions (beis)

Biogenic emissions were computed based on the same 11g version of the 2011 meteorology data used for the air quality modeling, and were developed using the Biogenic Emission Inventory System version 3.61 (BEIS3.61) within SMOKE. The landuse input into BEIS3.61 is the BELD version 4.1 which is based on an updated version of the USDA-USFS Forest Inventory and Analysis (FIA) vegetation speciation based data from 2001 to 2014 from the FIA version 5.1. After the 2011el/2023el cases, additional quality assurance of the BELD4.1 resulted in minor corrections to the landuse data in three states including Washington, Texas and Florida. These minor corrections were implemented in the 2011en/2023en modeling cases and representing about less than 1% reduction in biogenic emissions in these three states. For more information on biogenic emissions, see the original 2011v6.3 platform TSD (EPA, 2016a).

BEIS3.61 has some important updates from BEIS 3.14. These include the incorporation of Version 4.1 of the Biogenic Emissions Land use Database (BELD4) for the 2011v6.3 platform, and the incorporation of a canopy model to estimate leaf-level temperatures (Pouliot and Bash, 2015). BEIS3.61 includes a two-layer canopy model. Layer structure varies with light intensity and solar zenith angle. Both layers of the canopy model include estimates of sunlit and shaded leaf area based on solar zenith angle and light intensity, direct and diffuse solar radiation, and leaf temperature (Bash et al., 2015). The new algorithm requires additional meteorological variables over previous versions of BEIS. The variables output from the Meteorology-Chemistry Interface Processor (MCIP) that are used to convert WRF outputs to CMAQ inputs are shown in Table 2-22.

Table 2-22. Meteorological variables required by BEIS 3.61

Variable	Description
LAI	leaf-area index
PRSFC	surface pressure
Q2	mixing ratio at 2 m
RC	convective precipitation per met TSTEP
RGRND	solar rad reaching sfc
RN	nonconvective precipitation per met TSTEP
RSTOMI	inverse of bulk stomatal resistance
SLYTP	soil texture type by USDA category
SOIM1	volumetric soil moisture in top cm
SOIT1	soil temperature in top cm
TEMPG	skin temperature at ground
USTAR	cell averaged friction velocity
RADYNI	inverse of aerodynamic resistance
TEMP2	temperature at 2 m

BELD version 4.1 is based on an updated version of the USDA-USFS Forest Inventory and Analysis (FIA) vegetation speciation based data from 2001 to 2014 from the FIA version 5.1. Canopy coverage is based on the Landsat satellite National Land Cover Database (NLCD) product from 2011. The FIA includes approximately 250,000 representative plots of species fraction data that are within

approximately 75 km of one another in areas identified as forest by the NLCD canopy coverage. The 2011 NLCD provides land cover information with a native data grid spacing of 30 meters. For land areas outside the conterminous United States, 500 meter grid spacing land cover data from the Moderate Resolution Imaging Spectroradiometer (MODIS) is used.

Other improvements to the BELDv4.1 included the following:

- Used 30 meter NASA's Shuttle Radar Topography Mission (SRTM) elevation data (http://www2.jpl.nasa.gov/srtm/) which will more accurately define the elevation ranges of the vegetation species.
- Used the 2011 30 meter USDA Cropland Data Layer (CDL) data (http://www.nass.usda.gov/research/Cropland/Release/) to the BELD 4 agricultural categories.

To provide a sense of the scope and spatial distribution of the emissions, plots of annual BEIS outputs for isoprene and NO for 2011 are shown in Figure 2-3 and Figure 2-4, respectively.

2.9 SMOKE-ready non-anthropogenic inventories for chlorine

The ocean chlorine gas emission estimates are based on the build-up of molecular chlorine (Cl_2) concentrations in oceanic air masses (Bullock and Brehme, 2002). Data at 36 km and 12 km resolution were available and were not modified other than the model-species name "CHLORINE" was changed to "CL2" to support CMAQ modeling.

Figure 2-3. Annual NO emissions output from BEIS 3.61 for 2011

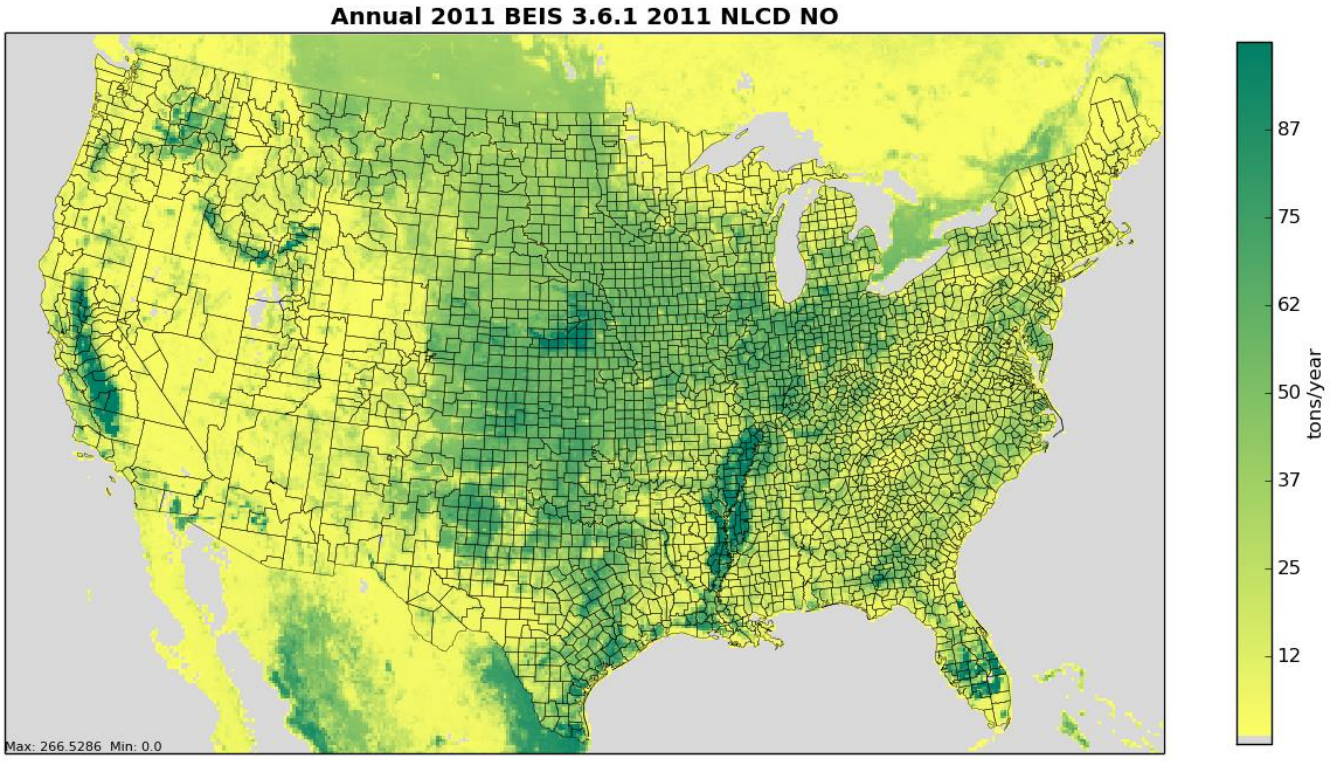
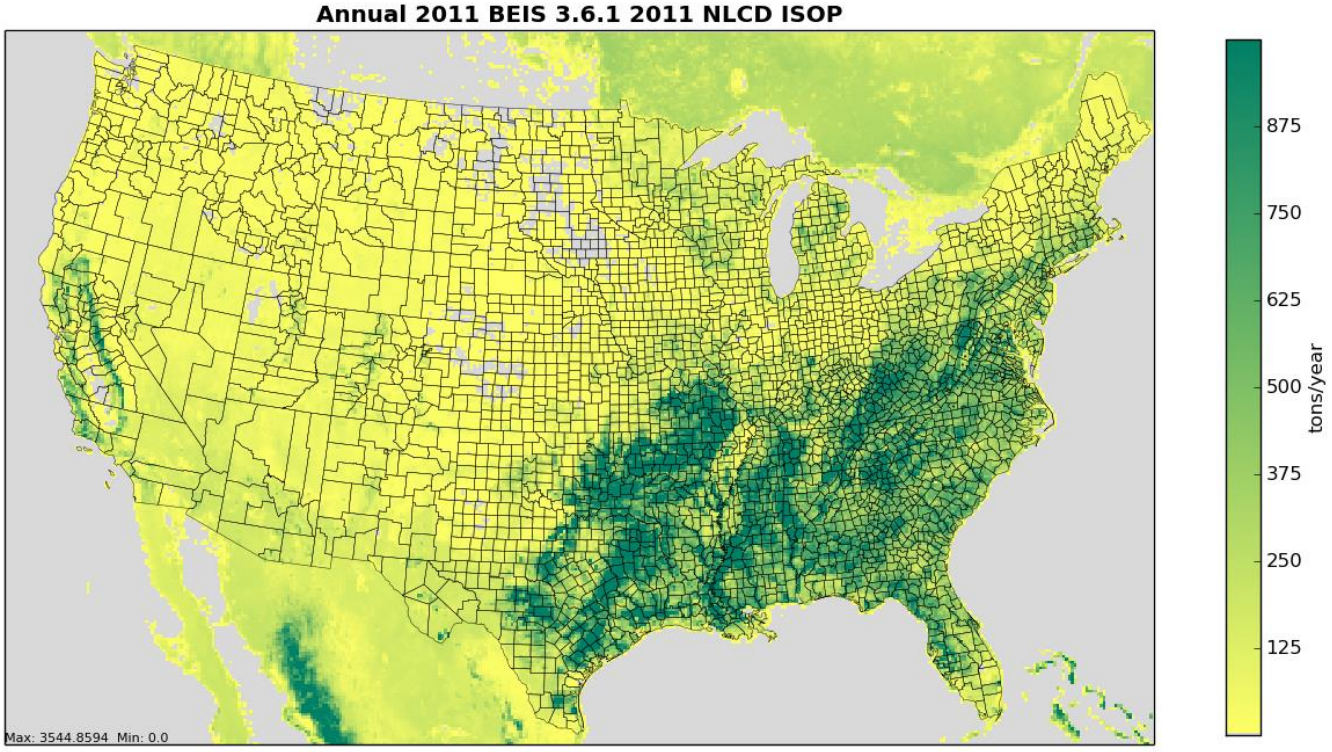


Figure 2-4. Annual isoprene emissions output from BEIS 3.61 for 2011



3 Emissions Modeling Summary

In Section 3, the descriptions of data are limited to updates to the ancillary data SMOKE uses to perform the emissions modeling steps. Note that all SMOKE inputs for this updated 2011v6.3 platform are available from the Air Emissions Modeling ftp site. While an overview of emissions modeling is given below, the details of the emissions modeling for the platform can be found in the original 2011v6.3 TSD (EPA, 2016a).

Both the CMAQ and CAMx models require hourly emissions of specific gas and particle species for the horizontal and vertical grid cells contained within the modeled region (i.e., modeling domain). To provide emissions in the form and format required by the model, it is necessary to "pre-process" the "raw" emissions (i.e., emissions input to SMOKE) for the sectors described above in Section 2. In brief, the process of emissions modeling transforms the emissions inventories from their original temporal resolution, pollutant resolution, and spatial resolution into the hourly, speciated, gridded resolution required by the air quality model. Emissions modeling includes temporal allocation, spatial allocation, and pollutant speciation. In some cases, emissions modeling also includes the vertical allocation of point sources, but many air quality models also perform this task because it greatly reduces the size of the input emissions files if the data are not provided for all vertical layers being modeled.

SMOKE version 3.7 was used to pre-process the raw emissions inventories into emissions inputs for each modeling sector in a format compatible with CMAQ. For projects that used CAMx, the CMAQ-formatted emissions were converted into the required CAMx formats using CAMx convertor programs. For sectors that have plume rise, the in-line emissions capability of the air quality models was used, which allows the creation of source-based and two-dimensional gridded emissions files that are much smaller than full three-dimensional gridded emissions files. For quality assurance of the emissions modeling steps, emissions totals for all species across the entire model domain are output as reports that are then compared to reports generated by SMOKE on the input inventories to ensure that mass is not lost or gained during the emissions modeling process.

The changes made to the ancillary emissions modeling files in the 2011en platform update are the following and are described in more detail in the subsections that follow:

- updates to speciation cross references for Canadian emissions;
- updates to temporal profiles for nonroad mobile source emissions;
- updates to temporal profiles used for U.S. EGUs;
- updates to temporal profiles for Canadian emissions;
- updates to plume rise treatment for U.S. C3 CMV sources;
- updates to spatial surrogates used in Canada, Mexico, and for U.S. CMV sources.

The changes made to the ancillary emissions modeling files in the 2011el platform update were the following and are described in more detail in the subsections that follow:

- updates related to the processing of MOVES-Mexico inventory data, including speciation, temporal, and gridding cross-references, speciation profiles, and inventory table;
- updates to the speciation cross reference to support fires in Canada and Mexico;
- development of speciation cross reference and GSPRO_COMBO files for 2023;

- updates to monthly temporal profiles and the temporal cross reference for processing 2023 California nonroad emissions;
- development of MRCLIST files for 2023 onroad emission factors;
- development of CFPRO files for 2011 and 2023 onroad California and Texas adjustments; and
- updates to NHAPEXCLUDE files for some 2023 sectors.

3.1 Emissions Modeling Overview

When preparing emissions for the air quality model, emissions for each sector are processed separately through SMOKE, and then the final merge program (Mrggrid) is run to combine the model-ready, sector-specific emissions across sectors. The SMOKE settings in the run scripts and the data in the SMOKE ancillary files control the approaches used by the individual SMOKE programs for each sector. Table 3-1 summarizes the major processing steps of each platform sector. The "Spatial" column shows the spatial approach used: "point" indicates that SMOKE maps the source from a point location (i.e., latitude and longitude) to a grid cell; "surrogates" indicates that some or all of the sources use spatial surrogates to allocate county emissions to grid cells; and "area-to-point" indicates that some of the sources use the SMOKE area-to-point feature to grid the emissions (further described in Section 3.4.2). The "Speciation" column indicates that all sectors use the SMOKE speciation step, though biogenic speciation is done within the Tmpbeis3 program and not as a separate SMOKE step. The "Inventory resolution" column shows the inventory temporal resolution from which SMOKE needs to calculate hourly emissions. Note that for some sectors (e.g., onroad, beis), there is no input inventory; instead, activity data and emission factors are used in combination with meteorological data to compute hourly emissions.

Finally, the "plume rise" column indicates the sectors for which the "in-line" approach is used. These sectors are the only ones with emissions in aloft layers based on plume rise. The term "in-line" means that the plume rise calculations are done inside of the air quality model instead of being computed by SMOKE. The air quality model computes the plume rise using the stack data and the hourly air quality model inputs found in the SMOKE output files for each model-ready emissions sector. The height of the plume rise determines the model layer into which the emissions are placed. The othpt sector has only "in-line" emissions, meaning that all of the emissions are treated as elevated sources and there are no emissions for those sectors in the two-dimensional, layer-1 files created by SMOKE. Day-specific point fires are treated separately. For CMAQ modeling, fire plume rise is done within CMAQ itself, but for CAMx, the plume rise is done by running SMOKE to create a three-dimensional output file and then those emissions are postprocessed into a point source format that CAMx can read. In either case, after plume rise is applied, there will be emissions in every layer from the ground up to the top of the plume.

Table 3-1. Key emissions modeling steps by sector for 2011en

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
afdust	Surrogates	Yes	annual	
ag	Surrogates	Yes	annual	
agfire	Surrogates	Yes	monthly	
beis	Pre-gridded land use	in BEIS3.61	computed hourly	
rail	Surrogates	Yes	annual	
cmv_c1c2	Surrogates	Yes	annual	

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
nonpt	Surrogates & area-to-point	Yes	annual	
nonroad	Surrogates & area-to-point	Yes	monthly	
np_oilgas	Surrogates	Yes	annual	
onroad	Surrogates	Yes	monthly activity, computed hourly	
othafdust	Surrogates	Yes	annual	
othar	Surrogates	Yes	annual & monthly	
othon	Surrogates	Yes	monthly	
othpt	Point	Yes	annual & monthly	in-line
cmv_c3	Point + surrogates	Yes	Annual	in-line
ptegu	Point	Yes	daily & hourly	in-line
ptfire	Point	Yes	daily	in-line
ptfire_mxca	Point	Yes	daily	in-line
ptnonipm	Point	Yes	annual	in-line
pt_oilgas	Point	Yes	annual	in-line
rwc	Surrogates	Yes	annual	

SMOKE has the option of grouping sources so that they are treated as a single stack when computing plume rise. For the 2011 platform, no grouping was performed because grouping combined with "in-line" processing will not give identical results as "offline" processing (i.e., when SMOKE creates three-dimensional files). This occurs when stacks with different stack parameters or latitudes/longitudes are grouped, thereby changing the parameters of one or more sources. The most straightforward way to get the same results between in-line and offline is to avoid the use of grouping.

To prepare fires for CAMx using a plume rise algorithm that is consistent with the algorithms in SMOKE and CMAQ, the following steps are performed:

1) The ptfire inventories are run through SMOKE programs to read the inventories, speciate, temporalize, and grid the emissions.

2) The SMOKE program laypoint is used to estimate the plume height and layer fractions for each fire (see https://www.cmascenter.org/smoke/documentation/3.7/html/ch06s06.html#sect_programs_laypoint_plume_rise_fires).

3) The emissions are gridded and layered, and then written as three-dimensional netCDF CMAQ ready files.

4) Species in the CMAQ-formatted file are converted to CAMx species using the *spcmap* program.

5) The netCDF **ptfire** files are converted to a CAMx "PTSOURCE" type file where each grid cell centroid represents one stack using the *cmaq2uam* program. Note that each virtual stack has default stack parameters of 1 m height, 1 m diameter, 273 K temperature, and 1 m/s

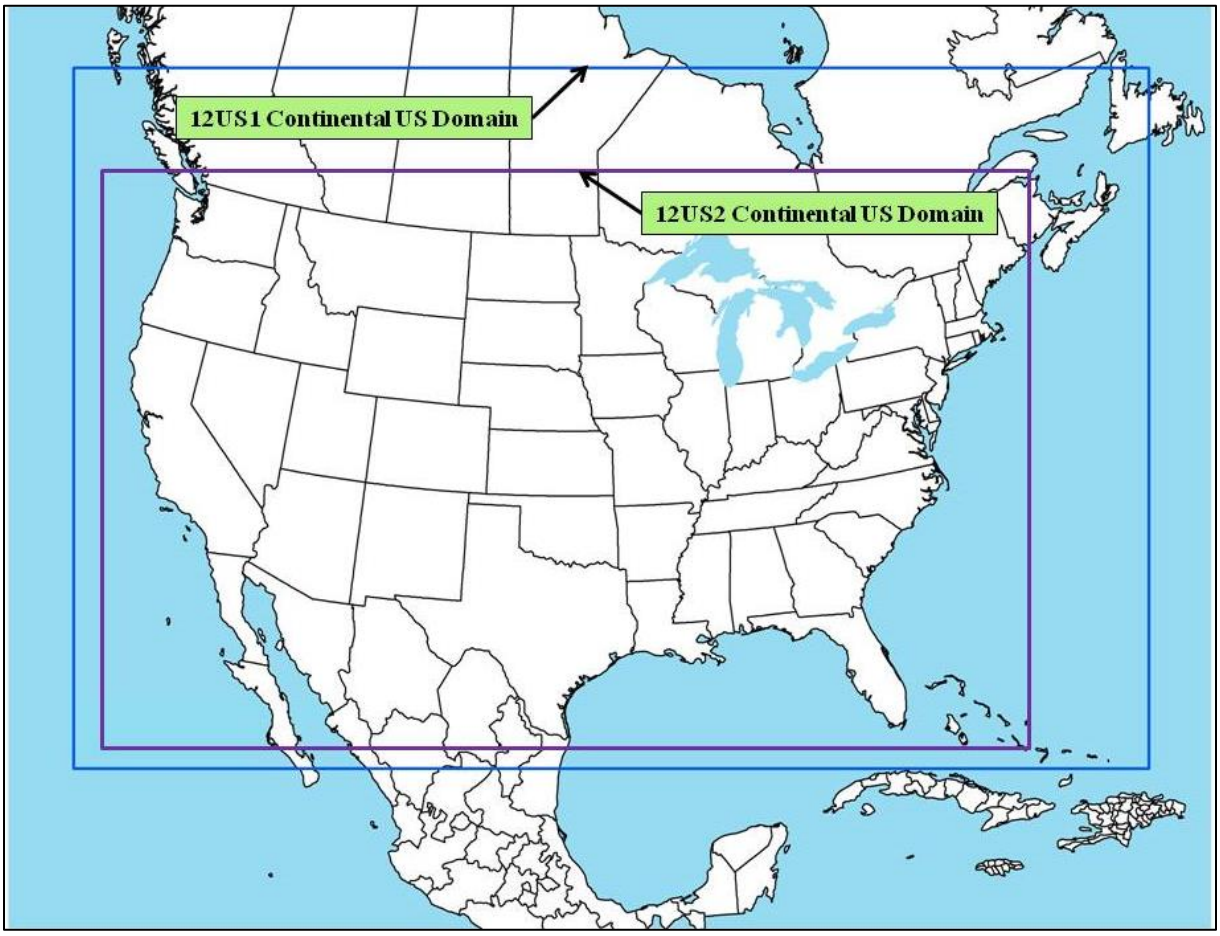
velocity. Also, an individual virtual stack point (grid cell centroid) will have all of the emissions for the grid cell divided up into layers with an effective plume height at each layer. Only the layers that contain emissions are kept for each virtual stack.

6) The program *pthtq* is run to add an effective plume height based on the cell center height from the METCRO3D (ZH).

7) The resulting PTSOURCE files have emissions as a stack at (x, y) that to up to layer z that is derived from the CMAQ 3D file, and are merged with the PTSOURCE sector files from other sectors into a single PTSOURCE file with stacks for all point sources. This file, along with the 2D emissions file, is input into the CAMx model.

SMOKE was run for the smaller 12-km CONtinental United States "CONUS" modeling domain (12US2) shown in Figure 3-1 and boundary conditions were obtained from a 2011 run of GEOS-Chem.

Figure 3-1. Air quality modeling domains



Both grids use a Lambert-Conformal projection, with Alpha = 33º, Beta = 45º and Gamma = -97º, with a center of X = -97º and Y = 40º. Table 3-2 describes the grids for the two domains.

Table 3-2. Descriptions of the platform grids

Common Name	Grid Cell Size	Description (see Figure 3-1)	Grid name	Parameters listed in SMOKE grid description (GRIDDESC) file: projection name, xorig, yorig, xcell, ycell, ncols, nrows, nthik
Continental 12km grid	12 km	Entire conterminous US plus some of Mexico/Canada	12US1_459X299	'LAM_40N97W', -2556000, -1728000, 12.D3, 12.D3, 459, 299, 1
US 12 km or "smaller" CONUS-12	12 km	Smaller 12km CONUS plus some of Mexico/Canada	12US2	'LAM_40N97W', -2412000 , -1620000, 12.D3, 12.D3, 396, 246, 1

Section 3.4 provides the details on the spatial surrogates and area-to-point data used to accomplish spatial allocation with SMOKE.

3.2 Chemical Speciation

The emissions modeling step for chemical speciation creates the "model species" needed by the air quality model for a specific chemical mechanism. These model species are either individual chemical compounds (i.e., "explicit species") or groups of species (i.e., "lumped species"). The chemical mechanism used for the 2011 platform is the CB6 mechanism (Yarwood, 2010). The 2011v6.2 platform was the first EPA modeling platform to use CB6; previous platforms used CB05 and earlier versions of the carbon bond mechanism. The key difference in CB6 from CB05 from an emissions modeling perspective is that it has additional lumped and explicit model species. The specific version of CAMx used in applications of this platform include secondary organic aerosol (SOA) and nitrous acid (HONO) enhancements. In addition, this platform generates the $PM_{2.5}$ model species associated with the CMAQ Aerosol Module version 6 (AE6), though many are not used by CAMx. Table 3-3 of the 2011v6.3 platform TSD lists the model species produced by SMOKE in the 2011v6.2 platform Table 3-4 of the 2011v6.3 platform TSD (EPA, 2016a) provides the cmaq2camx mapping file used to convert the SMOKE generated model species to the appropriate inputs for CAMx.

The total organic gas (TOG) and $PM_{2.5}$ speciation factors that are the basis of the chemical speciation approach were developed from the SPECIATE 4.4 database https://www.epa.gov/air-emissions-modeling/speciate-version-45-through-40), which is the EPA's repository of TOG and PM speciation profiles of air pollution sources. However, a few of the profiles used in the v6.3 platform such as composite profiles for chemical manufacturing and pulp and paper sources will be published in later versions of the SPECIATE database after the release of this documentation. The SPECIATE database development and maintenance is a collaboration involving the EPA's Office of Research and Development (ORD), Office of Transportation and Air Quality (OTAQ), and the Office of Air Quality Planning and Standards (OAQPS), in cooperation with Environment Canada (EPA, 2006a). The SPECIATE database contains speciation profiles for TOG, speciated into individual chemical compounds, VOC-to-TOG conversion factors associated with the TOG profiles, and speciation profiles for $PM_{2.5}$.

Some special species are available in the emissions output from SMOKE: VOC_INV and NH3_FERT. The VOC_INV specie is carried through the modeling of each of the sectors so that emission summaries can be prepared for VOC without having to sum back up the individual VOC species which have different molecular weights. The VOC_INV is the total the amount of VOC in the input inventories and

has units of g/s. The NH3_FERT is a specie that CMAQ uses for bidirectional ammonia modeling. It is set to the amount of ammonia from fertilizer sources. If the bidirectional option is turned off, the specie is ignored. It is also ignored for CAMx modeling.

Only minor changes were made to the speciation cross reference in 2011el update to the 2011v6.3 platform and there were no changes to U.S. speciation made for 2011en. Speciation for the updated 2011 emissions is the same as in the 2011 emissions from the 2011v6.3 platform, with the new ptfire_mxca sector emissions receiving the same speciation as the ptfire sector. Speciation for the 2023 emissions is the same as in the 2017 emissions from the 2011v6.3 platform, except for the VOC speciation COMBO profiles for bulk plant terminal-to-pump (BTP) emissions. COMBO profiles for 2023 were interpolated based on 2017 and 2025 COMBO profiles from the 2011v6.2 and 2011v6.3 emissions platforms.

The speciation cross reference and inventory table for the othon sector were configured so that VOC, $PM_{2.5}$ and NO_X are speciated in Canada only. In Mexico, pre-speciated VOC, $PM_{2.5}$, and NOx emissions from MOVES-Mexico are used. Some updates to speciation cross references in Canada were needed to accommodate new SCCs in the Canadian 2013 inventory.

Speciation profiles and cross-references for the 2011v6.3 platform are available in the SMOKE input files for the 2011v6.3 platform. Totals of each model species by state and sector can be found in the state-sector totals workbooks for the respective cases. In addition, the county-monthly reports for each case include EC and OC, and the 2011ek_county_SCC7_sector_CAP_PM.xlsx workbook contains speciated PM by county and the first seven digits of the SCC code.

Table 3-3. Emission model species produced for CB6 for CAM_X*

Inventory Pollutant	Model Species	Model species description
Cl_2	CL2	Atomic gas-phase chlorine
HCl	HCL	Hydrogen Chloride (hydrochloric acid) gas
CO	CO	Carbon monoxide
NO_X	NO	Nitrogen oxide
	NO2	Nitrogen dioxide
	HONO	Nitrous acid
SO_2	SO2	Sulfur dioxide
	SULF	Sulfuric acid vapor
NH_3	NH3	Ammonia
VOC	ACET	Acetone
	ALD2	Acetaldehyde
	ALDX	Propionaldehyde and higher aldehydes
	BENZ	Benzene
	CH4	Methane[6]
	ETH	Ethene
	ETHA	Ethane
	ETHY	Ethyne
	ETOH	Ethanol
	FORM	Formaldehyde
	KET	Ketone Groups

[6] Technically, CH_4 is not a VOC but part of TOG. Although emissions of CH_4 are derived, the AQ models do not use these emissions because the anthropogenic emissions are dwarfed by the CH_4 already in the atmosphere.

Inventory Pollutant	Model Species	Model species description
	IOLE	Internal olefin carbon bond (R-C=C-R)
	ISOP	Isoprene
	MEOH	Methanol
	OLE	Terminal olefin carbon bond (R-C=C)
	PAR	Paraffin carbon bond
	PRPA	Propane
	TOL	Toluene and other monoalkyl aromatics
	XYL	Xylene and other polyalkyl aromatics
VOC species from the biogenics model that do not map to model species above	SESQ	Sesquiterpenes
	TERP	Terpenes
PM_{10}	PMC	Coarse PM > 2.5 microns and ≤ 10 microns
$PM_{2.5}$	PAL	Aluminum
	PCA	Calcium
	PCL	Chloride
	PEC	Particulate elemental carbon ≤ 2.5 microns
	PFE	Iron
	PK	Potassium
	PH2O	Water
	PMG	Magnesium
	PMN	Manganese
	PMOTHR	$PM_{2.5}$ not in other AE6 species
	PNA	Sodium
	PNCOM	Non-carbon organic matter
	PNO3	Particulate nitrate ≤ 2.5 microns
	PNH4	Ammonium
	POC	Particulate organic carbon (carbon only) ≤ 2.5 microns
	PSI	Silica
	PSO4	Particulate Sulfate ≤ 2.5 microns
	PTI	Titanium
Sea-salt species (non – anthropogenic)[7]	PCL	Particulate chloride
	PNA	Particulate sodium

*Notes:

1. CL2 is not used in CAM_X and is provided above because of its use in CMAQ
2. CAM_X particulate sodium is NA (in CMAQ it is PNA)
3. CAM_X uses different names for species that are both in CB6 and SOA for the following: TOLA=TOL, XYLA=XYL, ISP=ISOP, TRP=TERP. They are duplicate species in CAM_X that are used in the SOA chemistry. CMAQ uses the same names in CB05 and SOA for these species.
4. CAM_X uses a different name for sesquiterpenes: CMAQ SESQ = CAM_X SQT
5. CAM_X particulate species have different names for organic carbon, coarse particulate matter and other particulate mass: CAM_X uses POA, CPRM, FCRS, and FPRM, respectively.

[7] These emissions are created outside of SMOKE

Table 3-4. Cmaq2camx mapping file

CMAQ Species	CMAQ to CAMx Factor	CAMx Species	Units	CMAQ Species	CMAQ to CAMx Factor	CAMx Species	Units
SO2	1	SO2	moles/hr	UNR	1	NR	moles/hr
SULF	1	SULF	moles/hr	NR	1	NR	moles/hr
NH3	1	NH3	moles/hr	TOL	1	TOLA	moles/hr
CO	1	CO	moles/hr	XYL	1	XYLA	moles/hr
NO	1	NO	moles/hr	PSO4	1	PSO4	g/hr
NO2	1	NO2	moles/hr	PH2O	1	PH2O	g/hr
HONO	1	HONO	moles/hr	PNH4	1	PNH4	g/hr
CL2	1	CL2	moles/hr	PNO3	1	PNO3	g/hr
HCL	1	HCL	moles/hr	PEC	1	PEC	g/hr
CH4	1	CH4	moles/hr	POC	1	POC	g/hr
PAR	1	PAR	moles/hr	PMOTHR	1	PMOTHR	g/hr
ETHA	1	ETHA	moles/hr	PMC	1	CPRM	g/hr
MEOH	1	MEOH	moles/hr	ISOP	1	ISP	moles/s
ETOH	1	ETOH	moles/hr	TERP	1	TRP	moles/s
ETH	1	ETH	moles/hr	SESQ	1	SQT	moles/s
OLE	1	OLE	moles/hr	PCL	1	PCL	g/hr
IOLE	1	IOLE	moles/hr	PNCOM	1	PNCOM	g/hr
ISOP	1	ISOP	moles/hr	PAL	1	PAL	g/hr
TERP	1	TERP	moles/hr	PCA	1	PCA	g/hr
FORM	1	FORM	moles/hr	PFE	1	PFE	g/hr
ALD2	1	ALD2	moles/hr	PMG	1	PMG	g/hr
ALDX	1	ALDX	moles/hr	PK	1	PK	g/hr
TOL	1	TOL	moles/hr	PMN	1	PMN	g/hr
XYL	1	XYL	moles/hr	PSI	1	PSI	g/hr
PRPA	1	PRPA	moles/hr	PTI	1	PTI	g/hr
ETHY	1	ETHY	moles/hr	PNA	1	NA	g/hr
BENZ	1	BENZ	moles/hr	POC	1	POA	g/hr
ACET	1	ACET	moles/hr	PNCOM	1	POA	g/hr
KET	1	KET	moles/hr				

3.2.1 VOC speciation

The concept of VOC speciation is to use emission source-related speciation profiles to convert VOC to TOG, to speciate TOG into individual chemical compounds, and to use a chemical mechanism mapping file to aggregate the chemical compounds to the chemical mechanism model species. The chemical mechanism mapping file is typically developed by the developer of the chemical mechanism.

SMOKE uses profiles that convert inventory species and TOG directly to the model species. The SMOKE-ready profiles are generated from the Speciation Tool which uses the "raw" (TOG to chemical compounds) SPECIATE profiles and the chemical mechanism mapping file.

For the 2011v6.3 platform, an updated CB6 chemical mapping file based on the August 2014 mechanism table for CB05 from Bill Carter was used for all sectors, including onroad mobile sources.

This CB6 mapping file included some corrections to the onroad CB05 profiles used in the 2011v6.2 platform. Similarly to previous platforms, HAP VOC inventory species were used in the VOC speciation process for some sectors as described below.

3.2.1.1 The combination of HAP BAFM (benzene, acetaldehyde, formaldehyde and methanol) and VOC for VOC speciation

The VOC speciation includes HAP emissions from the 2011NEIv2 in the speciation process. Instead of speciating VOC to generate all of the species listed in Table 3-3, emissions of four specific HAPs: benzene, acetaldehyde, formaldehyde and methanol (collectively known as "BAFM") from the NEI were "integrated" with the NEI VOC. The integration combines these HAPs with the VOC in a way that does not double count emissions and uses the HAP inventory directly in the speciation process. The basic process is to subtract the specified HAPs emissions mass from the VOC emissions mass, and to then use a special "integrated" profile to speciate the remainder of VOC to the model species excluding the specific HAPs. The EPA believes that the HAP emissions in the NEI are often more representative of emissions than HAP emissions generated via VOC speciation, although this varies by sector.

The BAFM HAPs were chosen for integration in previous platforms because, with the exception of BENZENE[8], they are the only explicit VOC HAPs in the base version of the CMAQ 5.0.2 (CAPs only with chlorine chemistry) model. These remain appropriate for the 2011v6.3 platform since they are all explicit in CAMx. Explicit means that they are not lumped chemical groups like PAR, IOLE and several other CB6 model species. These "explicit VOC HAPs" are model species that participate in the modeled chemistry using the CB6 chemical mechanism. The use of inventory HAP emissions along with VOC is called "HAP-CAP integration."

For specific sources, especially within the nonpt sector, the integration included ethanol. To differentiate when a source was integrating BAFM versus EBAFM (ethanol in addition to BAFM), the speciation profiles that do not include ethanol are referred to as an "E-profile" and should be used when ethanol comes from the inventory. For example, the E10 headspace gasoline evaporative speciation profile 8763 should be used when ethanol is speciated from VOC, but 8763E should be used when ethanol is obtained directly from the inventory.

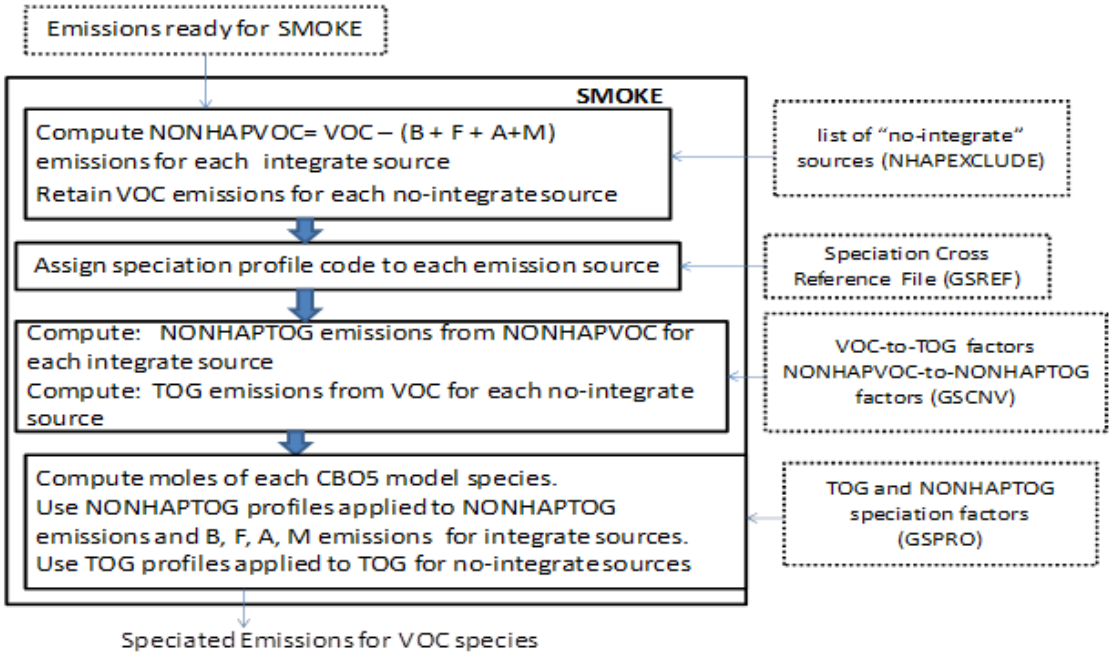
The integration of HAP VOC with VOC is a feature available in SMOKE for all inventory formats other than PTDAY (the format used for the ptfire sector). SMOKE allows the user to specify both the particular HAPs to integrate via the INVTABLE and the particular sources to integrate via the NHAPEXCLUDE file (which actually provides the sources to be *excluded* from integration[9]). For the "integrated" sources, SMOKE subtracts the "integrated" HAPs from the VOC (at the source level) to compute emissions for the new pollutant "NONHAPVOC." The user provides NONHAPVOC-to-NONHAPTOG factors and NONHAPTOG speciation profiles[10]. SMOKE computes NONHAPTOG and then applies the speciation profiles to allocate the NONHAPTOG to the other air quality model VOC species not including the integrated HAPs. After determining if a sector is to be integrated, if all sources have the appropriate HAP emissions, then the sector is considered fully integrated and does not

[8] BENZENE was chosen to keep its emissions consistent between the multi-pollutant and base versions of CMAQ.
[9] In SMOKE version 3.7, the options to specify sources for integration are expanded so that a user can specify the particular sources to include or exclude from integration, and there are settings to include or exclude all sources within a sector. In addition, the error checking is significantly stricter for integrated sources. If a source is supposed to be integrated, but it is missing BAFM or VOC, SMOKE will now raise an error.
[10] These ratios and profiles are typically generated from the Speciation Tool when it is run with integration of a specified list of pollutants, for example BAFM.

need a NHAPEXCLUDE file. If, on the other hand, certain sources do not have the necessary HAPs, then an NHAPEXCLUDE file must be provided based on the evaluation of each source's pollutant mix. The EPA considered CAP-HAP integration for all sectors and developed "integration criteria" for some of them (see Section 3.2.1.3 for details).

The process of partial integration for BAFM is illustrated in Figure 3-2 that the BAFM records in the input inventories do not need to be removed from any sources in a partially integrated sector because SMOKE does this automatically using the INVTABLE configuration. For EBAFM integration, this process is identical to that shown in the figure except for the addition of ethanol (E) to the list of subtracted HAP pollutants. For full integration, the process would be very similar except that the NHAPEXCLUDE file would not be used and all sources in the sector would be integrated.

Figure 3-2. Process of integrating BAFM with VOC for use in VOC Speciation



In SMOKE, the INVTABLE allows the user to specify both the particular HAPs to integrate. Two different types of INVTABLE files are included for use with different sectors of the platform. For sectors that had no integration across the entire sector (see Table 3-5), the EPA created a "no HAP use" INVTABLE in which the "KEEP" flag is set to "N" for BAFM pollutants. Thus, any BAFM pollutants in the inventory input into SMOKE are automatically dropped. This approach both avoids double-counting of these species and assumes that the VOC speciation is the best available approach for these species for sectors using this approach. The second INVTABLE, used for sectors in which one or more sources are integrated, causes SMOKE to keep the inventory BAFM pollutants and indicates that they are to be integrated with VOC. This is done by setting the "VOC or TOG component" field to "V" for all four HAP pollutants. This type of INVTABLE is further differentiated into a version for those sectors that integrate BAFM and another for those that integrate EBAFM.

Table 3-5. Integration approach for BAFM and EBAFM for each platform sector

Platform Sector	Approach for Integrating NEI emissions of Benzene (B), Acetaldehyde (A), Formaldehyde (F), Methanol (M), and Ethanol (E)
ptegu	No integration
ptnonipm	No integration
ptfire	No integration
othafdust	No integration
othar	No integration
othon	No integration
ag	N/A – sector contains no VOC
afdust	N/A – sector contains no VOC
biog	N/A – sector contains no inventory pollutant "VOC"; but rather specific VOC species
agfire	Partial integration (BAFM)
cmv	Partial integration (BAFM)
rail	Partial integration (BAFM)
nonpt	Partial integration (BAFM and EBAFM)
nonroad	Partial integration (BAFM)
np_oilgas	Partial integration (BAFM)
pt_oilgas	Partial integration (BAFM)
rwc	Partial integration (BAFM)
othpt	Partial integration (BAFM)
onroad	Full integration (internal to MOVES)[1]
[1]For the integration that is internal to MOVES, an extended list of HAPs are integrated, not just BAFM. See 3.2.1.3	

More details on the integration of specific sectors and additional details of the speciation are provided in Section 3.2.1.3.

3.2.1.2 County specific profile combinations (GSPRO_COMBO)

SMOKE can compute speciation profiles from mixtures of other profiles in user-specified proportions. The combinations are specified in the GSPRO_COMBO ancillary file by pollutant (including pollutant mode, e.g., EXH__VOC), state and county (i.e., state/county FIPS code) and time period (i.e., month). This feature was used to speciate nonroad mobile and gasoline-related stationary sources that use fuels with varying ethanol content. In these cases, the speciation profiles require different combinations of gasoline profiles, e.g. E0 and E10 profiles. Since the ethanol content varies spatially (e.g., by state or county), temporally (e.g., by month), and by modeling year (future years have more ethanol), the GSPRO_COMBO feature allows combinations to be specified at various levels for different years. SMOKE computes the resultant profile using the fraction of each specific profile assigned by county, month and emission mode.

The GSREF file indicates that a specific source uses a combination file with the profile code "COMBO." Because the GSPRO_COMBO file does not differentiate by SCC and there are various levels of integration across sectors, sector-specific GSPRO_COMBO files are used. Different profile combinations are specified by the mode (e.g., exhaust, evaporative) and by changing the pollutant name (e.g., EXH__NONHAPTOG, EVP__NONHAPTOG). For the nonpt sector, a combination of BAFM and EBAFM integration is used. Due to the lack of SCC-specificity in the GSPRO_COMBO, the only way to differentiate the sources that should use BAFM integrated profiles versus E-profiles is by changing the pollutant name. For example, the EPA changed the pollutant name for the PFC future year

inventory so the integration would use EVP__NONHAPVOC to correctly select the E-profile combinations, while other sources used NONHAPVOC to select the typical BAFM profiles.

3.2.1.3 Additional sector specific details

The decision to integrate HAPs into the speciation was made on a sector by sector basis. For some sectors, there is no integration and VOC is speciated directly; for some sectors, there is full integration meaning all sources are integrated; and for other sectors, there is partial integration, meaning some sources are not integrated and other sources are integrated. The integrated HAPs are either BAFM (BAFM HAPs subtracted from VOC) or EBAFM (ethanol and BAFM HAPs subtracted from VOC). Table 3-5 above summarizes the integration method for each platform sector.

For the cmv and rail sectors, the EPA integrated BAFM for most sources. There were a few sources that had zero BAFM and, therefore, they were not integrated. The CARB inventories (see Section 2.4.1) did not include HAPs and, therefore, all non-NEI source emissions in the cmv and rail sectors were not integrated. For California, the CARB inventory TOG was converted to VOC by dividing the inventory TOG by the available VOC-to-TOG speciation factor.

For the othpt sector, the C3 marine sources (see Section 2.4.2) are integrated. HAPs in this sector are derived identically to the U.S. C3 in the cmv sector. The rest of the sources in othpt are not integrated, thus the sector is partially integrated.

For the onroad sector, there are series of unique speciation issues. First, SMOKE-MOVES (see Section 2.3.1) is used to create emissions for these sectors and both the MEPROC and INVTABLE files are involved in controlling which pollutants are processed. Second, the speciation occurs within MOVES itself, not within SMOKE. The advantage of using MOVES to speciate VOC is that during the internal calculation of MOVES, the model has complete information on the characteristics of the fleet and fuels (e.g., model year, ethanol content, process, etc.), thereby allowing it to more accurately make use of specific speciation profiles. This means that MOVES produces EF tables that include inventory pollutants (e.g., TOG) and model-ready species (e.g., PAR, OLE, etc)[11]. SMOKE essentially calculates the model-ready species by using the appropriate emission factor without further speciation[12]. Third, MOVES' internal speciation uses full integration of an extended list of HAPs beyond EBAFM (called "M-profiles"). The M-profiles integration is very similar to BAFM integration explained above except that the integration calculation (see Figure 3-2) is performed on emissions factors instead of on emissions. The list of integrated HAPs is described in Table 3-6. An additional run of the speciation tool was necessary to create the M-profiles that were then loaded into the MOVES default database. Fourth, for California and Texas EPA applied adjustment factors to SMOKE-MOVES to produce California and Texas adjusted model-ready files (see Section 2.3.1 for details). By applying the ratios through SMOKE-MOVES, the CARB and TCEQ inventories are essentially speciated to match EPA estimated speciation.

[11] Because the EF table has the speciation "baked" into the factors, all counties that are in the county group (i.e., are mapped to that representative county) will have the same speciation.

[12] For more details on the use of model-ready EF, see the SMOKE 3.7 documentation: https://www.cmascenter.org/smoke/documentation/3.7/html/.

Table 3-6. MOVES integrated species in M-profiles

MOVES ID	Pollutant Name
5	Methane (CH4)
20	Benzene
21	Ethanol
22	MTBE
24	1,3-Butadiene
25	Formaldehyde
26	Acetaldehyde
27	Acrolein
40	2,2,4-Trimethylpentane
41	Ethyl Benzene
42	Hexane
43	Propionaldehyde
44	Styrene
45	Toluene
46	Xylene
185	Naphthalene gas

For the nonroad sector, CNG or LPG sources (SCCs beginning with 2268 or 2267) are not integrated because NMIM computed only VOC and not any HAPs for these SCCs. All other nonroad sources were integrated except in California. For California, the CARB inventory TOG was converted to VOC by dividing the inventory TOG by the available VOC-to-TOG speciation factor. SMOKE later applies the same VOC-to-TOG factor prior to computing speciated emissions. The CARB-based nonroad data includes exhaust and evaporative mode-specific data for VOC, but does not contain refueling. The CARB inventory does not include HAP estimates for all sources. Therefore, the sources which have VOC but not BAFM, or for which BAFM is greater than VOC, are not integrated and the remaining sources are integrated. The future year CARB inventories did not have BAFM so all sources for California were not integrated. The gasoline exhaust profiles were updated to 8750a and 8751a (this is true nation-wide).

Aircraft emissions use the profile 5565. In previous versions of the platform, a significant amount of VOC emissions associated with the pulp and paper and the chemical manufacturing industries did not have specific profiles assigned to them (i.e., they had the default VOC profile 0000). To address this, the EPA and Ramboll developed industry-wide average profiles to improve the speciation of these significant sources of VOC, since a large portion of the SCCs related to these industries used the default profile 00000. The two new composite profiles are "Composite Profile – Chemical Manufacturing (95325)" and "Composite Profile – Pulp and Paper Mills" (95326)[13].

For most sources in the rwc sector, the VOC emissions were greater than or equal to BAFM, and BAFM was not zero, so those sources were integrated, although a few specific sources that did not meet these criteria could not be integrated. For the oil and gas sources in the np_oilgas and pt_oilgas sectors, the basins studied in WRAP Phase III have basin-specific VOC speciation that takes into account the

[13] These profiles are expected to be included in SPECIATE 4.5.

distinct composition of gas. ENVIRON developed these basin-specific profiles using gas composition analysis data obtained from operators through surveys. ENVIRON separated out emissions and speciation from conventional/tight sands/shale gas from coal-bed methane (CBM) gas sources. Table 3-7 lists the basin- and gas composition-specific profiles used for the sources in the WRAP Phase III basins. For oil and gas sources outside of the WRAP Phase III basins, the profiles did not vary by region or basin (see Table 3-8). Table 3-9 lists the WRAP Phase III counties.

Table 3-7. VOC profiles for WRAP Phase III basins

Profile Code	Description
DJFLA	D-J Basin Flashing Gas Composition for Condensate
DJVNT	D-J Basin Produced Gas Composition
PNC01	Piceance Basin Gas Composition at Conventional Wells
PNC02	Piceance Basin Gas Composition at Oil Wells
PNC03	Piceance Basin Flashing Gas Composition for Condensate
PRBCO	Powder River Basin Produced Gas Composition for Conventional Wells
PRM01	Permian Basin Produced Gas Composition
SSJCO	South San Juan Basin Produced Gas Composition for Conventional Wells
SWFLA	SW Wyoming Basin Flash Gas Composition
SWVNT	SW Wyoming Basin Vented Gas Composition
UNT02	Uinta Basin Gas Composition at Conventional Wells
UNT03	Uinta Basin Flashing Gas Composition for Oil
UNT04	Uinta Basin Flashing Gas Composition for Condensate
WRBCO	Wind River Basin Produced Gas Composition for Conventional Wells

Table 3-8. National VOC profiles for oil and gas

Profile	Description
0000	Over All Average
0001	External Combustion Boiler - Residual Oil
0002	External Combustion Boiler - Distillate Oil
0003	External Combustion Boiler - Natural Gas
0004	External Combustion Boiler - Refinery Gas
0007	Natural Gas Turbine
0008	Reciprocating Diesel Engine
0051	Flares - Natural Gas
0296	Fixed Roof Tank - Crude Oil Production
1001	Internal Combustion Engine - Natural Gas
1010	Oil and Gas Production - Fugitives - Unclassified
1011	Oil and Gas Production - Fugitives - Valves and Fittings - Liquid Service
1012	Oil and Gas Production - Fugitives - Valves and Fittings - Gas Service
1207	Well Heads (Water Flood) Composite
2487	Composite of 7 Emission Profiles from Crude Oil Storage Tanks - 1993
2489	Composite of 15 Fugitive Emission Profiles from Petroleum Storage Facilities - 1993
8489	Natural Gas Production
8950	Natural Gas Transmission

Table 3-9. Counties included in the WRAP Dataset

FIPS	State	County
08001	CO	Adams
08005	CO	Arapahoe
08007	CO	Archuleta
08013	CO	Boulder
08014	CO	Broomfield
08029	CO	Delta
08031	CO	Denver
08039	CO	Elbert
08043	CO	Fremont
08045	CO	Garfield
08051	CO	Gunnison
08059	CO	Jefferson
08063	CO	Kit Carson
08067	CO	La Plata
08069	CO	Larimer
08073	CO	Lincoln
08075	CO	Logan
08077	CO	Mesa
08081	CO	Moffat
08087	CO	Morgan
08095	CO	Phillips
08097	CO	Pitkin
08103	CO	Rio Blanco
08107	CO	Routt
08115	CO	Sedgwick
08121	CO	Washington
08123	CO	Weld
08125	CO	Yuma
30003	MT	Big Horn
30075	MT	Powder River
35005	NM	Chaves
35015	NM	Eddy
35015	NM	Lea
35031	NM	Mc Kinley
35039	NM	Rio Arriba
35041	NM	Roosevelt
35043	NM	Sandoval
35045	NM	San Juan
48003	TX	Andrews
48033	TX	Borden
48079	TX	Cochran
48081	TX	Coke
48103	TX	Crane
48105	TX	Crockett
48107	TX	Crosby
48109	TX	Culberson
48115	TX	Dawson
48125	TX	Dickens
48135	TX	Ector
48141	TX	El Paso
48151	TX	Fisher
48165	TX	Gaines
48169	TX	Garza
48173	TX	Glasscock
48219	TX	Hockley
48227	TX	Howard
48229	TX	Hudspeth
48235	TX	Irion
48263	TX	Kent
48269	TX	King
48301	TX	Loving
48303	TX	Lubbock
48305	TX	Lynn
48317	TX	Martin
48329	TX	Midland
48335	TX	Mitchell
48353	TX	Nolan
48371	TX	Pecos
48383	TX	Reagan
48389	TX	Reeves
48413	TX	Schleicher
48415	TX	Scurry
48431	TX	Sterling
48435	TX	Sutton
48445	TX	Terry
48451	TX	Tom Green
48461	TX	Upton
48475	TX	Ward
48495	TX	Winkler
48501	TX	Yoakum
49007	UT	Carbon
49009	UT	Daggett
49013	UT	Duchesne
49015	UT	Emery
49019	UT	Grand
49043	UT	Summit
49047	UT	Uintah
56001	WY	Albany
56005	WY	Campbell
56007	WY	Carbon
56009	WY	Converse
56011	WY	Crook
56013	WY	Fremont
56019	WY	Johnson
56023	WY	Lincoln
56025	WY	Natrona
56027	WY	Niobrara
56033	WY	Sheridan
56035	WY	Sublette
56037	WY	Sweetwater
56041	WY	Uinta
56045	WY	Weston

Everywhere in the WRAP region (Table 3-9), WRAP speciation was applied instead of applying BAFM integration. VOC-to-TOG factors for WRAP speciation profiles were also updated for the 2011v6.3 platform. For the biog sector, the speciation profiles used by BEIS are not included in SPECIATE. The 2011 platform uses BEIS3.61, which includes a new species (SESQ) that was mapped to the model species SESQT. The profile code associated with BEIS3.61 for use with CB05 is "B10C5," while the

profile for use with CB6 is "B10C6." The main difference between the profiles is the explicit treatment of acetone emissions in B10C6.

For the nonpt sector, where VOC emissions were greater than or equal to BAFM and BAFM was not zero, the sources were integrated. For portable fuel containers (PFCs) and fuel distribution operations associated with the bulk-plant-to-pump (BTP) distribution, ethanol may be mixed into the fuels; therefore, county- and month-specific COMBO speciation was used (via the GSPRO_COMBO file). Refinery to bulk terminal (RBT) fuel distribution and bulk plant storage (BPS) speciation are considered upstream from the introduction of ethanol into the fuel; therefore a single profile is sufficient for these sources. No refined information on potential VOC speciation differences between cellulosic diesel and cellulosic ethanol sources was available; therefore cellulosic diesel and cellulosic ethanol sources used the same SCC (30125010: Industrial Chemical Manufacturing, Ethanol by Fermentation production) for VOC speciation as was used for corn ethanol plants. For the future year, PFC and the cellulosic sources were integrated EBAFM (i.e., used E-profiles) because ethanol was present in those inventories.

3.2.1.4 Future year speciation

The VOC speciation approach used for the future year case is customized to account for the impact of fuel changes. These changes affect the onroad, nonroad, and parts of the nonpt and ptnonipm sectors.

Speciation profiles for VOC in the nonroad sector account for the changes in ethanol content of fuels across years. A description of the actual fuel formulations for 2011 can be found in the 2011NEIv2 TSD, and for 2023, see Section 4.3. For 2011, the EPA used "COMBO" profiles to model combinations of profiles for E0 and E10 fuel use. For 2023, the EPA assumed E10 fuel use for all nonroad gasoline processes.

The speciation changes from fuels in the nonpt sector are for PFCs and fuel distribution operations associated with the BTP distribution. For these sources, ethanol may be mixed into the fuels, in which case speciation would change across years. The speciation changes from fuels in the ptnonipm sector include BTP distribution operations inventoried as point sources. RBT fuel distribution and BPS speciation does not change across the modeling cases because this is considered upstream from the introduction of ethanol into the fuel. For PFCs, ethanol was present in the future inventories and, therefore, EBAFM profiles were used to integrate ethanol in the future year speciation.

Table 3-10 summarizes the different profiles utilized for the fuel-related sources in each of the sectors for 2011 and the future year cases. This table indicates when "E-profiles" were used instead of BAFM integrated profiles. The term "COMBO" indicates that a combination of the profiles listed was used to speciate that subcategory using the GSPRO_COMBO file.

Table 3-10. Select VOC profiles 2011 vs 2023

Sector	Sub-category	2011	2023
nonroad	gasoline exhaust	COMBO 8750a Pre-Tier 2 E0 exhaust 8751a Pre-Tier 2 E10 exhaust	8751a Pre-Tier 2 E10 exhaust
nonroad	gasoline evap-orative	COMBO 8753 E0 evap 8754 E10 evap	8754 E10 evap

Sector	Sub-category	2011		2023	
nonroad	gasoline refueling	COMBO 8869 8870	 E0 Headspace E10 Headspace	8870	E10 Headspace
nonroad	diesel exhaust	8774	Pre-2007 MY HDD exhaust	8774	Pre-2007 MY HDD exhaust
nonroad	diesel evap-orative	4547	Diesel Headspace	4547	Diesel Headspace
nonroad	diesel refueling	4547	Diesel Headspace	4547	Diesel Headspace
nonpt/ ptnonipm	PFC	COMBO 8869 8870	 E0 Headspace E10 Headspace	8870E	E10 Headspace
nonpt/ ptnonipm	BTP	COMBO 8869 8870	 E0 Headspace E10 Headspace	COMBO 8870 8871 8934	 E10 Headspace E15 Headspace E85 Evap
nonpt/ ptnonipm	BPS/RBT	8869	E0 Headspace	8869	E0 Headspace

The speciation of onroad VOC occurs within MOVES. MOVES takes into account fuel type and properties, emission standards as they affect different vehicle types and model years, and specific emission processes. A description of the actual fuel formulations for 2011 can be found in the 2011NEIv2 TSD. For 2017, see Section 4.3. Table 3-11 describes all of the M-profiles available to MOVES depending on the model year range, MOVES process (processID), fuel sub-type (fuelSubTypeID), and regulatory class (regClassID). Table 3-12 to Table 3-14 describe the meaning of these MOVES codes. For a specific representative county and future year, there will be a different mix of these profiles. For example, for HD diesel exhaust, the emissions will use a combination of profiles 8774M and 8775M depending on the proportion of HD vehicles that are pre-2007 model years (MY) in that particular county. As that county is projected farther into the future, the proportion of pre-2007 MY vehicles will decrease. A second example, for gasoline exhaust (not including E-85), the emissions will use a combination of profiles 8756M, 8757M, 8758M, 8750aM, and 8751aM. Each representative county has a different mix of these key properties and therefore has a unique combination of the specific M-profiles.

Table 3-11. Onroad M-profiles

Profile	Profile Description	Model Years	ProcessID	FuelSubTypeID	RegClassID
1001M	CNG Exhaust	1940-2050	1,2,15,16	30	48
4547M	Diesel Headspace	1940-2050	11	20,21,22	0
4547M	Diesel Headspace	1940-2050	12,13,18,19	20,21,22	10,20,30,40,41, 42,46,47,48
8753M	E0 Evap	1940-2050	12,13,19	10	10,20,30,40,41,42, 46,47,48
8754M	E10 Evap	1940-2050	12,13,19	12,13,14	10,20,30,40,41, 42,46,47,48
8756M	Tier 2 E0 Exhaust	2001-2050	1,2,15,16	10	20,30
8757M	Tier 2 E10 Exhaust	2001-2050	1,2,15,16	12,13,14	20,30

Profile	Profile Description	Model Years	ProcessID	FuelSubTypeID	RegClassID
8758M	Tier 2 E15 Exhaust	1940-2050	1,2,15,16	15,18	10,20,30,40,41, 42,46,47,48
8766M	E0 evap permeation	1940-2050	11	10	0
8769M	E10 evap permeation	1940-2050	11	12,13,14	0
8770M	E15 evap permeation	1940-2050	11	15,18	0
8774M	Pre-2007 MY HDD exhaust	1940-2006	1,2,15,16,17,90	20, 21, 22	40,41,42,46,47, 48
8774M	Pre-2007 MY HDD exhaust	1940-2050	91[14]	20, 21, 22	46,47
8774M	Pre-2007 MY HDD exhaust	1940-2006	1,2,15,16	20, 21, 22	20,30
8775M	2007+ MY HDD exhaust	2007-2050	1,2,15,16	20, 21, 22	20,30
8775M	2007+ MY HDD exhaust	2007-2050	1,2,15,16,17,90	20, 21, 22	40,41,42,46,47,48
8855M	Tier 2 E85 Exhaust	1940-2050	1,2,15,16	50, 51, 52	10,20,30,40,41, 42,46,47,48
8869M	E0 Headspace	1940-2050	18	10	10,20,30,40,41, 42,46,47,48
8870M	E10 Headspace	1940-2050	18	12,13,14	10,20,30,40,41, 42,46,47,48
8871M	E15 Headspace	1940-2050	18	15,18	10,20,30,40,41, 42,46,47,48
8872M	E15 Evap	1940-2050	12,13,19	15,18	10,20,30,40,41, 42,46,47,48
8934M	E85 Evap	1940-2050	11	50,51,52	0
8934M	E85 Evap	1940-2050	12,13,18,19	50,51,52	10,20,30,40,41, 42,46,47,48
8750aM	Pre-Tier 2 E0 exhaust	1940-2000	1,2,15,16	10	20,30
8750aM	Pre-Tier 2 E0 exhaust	1940-2050	1,2,15,16	10	10,40,41,42,46,47,48
8751aM	Pre-Tier 2 E10 exhaust	1940-2000	1,2,15,16	11,12,13,14	20,30
8751aM	Pre-Tier 2 E10 exhaust	1940-2050	1,2,15,16	11,12,13,14,15, 18[15]	10,40,41,42,46,47,48

Table 3-12. MOVES Process IDs

Process ID	Process Name
1	Running Exhaust
2	Start Exhaust
11	Evap Permeation
12	Evap Fuel Vapor Venting
13	Evap Fuel Leaks
15	Crankcase Running Exhaust
16	Crankcase Start Exhaust
17	Crankcase Extended Idle Exhaust
18	Refueling Displacement Vapor Loss

[14] 91 is the processed for APUs which are diesel engines not covered by the 2007 Heavey-Duty Rule, so the older technology applieds to all years.

[15] The profile assingments for pre-2001 gasoline vehicles fueled on E15/E20 fuels (subtypes 15 and 18) were corrected for MOVES2014a. This model year range, process, fuelsubtype regclass combinate is already assigned to profile 8758.

Process ID	Process Name
19	Refueling Spillage Loss
20	Evap Tank Permeation
21	Evap Hose Permeation
22	Evap RecMar Neck Hose Permeation
23	Evap RecMar Supply/Ret Hose Permeation
24	Evap RecMar Vent Hose Permeation
30	Diurnal Fuel Vapor Venting
31	HotSoak Fuel Vapor Venting
32	RunningLoss Fuel Vapor Venting
40	Nonroad
90	Extended Idle Exhaust
91	Auxiliary Power Exhaust

Table 3-13. MOVES Fuel subtype IDs

Fuel Subtype ID	Fuel Subtype Descriptions
10	Conventional Gasoline
11	Reformulated Gasoline (RFG)
12	Gasohol (E10)
13	Gasohol (E8)
14	Gasohol (E5)
15	Gasohol (E15)
18	Ethanol (E20)
20	Conventional Diesel Fuel
21	Biodiesel (BD20)
22	Fischer-Tropsch Diesel (FTD100)
30	Compressed Natural Gas (CNG)
50	Ethanol
51	Ethanol (E85)
52	Ethanol (E70)

Table 3-14. MOVES Regclass IDs

Reg. Class ID	Regulatory Class Description
0	Doesn't Matter
10	Motorcycles
20	Light Duty Vehicles
30	Light Duty Trucks
40	Class 2b Trucks with 2 Axles and 4 Tires (8,500 lbs < GVWR <= 10,000 lbs)
41	Class 2b Trucks with 2 Axles and at least 6 Tires or Class 3 Trucks (8,500 lbs < GVWR <= 14,000 lbs)
42	Class 4 and 5 Trucks (14,000 lbs < GVWR <= 19,500 lbs)
46	Class 6 and 7 Trucks (19,500 lbs < GVWR <= 33,000 lbs)
47	Class 8a and 8b Trucks (GVWR > 33,000 lbs)
48	Urban Bus (see CFR Sec 86.091_2)

3.2.2 PM speciation

In addition to VOC profiles, the SPECIATE database also contains the $PM_{2.5}$ speciated into both individual chemical compounds (e.g., zinc, potassium, manganese, lead), and into the "simplified" $PM_{2.5}$ components used in the air quality model. We speciated $PM_{2.5}$ into the AE6 species associated with CMAQ 5.0.1 and later versions. While provided in the platform, they are not used in CAM_X but rather converted to the $PM_{2.5}$ species based on the cmaq2camx file presented in Table 3-4.

Table 3-15 shows the mapping of AE5 and AE6 for historical reference. The majority of the 2011 platform PM profiles come from the 911XX series which include updated AE6 speciation[16]. The 2011ek_cb6v2 and 2017ek_cb6v2 state-sector totals workbooks include state totals of the PM emissions for each state for the sectors that include PM.

Table 3-15. PM model species: AE5 versus AE6

Species name	Species description	AE5	AE6
POC	organic carbon	Y	Y
PEC	elemental carbon	Y	Y
PSO4	Sulfate	Y	Y
PNO3	Nitrate	Y	Y
PMFINE	unspeciated $PM_{2.5}$	Y	N
PNH4	Ammonium	N	Y
PNCOM	non-carbon organic matter	N	Y
PFE	Iron	N	Y
PAL	Aluminum	N	Y
PSI	Silica	N	Y
PTI	Titanium	N	Y
PCA	Calcium	N	Y
PMG	Magnesium	N	Y
PK	potassium	N	Y
PMN	Manganese	N	Y
PNA	Sodium	N	Y
PCL	Chloride	N	Y
PH2O	Water	N	Y
PMOTHR	$PM_{2.5}$ not in other AE6 species	N	Y

For the onroad sector, for all processes except brake and tire wear, PM speciation occurs within MOVES itself, not within SMOKE (similar to the VOC speciation described above). The advantage of using MOVES to speciate PM is that during the internal calculation of MOVES, the model has complete information on the characteristics of the fleet and fuels (e.g., model year, sulfur content, process, etc.) to accurately match to specific profiles. This means that MOVES produces EF tables that include total PM

[16] The exceptions are 5674 (Marine Vessel – Marine Engine – Heavy Fuel Oil) used for cmv and 92018 (Draft Cigarette Smoke – Simplified) used in nonpt.

(e.g., PM_{10} and $PM_{2.5}$) and speciated PM (e.g., PEC, PFE, etc). SMOKE essentially calculates the PM components by using the appropriate EF without further speciation[17]. For onroad brake and tire wear, the PM is speciated in the *moves2smk* postprocessor that prepares the emission factors for processing in SMOKE. The formulas for this are based on the standard speciation factors that would otherwise be used in SMOKE via the profiles 91134 for brake wear and 91150 for tire wear:

```
POC = 0.4715 * PM25TIRE + 0.107 * PM25BRAKE
PEC = 0.22 * PM25TIRE + 0.0261 * PM25BRAKE
PNO3 = 0.0015 * PM25TIRE + 0.0016 * PM25BRAKE
PSO4 = 0.0311 * PM25TIRE + 0.0334 * PM25BRAKE
PNH4 = 0.00019 * PM25TIRE + 0.00003 * PM25BRAKE
PNCOM = 0.1886 * PM25TIRE + 0.0428 * PM25BRAKE
```

For California and Texas onroad emissions, adjustment factors were applied to SMOKE-MOVES to produce California and Texas adjusted model-ready files (see Section 2.3.1 for details). California did not supply speciated PM, therefore, the adjustment factors applied to PM2.5 were also applied to the speciated PM components. By applying the ratios through SMOKE-MOVES, the CARB inventories are essentially speciated to match EPA estimated speciation. Texas did supply speciated PM, but it was determined that Texas's PM speciation was very similar to the PM speciation from MOVES, so EPA-estimated speciation was preserved in Texas as well as California.

3.2.3 NO_X speciation

NO_X can be speciated into NO, NO_2, and/or HONO. For the non-mobile sources, the EPA used a single profile "NHONO" to split NO_X into NO and NO_2. For the mobile sources, except for onroad (including nonroad, cmv, rail, othon sectors), and for specific SCCs in othar and ptnonipm, the profile "HONO" splits NO_X into NO, NO_2, and HONO. Table 3-16 gives the split factor for these two profiles. The onroad sector does not use the "HONO" profile to speciate NO_X. MOVES2014 produces speciated NO, NO_2, and HONO by source, including emission factors for these species in the emission factor tables used by SMOKE-MOVES. Within MOVES, the HONO fraction is a constant 0.008 of NO_X. The NO fraction varies by heavy duty versus light duty, fuel type, and model year. The NO_2 fraction = 1 – NO – HONO. For more details on the NO_X fractions within MOVES, see http://www.epa.gov/otaq/models/moves/documents/420r12022.pdf.

Table 3-16. NO_X speciation profiles

Profile	pollutant	species	split factor
HONO	NOX	NO2	0.092
HONO	NOX	NO	0.9
HONO	NOX	HONO	0.008
NHONO	NOX	NO2	0.1
NHONO	NOX	NO	0.9

[17] Unlike previous platforms, the PM components (e.g., POC) are now consistently defined between MOVES2014 and CMAQ. For more details on the use of model-ready EF, see the SMOKE 3.7 documentation: https://www.cmascenter.org/smoke/documentation/3.7/html/.

3.3 Temporal Allocation

Temporal allocation (i.e., temporalization) is the process of distributing aggregated emissions to a finer temporal resolution, thereby converting annual emissions to hourly emissions. While the total emissions are important, the timing of the occurrence of emissions is also essential for accurately simulating ozone, PM, and other pollutant concentrations in the atmosphere. Many emissions inventories are annual or monthly in nature. Temporalization takes these aggregated emissions and, if needed, distributes them to the month, and then distributes the monthly emissions to the day and the daily emissions to the hours of each day. This process is typically done by applying temporal profiles to the inventories in this order: monthly, day of the week, and diurnal. A summary of emissions by temporal profile and sector for the 2011ek case is available from the reports area of the FTP site for the original 2011v6.3 platform ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/.

In SMOKE 3.7 and in the 2011v6.3 platform, more readable and flexible file formats are used for temporal profiles and cross references. The temporal factors applied to the inventory are selected using some combination of country, state, county, SCC, and pollutant. Table 3-17 summarizes the temporal aspects of emissions modeling by comparing the key approaches used for temporal processing across the sectors. In the table, "Daily temporal approach" refers to the temporal approach for getting daily emissions from the inventory using the SMOKE Temporal program. The values given are the values of the SMOKE L_TYPE setting. The "Merge processing approach" refers to the days used to represent other days in the month for the merge step. If this is not "all," then the SMOKE merge step runs only for representative days, which could include holidays as indicated by the right-most column. The values given are those used for the SMOKE M_TYPE setting (see below for more information).

Table 3-17. Temporal settings used for the platform sectors in SMOKE for 2011en

Platform sector short name	Inventory resolutions	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process Holidays as separate days
afdust_adj	Annual	Yes	week	all	Yes
ag	Annual	Yes	all	all	Yes
agfire	Monthly		week	week	Yes
beis	Hourly		n/a	all	Yes
cmv_c1c2	Annual	Yes	aveday	aveday	
cmv_c3	Annual	Yes	aveday	aveday	
rail	Annual	Yes	aveday	aveday	
nonpt	Annual	Yes	week	week	Yes
nonroad	Monthly		mwdss	mwdss	Yes
np_oilgas	Annual	Yes	week	week	Yes
onroad	Annual & monthly[1]		all	all	Yes
onroad_ca_adj	Annual & monthly[1]		all	all	Yes
othafdust_adj	Annual	Yes	week	all	
othar	Annual & monthly	yes	week	week	
othon	Monthly		week	week	
othpt	Annual & monthly	yes	mwdss	mwdss	
pt_oilgas	Annual	yes	mwdss	mwdss	Yes

Platform sector short name	Inventory resolutions	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process Holidays as separate days
ptegu	Daily & hourly		all	all	Yes
ptnonipm	Annual	yes	mwdss	mwdss	Yes
ptfire	Daily		all	all	Yes
ptfire_mxca	Daily		all	all	Yes
rwc	Annual	no	met-based	all	Yes

[1] Note the annual and monthly "inventory" actually refers to the activity data (VMT and VPOP) for onroad. The actual emissions are computed on an hourly basis.

The following values are used in the table. The value "all" means that hourly emissions are computed for every day of the year and that emissions potentially have day-of-year variation. The value "week" means that hourly emissions computed for all days in one "representative" week, representing all weeks for each month. This means emissions have day-of-week variation, but not week-to-week variation within the month. The value "mwdss" means hourly emissions for one representative Monday, representative weekday (Tuesday through Friday), representative Saturday, and representative Sunday for each month. This means emissions have variation between Mondays, other weekdays, Saturdays and Sundays within the month, but not week-to-week variation within the month. The value "aveday" means hourly emissions computed for one representative day of each month, meaning emissions for all days within a month are the same. Special situations with respect to temporalization are described in the following subsections.

In addition to the resolution, temporal processing includes a ramp-up period for several days prior to January 1, 2011, which is intended to mitigate the effects of initial condition concentrations. The ramp-up period was 10 days (December 22-31, 2010). For most sectors, emissions from December 2011 were used to fill in surrogate emissions for the end of December 2010. In particular, December 2011 emissions (representative days) were used for December 2010. For biogenic emissions, December 2010 emissions were processed using 2010 meteorology.

3.3.1 Use of FF10 format for finer than annual emissions

The Flat File 2010 format (FF10) inventory format used by SMOKE provides a more consolidated format for monthly, daily, and hourly emissions inventories than prior formats supported. Previously, processing monthly inventory data required the use of 12 separate inventory files. With the FF10 format, a single inventory file can contain emissions for all 12 months and the annual emissions in a single record. This helps simplify the management of numerous inventories. Similarly, daily and hourly FF10 inventories contain individual records with data for all days in a month and all hours in a day, respectively.

SMOKE prevents the application of temporal profiles on top of the "native" resolution of the inventory. For example, a monthly inventory should not have annual-to-month temporalization applied to it; rather, it should only have month-to-day and diurnal temporalization. This becomes particularly important when specific sectors have a mix of annual, monthly, daily, and/or hourly inventories. The flags that control temporalization for a mixed set of inventories are discussed in the SMOKE documentation. The modeling platform sectors that make use of monthly values in the FF10 files are agfire, nonroad, onroad activity data, and ptegu.

3.3.2 Nonroad temporalization (nonroad)

The only change to the temporal allocation process in the 2011el platform was the monthly temporalization of California nonroad emissions in 2023. In prior platforms, annual nonroad emissions in California were allocated to monthly values based on monthly distributions of the National Mobile Inventory Model (NMIM) emissions at the SCC7 level. This resulted in unrealistic monthly temporalization for some sub-SCC7 categories, for example, snowmobile emissions in the summer. A different set of monthly temporal profiles was applied to California nonroad emissions for 2023 with assignments based on full SCC, not SCC7, so that snowmobiles and other specific categories receive a more realistic monthly profile.

For the 2011en platform, temporal profile updates were implemented for nonroad emissions as shown in Figure 3-3 and Figure 3-4. Specifically, construction and commercial lawn and garden day-of-week profiles were updated from profile 18 to profile 19 while residential lawn and garden was unchanged from profile 9 and agriculture was unchanged from profile 18. Hour-of-day profiles for all four of these categories were updated from profile 26 to the following new assignments: construction now uses profile 26a, commercial lawn and garden uses 25a, residential lawn and garden uses 27, and agriculture uses 26a. In general, the goal of these updates was to put fewer emissions in overnight hours and to refine the weekday/weekend split for these source categories.

Figure 3-3. Original and updated nonroad day-of-week profiles

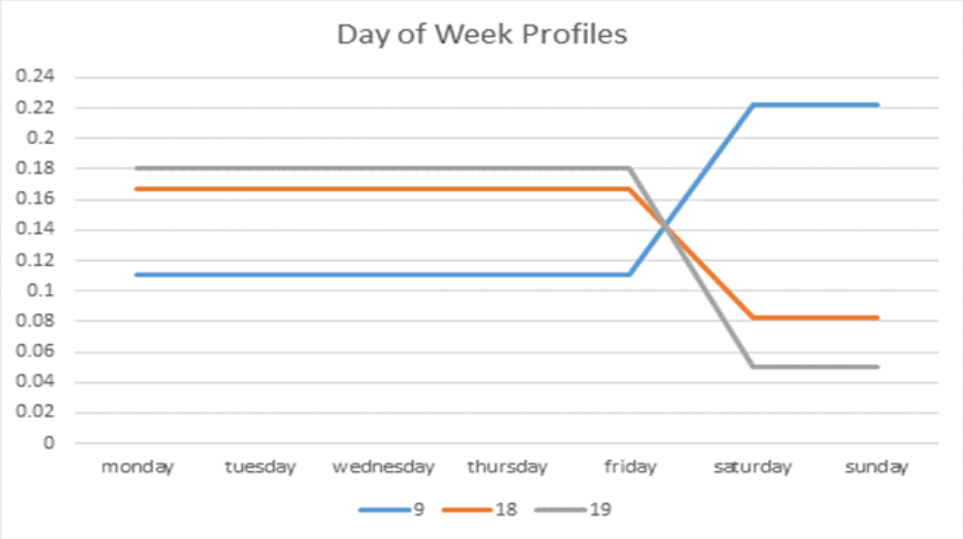
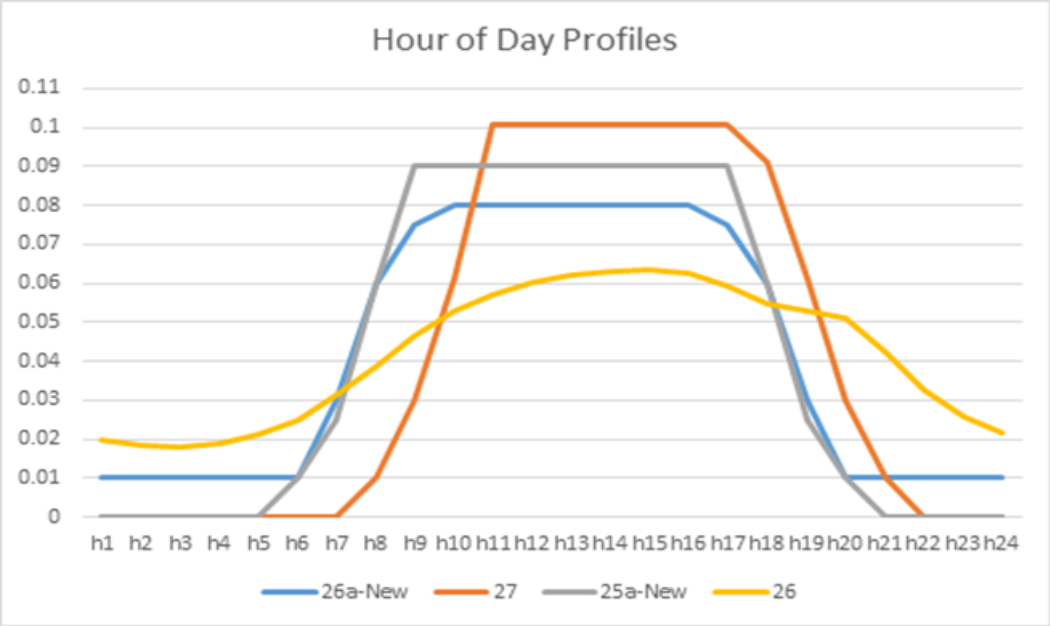


Figure 3-4. Original and updated nonroad hour-of-day profiles



3.3.3 Electric Generating Utility temporal allocation (ptegu)

Base year temporal allocation of EGUs

The 2011NEIv2 annual EGU emissions not matched to CEMS sources are allocated to hourly emissions using the following 3-step methodology: annual value to month, month to day, and day to hour. In the 2011v6.3 platforms, the CEMS data were processed using a tool that reviewed the data quality flags that indicate the data were not measured. Unmeasured data can cause erroneously high values in the CEMS data. If the data were not measured at specific hours, and those values were found to be more than three times the annual mean for that unit, the data for those hours were replaced with annual mean values (Adelman et al., 2012). These adjusted CEMS data were then used for the remainder of the temporalization process described below (see Figure 3-5 for an example). Winter and summer seasons are included in the development of the diurnal profiles as opposed to using data for the entire year because analysis of the hourly CEMS data revealed that there were different diurnal patterns in winter versus summer in many areas. Typically, a single mid-day peak is visible in the summer, while there are morning and evening peaks in the winter as shown in Figure 3-6.

The temporal allocation procedure is differentiated by whether or not the source could be directly matched to a CEMS unit via ORIS facility code and boiler ID. Prior to temporal allocation, as many sources as possible were matched to CEMS data via ORIS facility code and boiler ID. Units were considered matches if the FIPS state/county code matched, the facility name was similar, and the NO_x and SO_2 emissions were similar. The EIS stores a base set of previously matched units via alternate facility and unit IDs. Additions to these matches were made for the 2011v6.3 platform due to additional specificity available in SMOKE but not in EIS, and also based on comments. For any units that are matched, the ORIS facility and boiler ID columns of the point FF10 inventory files are filled with the information on the rows for the corresponding NEI unit. Note that for units matched to CEMS data, annual totals of their emissions may be different than the annual values in 2011NEIv2 because the CEMS data actually replaces the inventory data for the seasons in which the CEMS are operating. If a CEMS-matched unit is determined to be a partial year reporter, as can happen for sources that run CEMS only in

the summer, emissions totaling the difference between the annual emissions and the total CEMS emissions are allocated to the non-summer months.

Figure 3-5. Eliminating unmeasured spikes in CEMS data

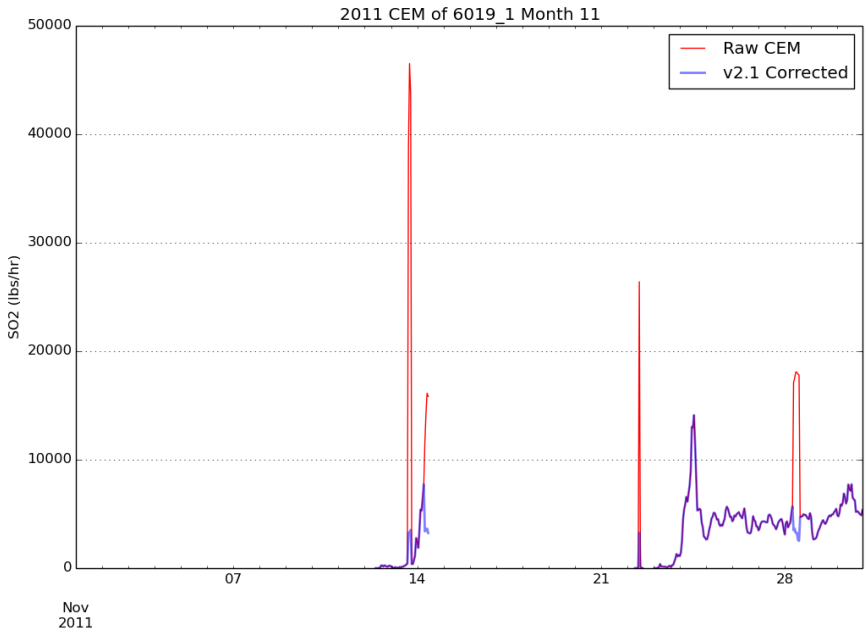
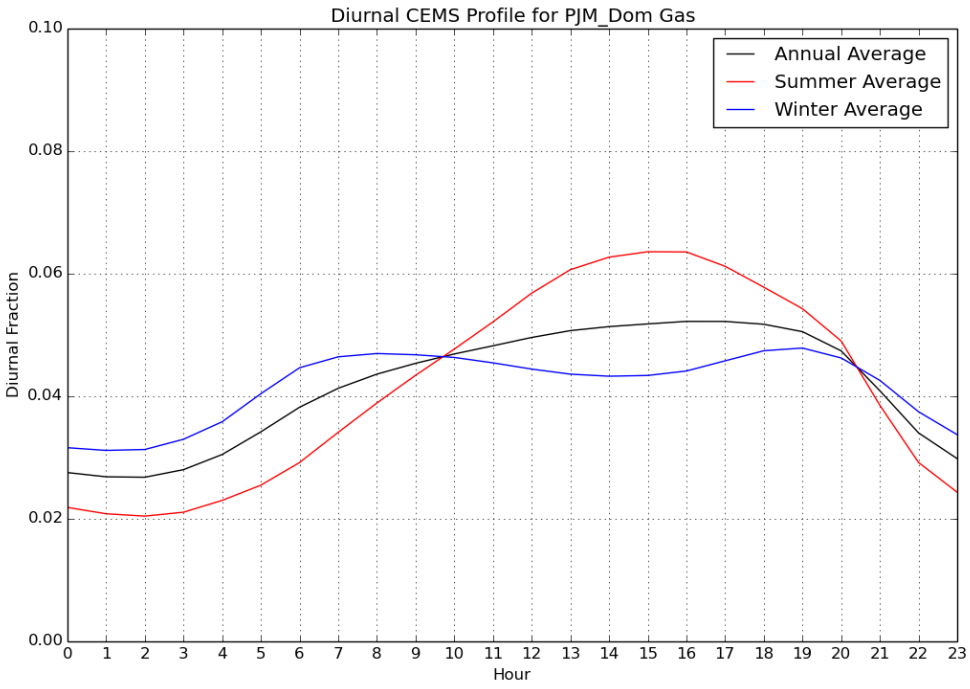


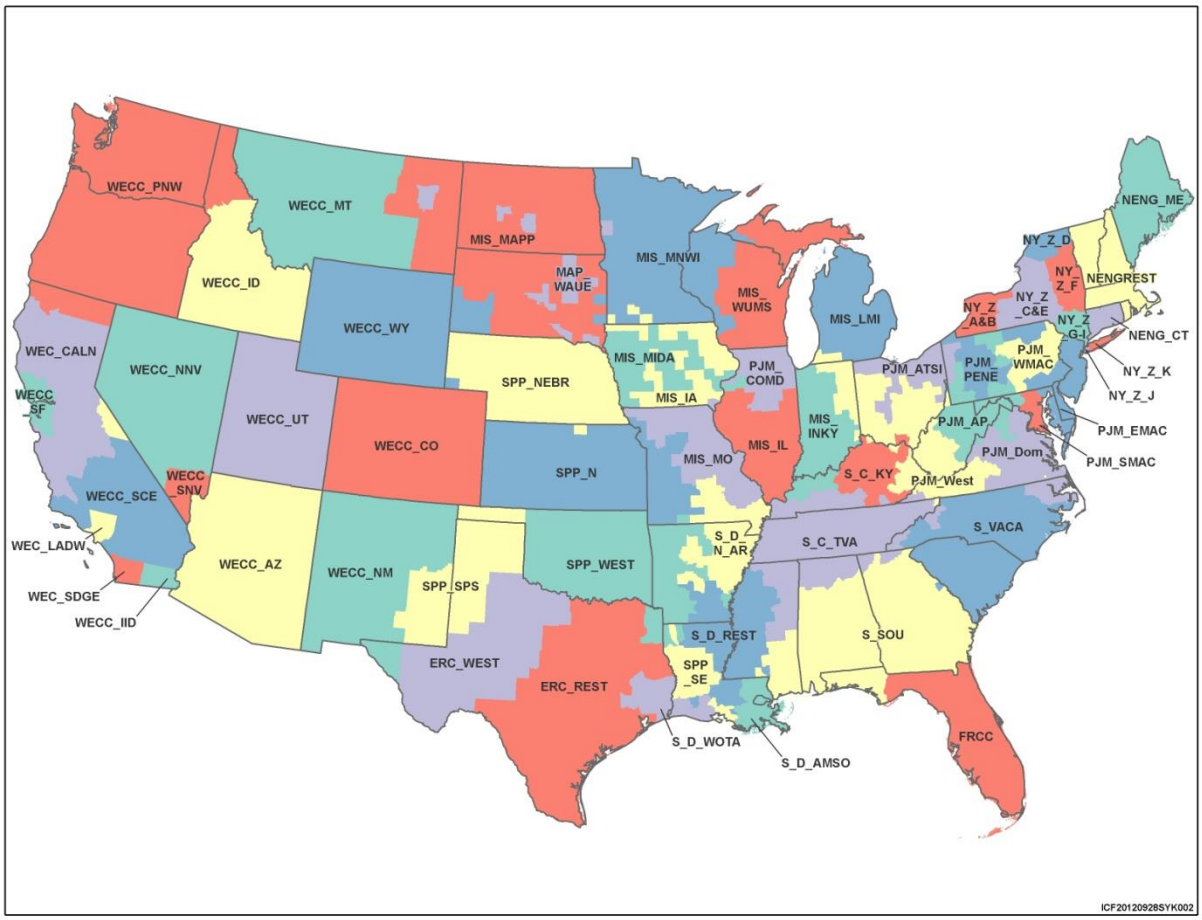
Figure 3-6. Seasonal diurnal profiles for EGU emissions in a Virginia Region



For sources not matched to CEMS units, the allocation of annual emissions to months and then days are done outside of SMOKE and then daily emissions are output to day-specific inventory files. For these

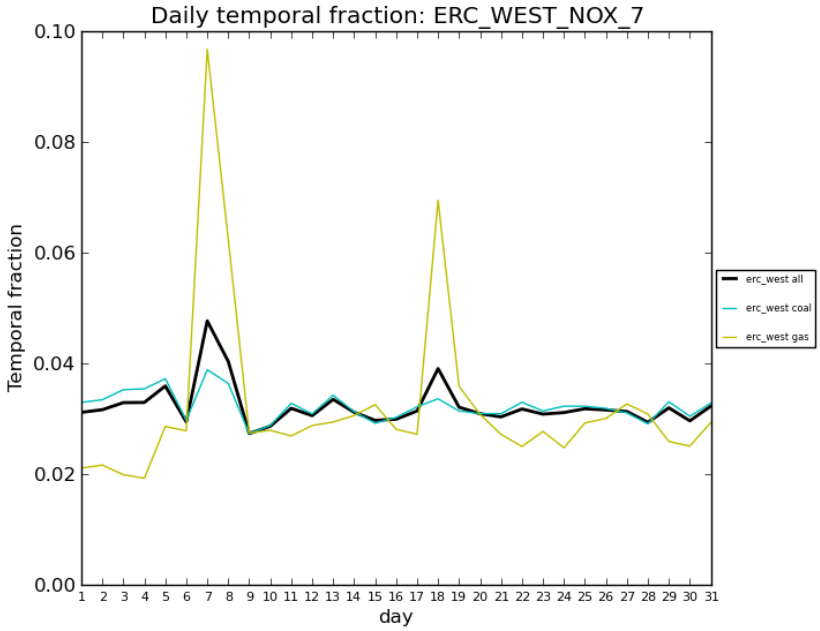
units, the allocation of the inventory annual emissions to months is done using average fuel-specific season-to-month factors generated for each of the 64 IPM regions shown in Figure 3-7. These factors are based on 2011 CEMS data only. In each region, separate factors were developed for the fuels: coal, natural gas, and "other," where the types of fuels included in "other" vary by region. Separate profiles were computed for NO_x, SO_2, and heat input. An overall composite profile was also computed and used when there were no CEMS units with the specified fuel in the region containing the unit. For both CEMS-matched units and units not matched to CEMS, NO_x and SO_2 CEMS data are used to allocate NO_x and SO_2 emissions to monthly emissions, respectively, while heat input data are used to allocate emissions of all other pollutants and to allocate emissions of all pollutants from monthly to daily emissions.

Figure 3-7. IPM Regions in Version 5.16



Daily temporal allocation of units matched to CEMS was performed using a procedure similar to the approach to allocate emissions to months in that the CEMS data replaces the inventory data for each pollutant. For units without CEMS data, emissions were allocated from month to day using IPM-region and fuel-specific average month-to-day factors based on the 2011 CEMS data. Separate month-to-day allocation factors were computed for each month of the year using heat input for the fuels coal, natural gas, and "other" in each region. For both CEMS and non-CEMS matched units, NO_x and SO_2 CEMS data are used to allocate NO_x and SO_2 emissions, while CEMS heat input data are used to allocate all other pollutants. An example of month-to-day profiles for gas, coal, and an overall composite for a region in western Texas is shown in Figure 3-8.

Figure 3-8. Month-to-day profiles for different fuels in a West Texas Region



For units matched to CEMS data, hourly emissions use the hourly CEMS values for NO_x and SO_2, while other pollutants are allocated according to heat input values. For units not matched to CEMS data, temporal profiles from days to hours are computed based on the season-, region- and fuel-specific average day-to-hour factors derived from the CEMS data for those fuels and regions using the appropriate subset of data. For the unmatched units, CEMS heat input data are used to allocate *all* pollutants (including NO_x and SO_2) because the heat input data was generally found to be more complete than the pollutant-specific data. SMOKE then allocates the daily emissions data to hours using the temporal profiles obtained from the CEMS data for the analysis base year (i.e., 2011 in this case).

In the 2011en platform, MWCs and cogeneration units were specified to use flat hourly temporal allocation such that the emissions are allocated to constant levels for every hour of the year. These sources do not use hourly CEMs, and instead use a PTDAY file with the same emissions for each day, combined with a flat hourly temporal profile applied by SMOKE.

Future year temporal allocation of EGUs

For future year temporal allocation of unit-level EGU emissions, estimates of average winter (representing October through April) and average summer (representing May through September) values were provided for all units that submitted CEMS data to EPA as part of the Cross-State Air Pollution Rule and Acid Rain Programs. For the 2023el case, the seasonal emissions were produced by postprocessing of outputs from the Integrated Planning Model (IPM), while for the 2023en case the unit-level emissions were developed using an engineering analysis approach (see Section 4.1 for more details). For both cases, the unit-level data was converted into hourly values through the temporal allocation process using a 3-step methodology: annualized summer/winter value to month, month to day, and day to hour. CEMS data from the air quality analysis year (e.g., 2011) is used as much as possible to temporally allocate the EGU emissions. In the 2011v6.3 platforms, temporal profiles are developed in SMOKE temporal profile formats instead of the earlier method of some temporal allocation being done by SMOKE and some by external programs.

The goal of the temporal allocation process is to reflect the variability in the unit-level emissions that can impact air quality over seasonal, daily, or hourly time scales, in a manner compatible with incorporating future-year emission projections into future-year air quality modeling. The temporal allocation process is applied to the seasonal emission projections for two seasons: summer (May through September) and winter (October through April). The Flat File used as the input to the temporal allocation process contains unit-level emissions and stack parameters (i.e., stack location and other characteristics consistent with information found in the NEI). When the flat file is produced from post-processed IPM outputs, a cross reference is used to map the units in the IPM National Electric Energy Database System (NEEDS) database to the stack parameter and facility, unit, release point, and process identifiers used in the NEI. The cross reference also maps sources to the hourly CEMS data used to temporally allocate the emissions in the base year air quality modeling. For the 2023el case, the v5.16 cross reference information along with other key inputs to the flat file generation process are in the file IPM5.16_FlatFile_Inputs.xlsx that is available in the reports section of the 2011v6.3 platform FTP area: ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/reports/. Note that for 2023en, this file is not used because the 2023en EGU emissions were not generated using IPM.

For units that had seasonal information provided in the future year flat file, the monthly values in the Flat File input to the temporal allocation process are computed by multiplying the average summer day and average winter day emissions by the number of days in the respective month. In summary, the monthly emission values shown in the Flat File are not intended to represent an actual month-to-month emission pattern. Instead, they are interim values that have translated IPM's seasonal projections into month-level data that serve as a starting point for the temporal allocation process. In 2023en, units without CEMS data only had annual emissions specified. For those units, monthly temporalization factors were generated by source and pollutant based on 2011en emissions. These factors were then applied to the 2023en annual emissions to create the 2023en monthly emissions.

The monthly emissions within the Flat File undergo a multi-step temporal allocation process to yield the hourly emission values at each unit, as is needed for air quality modeling: summer or winter value to month, month to day, and day to hour. For sources not matched to unit-specific CEMS data, the first two steps are done outside of SMOKE and the third step to get to hourly values is done by SMOKE using the daily emissions files created from the first two steps. For each of these three temporal allocation steps, NO_x and SO_2 CEMS data are used to allocate NO_x and SO_2 emissions, while CEMS heat input data are used to allocate all other pollutants. The approach defined here gives priority to temporalization based on the base year CEMS data to the maximum extent possible for both base and future year modeling.

Prior to using the 2011 CEMS data to develop monthly, daily, and hourly profiles, the CEMS data were processed through a tool that found data quality flags that indicated the data were measured. These adjusted CEMS data were used to compute the monthly, daily, and hourly profiles described below.

For units that have CEMS data available and that have CEMS units match to the NEI sources, the emissions are temporalized based on the CEMS data for that unit and pollutant. For units that are not matched to the NEI or for which CEMS data are not available, the allocation of the seasonal emissions to months is done using average fuel-specific season-to-month factors generated for each of the 64 IPM regions shown in Figure 3-7. These factors are based on a single year of CEMS data for the modeling base year associated with the air quality modeling analysis being performed, such as 2011. The fuels used for creating the profiles for a region are coal, natural gas, and other, where the other fuels used include oil and wood and vary by region. Separate profiles are computed for NO_x, SO_2, and heat input. An overall composite profile across all fuels is also computed and can be used in the event that a region has too few

units of a fuel type to make a reasonable average profile, or in the case when a unit changes fuels between the base and future year and there were previously no units with that fuel in the region containing the unit.

The monthly emission values in the Flat File are first reallocated across the months in that season to align the month-to-month emission pattern at each stack with historic seasonal emission patterns[18]. While this reallocation affects the monthly pattern of each unit's future-year seasonal emissions, the seasonal totals are held equal to the IPM projection for that unit and season. Second, the reallocated monthly emission values at each stack are disaggregated down to the daily level consistent with historic daily emission patterns in the given month at the given stack using separate profiles for NO_x, SO_2, and heat input. This process helps to capture the influence of meteorological episodes that cause electricity demand to vary from day-to-day, as well as weekday-weekend effects that change demand during the course of a given week. Third, this data set of emission values for each day of the year at each unit is input into SMOKE, which uses temporal profiles to disaggregate the daily values into specific values for each hour of the year.

For units without or not matched to CEMS data, or for which the CEMS data are found to be unsuitable for use in the future year, emissions are allocated from month to day using IPM-region and fuel-specific average month-to-day factors based on CEMS data from the base year of the air quality modeling analysis. These instances include units that did not operate in the base year or for which it may not have been possible to match the unit to a specific unit in the NEI. Average profiles are used for some units with CEMS data in the base year when one of the following cases is true: (1) units are projected to have substantially increased emissions in the future year compared to its emissions in the base (historic) year[19]; (2) CEMS data are only available for a limited number of hours in that base year; (3) units change fuels in the future year; (4) the unit is new in the future year; (5) when there are no CEMS data for one season in the base year but IPM runs the unit during both seasons; or (6) units experienced atypical conditions during the base year, such as lengthy downtimes for maintenance or installation of controls. The temporal profiles that map emissions from days to hours are computed based on the region and fuel-specific seasonal (i.e., winter and summer) average day-to-hour factors derived from the CEMS data for those fuels and regions using only heat input data for that season. Only heat input is used because it is the variable that is the most complete in the CEMS data. SMOKE uses these profiles to allocate the daily emissions data to hours.

The emissions from units for which unit-specific profiles are not used are temporally allocated to hours reflecting patterns typical of the region in which the unit is located. Analysis of CEMS data for units in each of the 64 IPM regions revealed that there were differences in the temporal patterns of historic emission data that correlate with fuel type (e.g., coal, gas, and other), time of year, pollutant, season (i.e., winter versus summer) and region of the country. The correlation of the temporal pattern with fuel type is explained by the relationship of units' operating practices with the fuel burned. For example, coal units take longer to ramp up and ramp down than natural gas units, and some oil units are used only when electricity demand cannot otherwise be met. Geographically, the patterns were less dependent on state location than they were on IPM regional location. For temporal allocation of emissions at these units,

[18] For example, the total emissions for a unit in May would not typically be the same as the total emissions for the same unit in July, even though May and July are both in the summer season and the number of days in those months is the same. This is because the weather changes over the course of each season, and thus the operating behavior of a specific unit can also vary throughout each season. Therefore, part of the temporal allocation process is intended to create month-specific emissions totals that reflect this intra-seasonal variation in unit operation and associated emissions.

[19] In such instances, the EPA does not use that unit's CEMS data for temporal allocation in order to avoid assigning large increases in emissions over short time periods in the unit's hourly emission profile.

Figure 3-8 provides an example of daily coal, gas, and composite profiles in one IPM region. The EPA developed seasonal average emission profiles, each derived from base year CEMS data for each season across all units sharing both IPM region and fuel type[20]. Figure 3-6 provides an example of seasonal profiles that allocate daily emissions to hours in one IPM region. These average day-to-hour temporal profiles were also used for sources during seasons of the year for which there were no CEMS data available, but for which IPM predicted emissions in that season. This situation can occur for multiple reasons, including how the CEMS was run at each source in the base year.
For units that do have CEMS data in the base year and are matched to units in the IPM output, the base year CEMS data are scaled so that their seasonal emissions match the IPM-projected totals. In particular, the fraction of the unit's seasonal emissions in the base year is computed for each hour of the season, and then applied to the seasonal emissions in the future year. Any pollutants other than NO_x and SO_2 are temporally allocated using heat input as a surrogate. Distinct factors are used for the fuels coal, natural gas, and "other." Through the temporal allocation process, the future year emissions have the same temporal pattern as the base year CEMS data while the future-year seasonal total emissions for each unit match the future-year unit-specific projection for each season (see example in Figure 3-9).

In cases when the emissions for a particular unit are projected to be substantially higher in the future year than in the base year, the proportional scaling method to match the emission patterns in the base year described above can yield emissions for a unit that are much higher than the historic maximum emissions for that unit. To help address this issue in the future case, the maximum measured emissions of NO_x and SO_2 in the period of 2011-2014 were computed. The temporally allocated emissions were then evaluated at each hour to determine whether they were above this maximum. The amount of "excess emissions" over the maximum was then computed. For units for which the "excess emissions" could be reallocated to other hours, those emissions were distributed evenly to hours that were below the maximum. Those hourly emissions were then reevaluated against the maximum, and the procedure of reallocating the excess emissions to other hours was repeated until all of the hours had emissions below the maximum, whenever possible (see example in Figure 3-10).

[20] The EPA also uses an overall composite profile across all fuels for each IPM region in instances where a unit is projected to burn a fuel for which the EPA cannot construct an average emission profile (because there were no other units in that IPM region whose historic CEMS data represent emissions from burning that fuel).

Figure 3-9. Future year emissions follow pattern of base year emissions

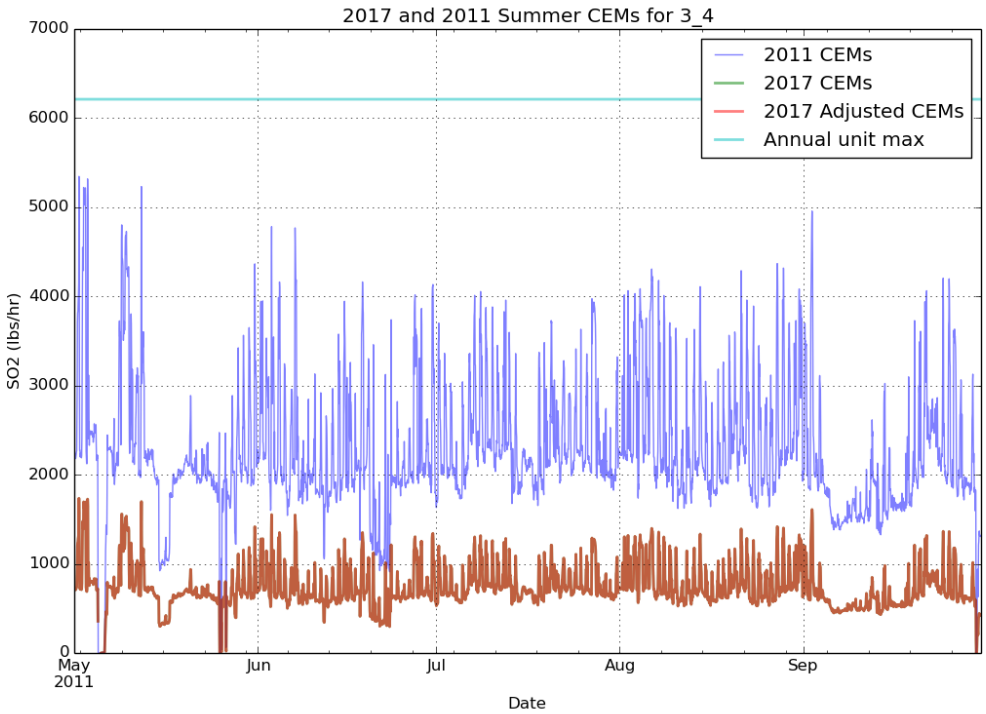
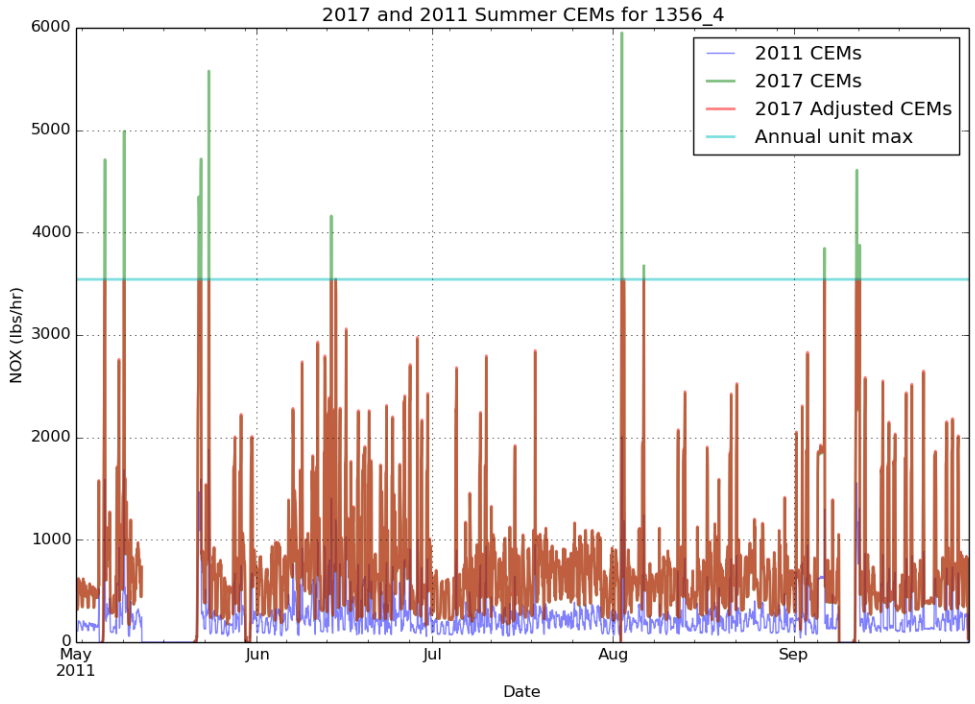


Figure 3-10. Excess emissions apportioned to hours less than maximum



Using the above approach, it was not always possible to reallocate excess emissions to hours below the historic maximum, such as when the total seasonal emissions of NO_x or SO_2 for a unit divided by the number of hours of operation are greater than the 2011-2014 maximum emissions level. For these units,

the *regional* fuel-specific average profile was applied to all pollutants, including heat input, for that season (see example in Figure 3-11). An exception to this is if the fuel for that unit is not gas or coal. In that case, the composite (non-fuel-specific) profile was used for that unit. This is because many sources that used "other" fuel profiles had very irregular shapes due to a small number of sources in the region, and the allocated emissions frequently still exceeded the 2011-2014 maximum. Note that it was not possible for SMOKE to use regional profiles for some pollutants and adjusted CEMS data for other pollutants for the same unit/season, therefore, all pollutants are assigned to regional profiles when regional profiles are needed. Also note that for some units, some hours still exceed the 2011-2014 annual maximum for the unit even after regional profiles were applied (see example in Figure 3-12).

For more information on the development of IPM emission estimates for the 2011el case and the temporalization of those, see the IPM 5.16 section of https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling, in particular the Air Quality Modeling Flat File Documentation and accompanying inputs.

Figure 3-11. Adjustment to Hours Less than Maximum Not Possible so Regional Profile Applied

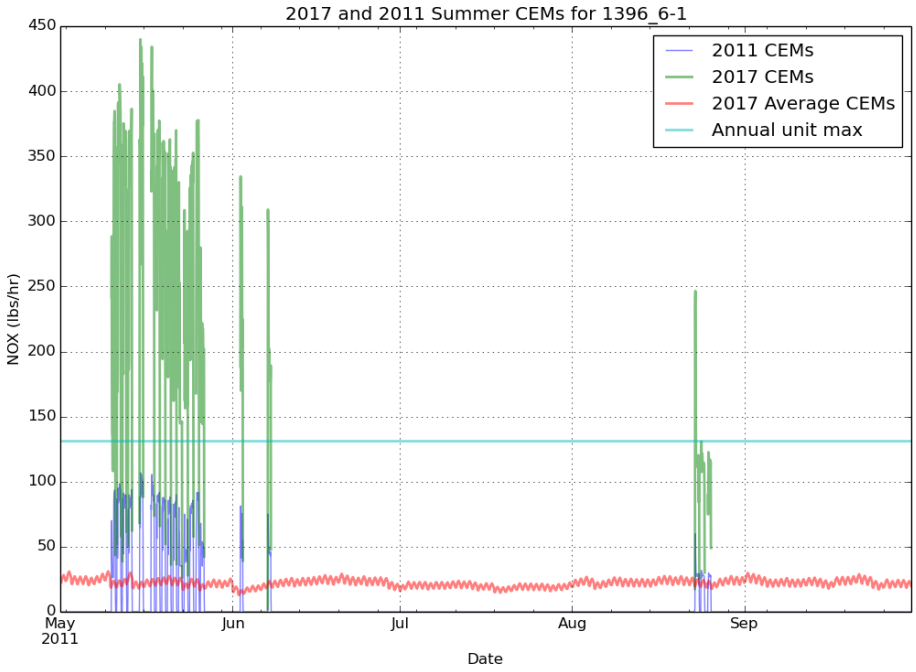
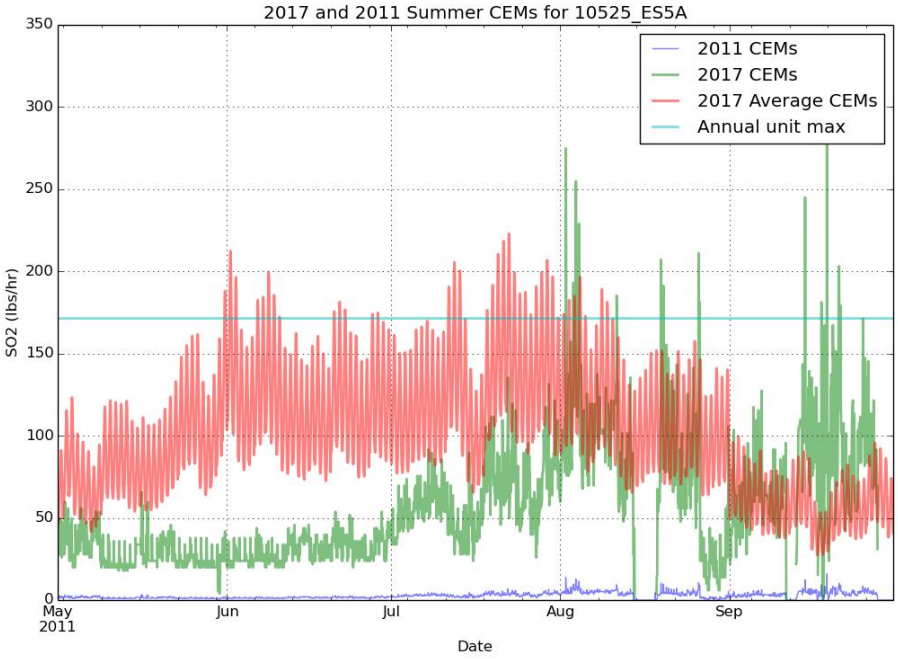


Figure 3-12. Regional Profile Applied, but Exceeds Maximum in Some Hours



3.3.4 Residential Wood Combustion Temporalization (rwc)

There are many factors that impact the timing of when emissions occur, and for some sectors this includes meteorology. The benefits of utilizing meteorology as method for temporalization are: (1) a meteorological dataset consistent with that used by the AQ model is available (e.g., outputs from WRF); (2) the meteorological model data are highly resolved in terms of spatial resolution; and (3) the meteorological variables vary at hourly resolution and can therefore be translated into hour-specific temporalization.

The SMOKE program GenTPRO provides a method for developing meteorology-based temporalization. Currently, the program can utilize three types of temporal algorithms: annual-to-day temporalization for residential wood combustion (RWC); month-to-hour temporalization for agricultural livestock NH_3; and a generic meteorology-based algorithm for other situations. For the 2011 platform, meteorological-based temporalization was used for portions of the rwc sector and for livestock within the ag sector.

GenTPRO reads in gridded meteorological data (output from MCIP) along with spatial surrogates, and uses the specified algorithm to produce a new temporal profile that can be input into SMOKE. The meteorological variables and the resolution of the generated temporal profile (hourly, daily, etc.) depend on the selected algorithm and the run parameters. For more details on the development of these algorithms and running GenTPRO, see the GenTPRO documentation and the SMOKE documentation at http://www.cmascenter.org/smoke/documentation/3.1/GenTPRO_TechnicalSummary_Aug2012_Final.pdf and https://www.cmascenter.org/smoke/documentation/3.7/html/ch05s03s06.html, respectively.

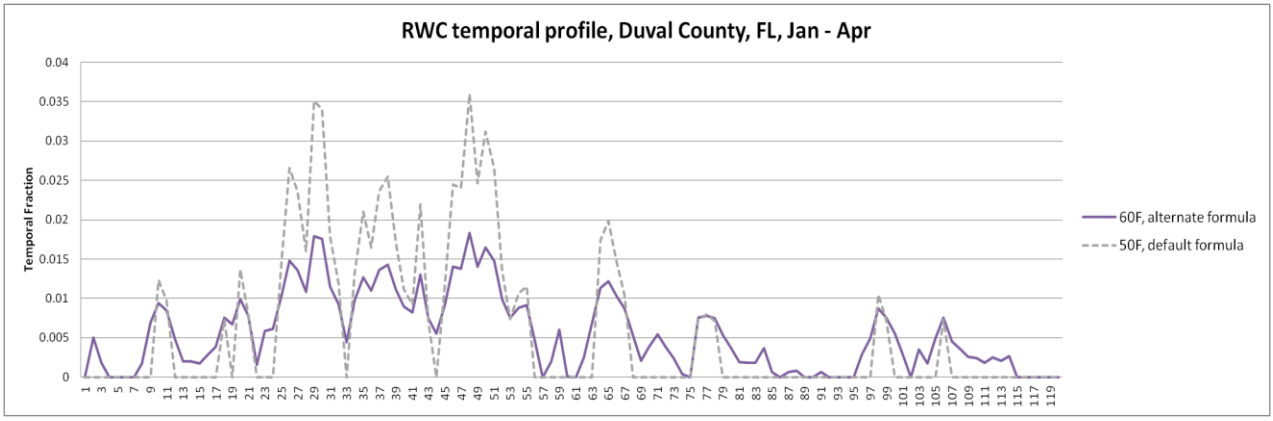
As of the 2011v6.2 platform and in SMOKE 3.6.5, the temporal profile format was updated. GenTPRO now produces separate files including the monthly temporal profiles (ATPRO_MONTHLY) and day-of-month temporal profiles (ATPRO_DAILY), instead of a single ATPRO_DAILY with day-of-year temporal profiles as it did in SMOKE 3.5. The results are the same either way, so the temporal profiles

themselves are effectively the same in 2011v6.2 as they were in 2011v6.0 since the meteorology is the same, but they are formatted differently.

For the RWC algorithm, GenTPRO uses the daily minimum temperature to determine the temporal allocation of emissions to days. GenTPRO was used to create an annual-to-day temporal profile for the RWC sources. These generated profiles distribute annual RWC emissions to the coldest days of the year. On days where the minimum temperature does not drop below a user-defined threshold, RWC emissions for most sources in the sector are zero. Conversely, the program temporally allocates the largest percentage of emissions to the coldest days. Similar to other temporal allocation profiles, the total annual emissions do not change, only the distribution of the emissions within the year is affected. The temperature threshold for rwc emissions was 50 ˚F for most of the country, and 60 ˚F for the following states: Alabama, Arizona, California, Florida, Georgia, Louisiana, Mississippi, South Carolina, and Texas.

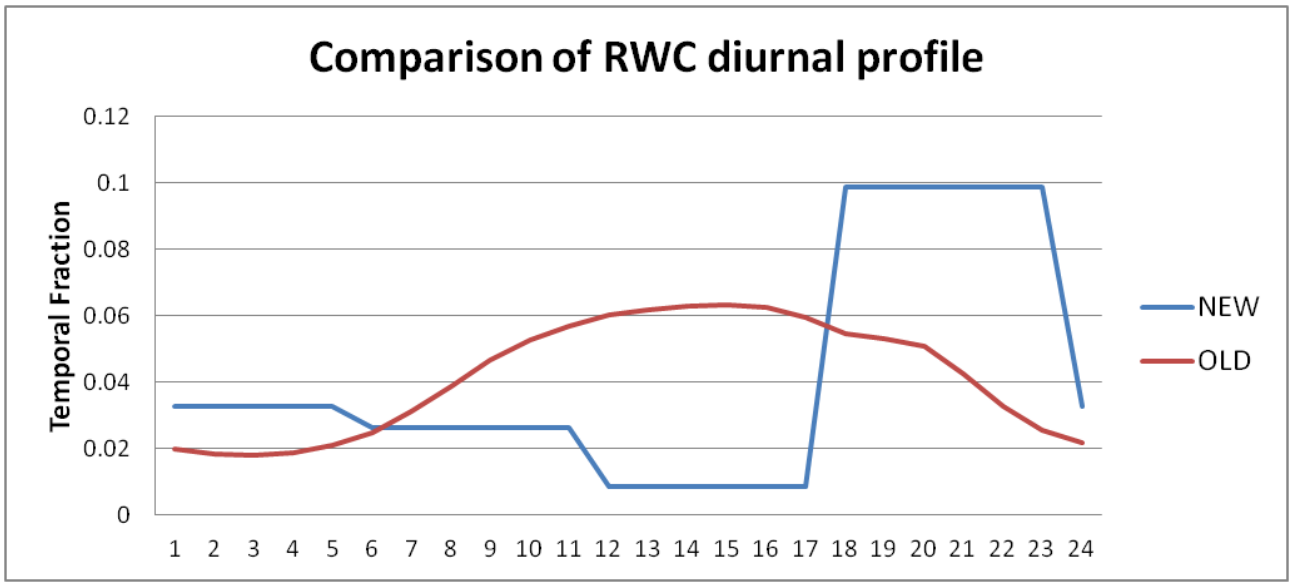
Figure 3-13 illustrates the impact of changing the temperature threshold for a warm climate county. The plot shows the temporal fraction by day for Duval County, Florida, for the first four months of 2007. The default 50 ˚F threshold creates large spikes on a few days, while the 60 ˚F threshold dampens these spikes and distributes a small amount of emissions to the days that have a minimum temperature between 50 and 60 ˚F.

Figure 3-13. Example of RWC temporalization in 2007 using a 50 versus 60 ˚F threshold



The diurnal profile for used for most RWC sources (see Figure 3-14) places more of the RWC emissions in the morning and the evening when people are typically using these sources. This profile is based on a 2004 MANE-VU survey based temporal profiles (see http://www.marama.org/publications_folder/ResWoodCombustion/Final_report.pdf). This profile was created by averaging three indoor and three RWC outdoor temporal profiles from counties in Delaware and aggregating them into a single RWC diurnal profile. This new profile was compared to a concentration based analysis of aethalometer measurements in Rochester, New York (Wang *et al.* 2011) for various seasons and day of the week and found that the new RWC profile generally tracked the concentration based temporal patterns.

Figure 3-14. RWC diurnal temporal profile



The temporalization for "Outdoor Hydronic Heaters" (i.e., "OHH," SCC=2104008610) and "Outdoor wood burning device, NEC (fire-pits, chimneas, etc.)" (i.e., "recreational RWC," SCC=21040087000) were updated because the meteorological-based temporalization used for the rest of the rwc sector did not agree with observations for how these appliances are used.

For OHH, the annual-to-month, day-of-week and diurnal profiles were modified based on information in the New York State Energy Research and Development Authority's (NYSERDA) "Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater Technologies, Final Report" (NYSERDA, 2012), as well as a Northeast States for Coordinated Air Use Management (NESCAUM) report "Assessment of Outdoor Wood-fired Boilers" (NESCAUM, 2006). A Minnesota 2008 Residential Fuelwood Assessment Survey of individual household responses (MDNR, 2008) provided additional annual-to-month, day-of-week and diurnal activity information for OHH as well as recreational RWC usage.

The diurnal profile for OHH, shown in Figure 3-15, is based on a conventional single-stage heat load unit burning red oak in Syracuse, New York. As shown in Figure 3-16, the NESCAUM report describes how for individual units, OHH are highly variable day-to-day but that in the aggregate, these emissions have no day-of-week variation. In contrast, the day-of-week profile for recreational RWC follows a typical "recreational" profile with emissions peaked on weekends.

Annual-to-month temporalization for OHH as well as recreational RWC were computed from the MDNR 2008 survey and are illustrated in Figure 3-17. The OHH emissions still exhibit strong seasonal variability, but do not drop to zero because many units operate year round for water and pool heating. In contrast to all other RWC appliances, recreational RWC emissions are used far more frequently during the warm season.

Figure 3-15. Diurnal profile for OHH, based on heat load (BTU/hr)

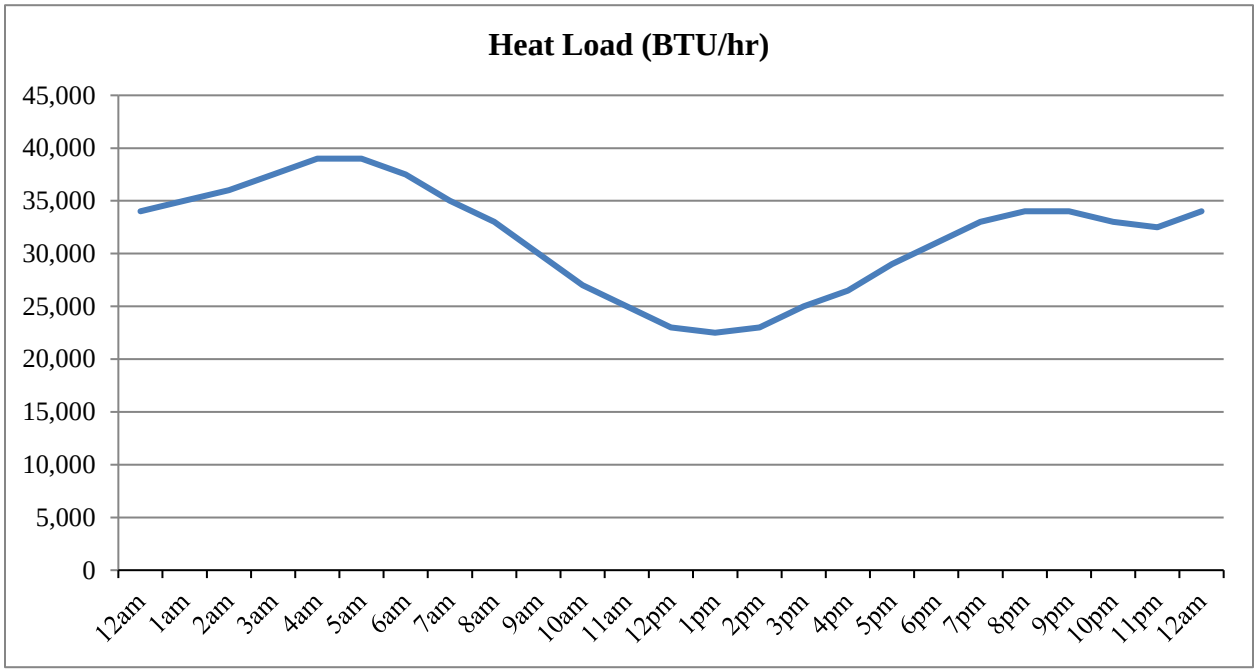


Figure 3-16. Day-of-week temporal profiles for OHH and Recreational RWC

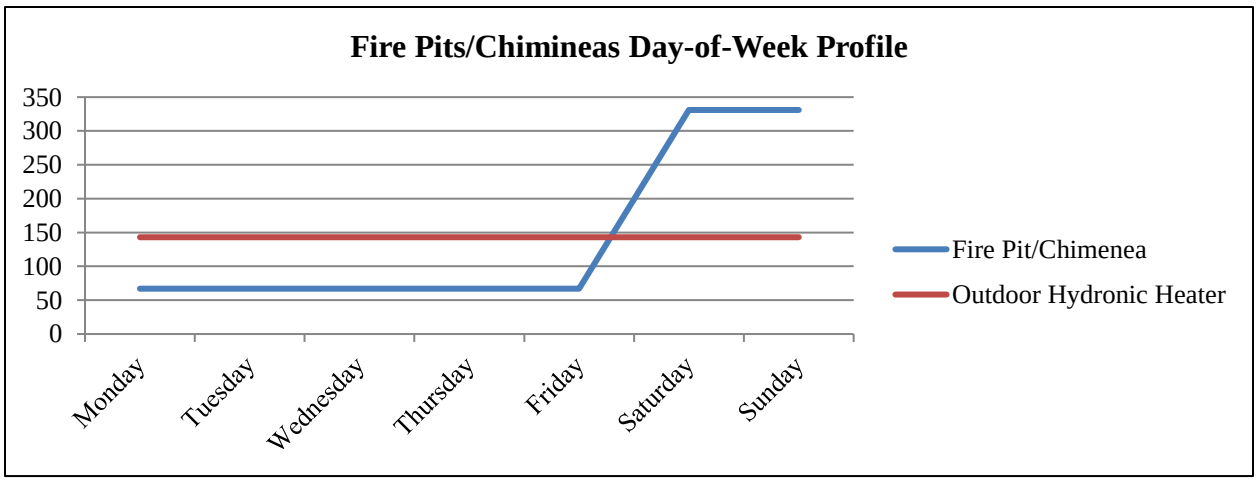
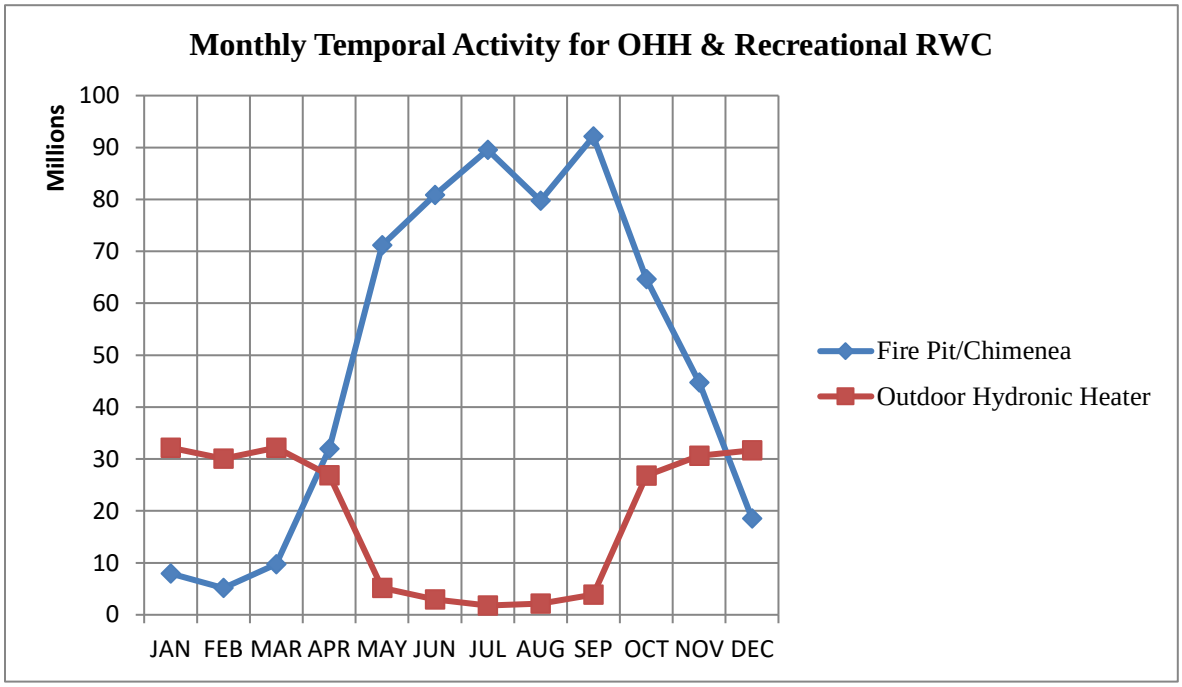


Figure 3-17. Annual-to-month temporal profiles for OHH and recreational RWC



3.3.5 Agricultural Ammonia Temporal Profiles (ag)

For the agricultural livestock NH_3 algorithm, the GenTPRO algorithm is based on an equation derived by Jesse Bash of the EPA's ORD based on the Zhu, Henze, et al. (2013) empirical equation. This equation is based on observations from the TES satellite instrument with the GEOS-Chem model and its adjoint to estimate diurnal NH3 emission variations from livestock as a function of ambient temperature, aerodynamic resistance, and wind speed. The equations are:

$$E_{i,h} = [161500/T_{i,h} \times e^{(-1380/T_{i,h})}] \times AR_{i,h}$$

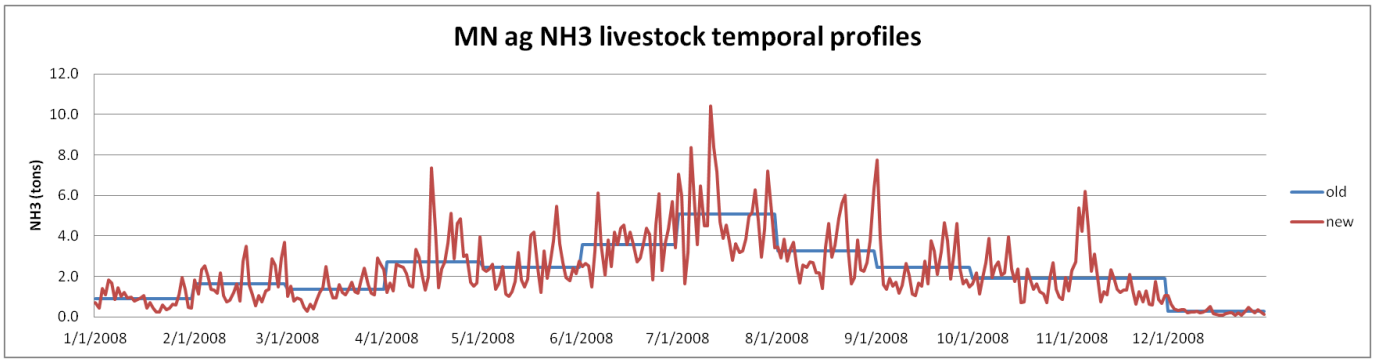
$$PE_{i,h} = E_{i,h} / Sum(E_{i,h})$$

where

- $PE_{i,h}$ = Percentage of emissions in county *i* on hour *h*
- $E_{i,h}$ = Emission rate in county *i* on hour *h*
- $T_{i,h}$ = Ambient temperature (Kelvin) in county *i* on hour *h*
- $V_{i,h}$ = Wind speed (meter/sec) in county *i* (minimum wind speed is 0.1 meter/sec)
- $AR_{i,h}$ = Aerodynamic resistance in county *i*

GenTPRO was run using the "BASH_NH3" profile method to create month-to-hour temporal profiles for these sources. Because these profiles distribute to the hour based on monthly emissions, the monthly emissions are obtained from a monthly inventory, or from an annual inventory that has been temporalized to the month. Figure 3-18 compares the daily emissions for Minnesota from the "old" approach (uniform monthly profile) with the "new" approach (GenTPRO generated month-to-hour profiles). Although the GenTPRO profiles show daily (and hourly variability), the monthly total emissions are the same between the two approaches.

Figure 3-18. Example of animal NH_3 emissions temporalization approach, summed to daily emissions



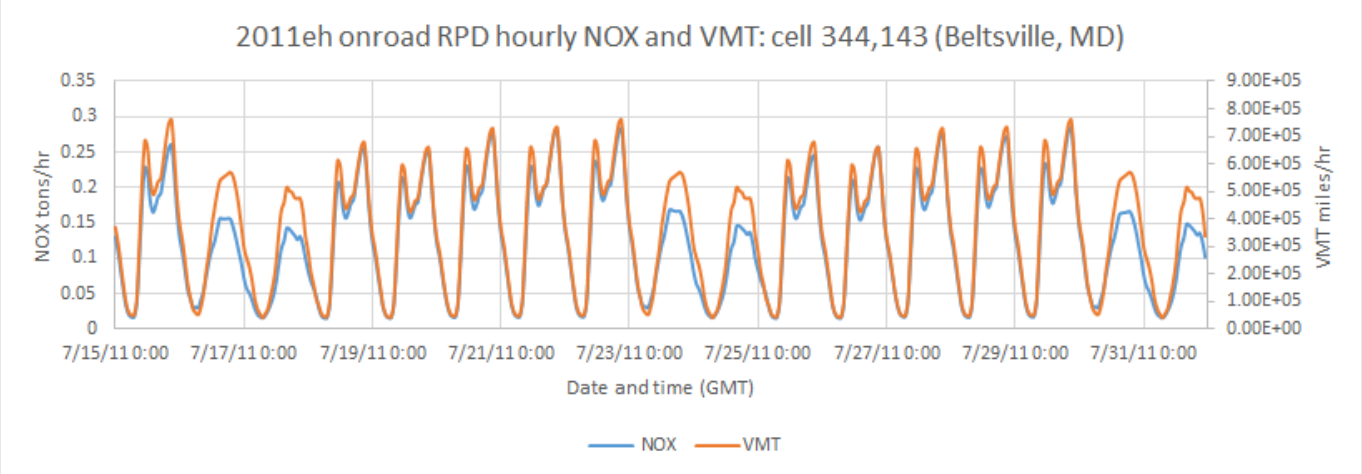
3.3.6 Onroad mobile temporalization (onroad)

For the onroad sector, the temporal distribution of emissions is a combination of more traditional temporal profiles and the influence of meteorology. This section will discuss both the meteorological influences and the diurnal temporal profiles for this platform.

Meteorology is not used in the development of the temporal profiles, but rather it impacts the calculation of the hourly emissions through the program Movesmrg. The result is that the emissions vary at the hourly level by grid cell. More specifically, the on-network (RPD) and the off-network parked vehicle (RPV, RPH, and RPP) processes use the gridded meteorology (MCIP) directly. Movesmrg determines the temperature for each hour and grid cell and uses that information to select the appropriate emission factor for the specified SCC/pollutant/mode combination. In the 2011 platform (and for the 2011NEIv2), RPP was updated to use the gridded minimum and maximum temperature for the day. This more spatially resolved temperature range produces more accurate emissions for each grid cell. The combination of these four processes (RPD, RPV, RPH, and RPP) is the total onroad sector emissions. The onroad sector show a strong meteorological influence on their temporal patterns (see the 2011NEIv2 TSD for more details).

Figure 3-19 illustrates the temporalization of the onroad sector and the meteorological influence via SMOKE-MOVES. Similar temporalization is done for the VMT in SMOKE-MOVES, but the meteorologically varying emission factors add an additional variation on top of the temporalization.

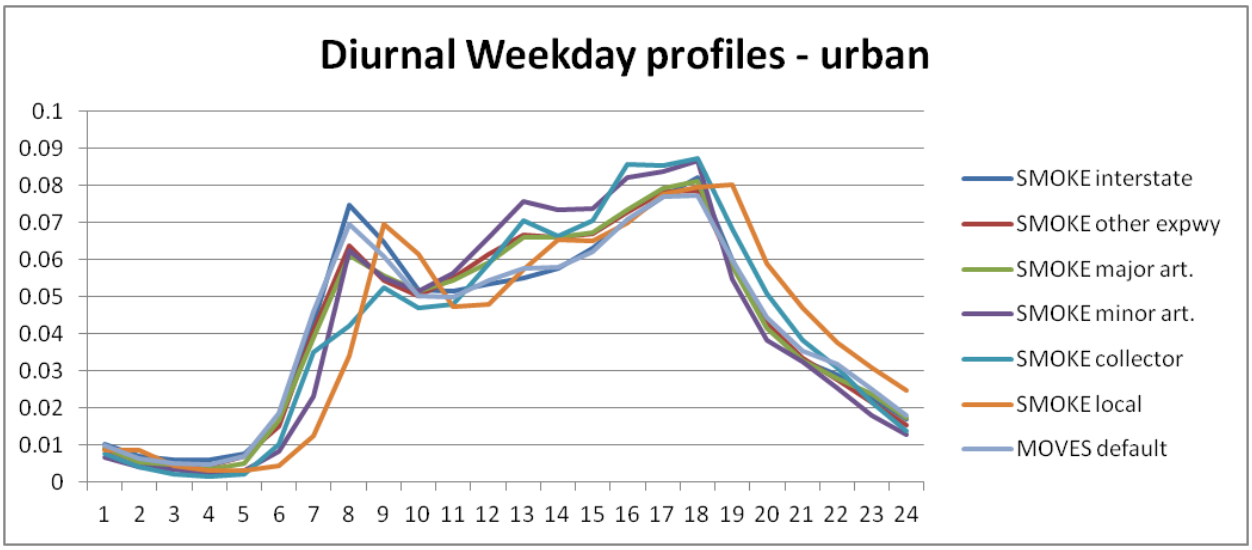
Figure 3-19. Example of SMOKE-MOVES temporal variability of NO_X emissions



For the onroad sector, the "inventories" referred to in Table 3-17 actually consist of activity data, not emissions. For RPP and RPV processes, the VPOP inventory is annual and does not need temporalization. For RPD, the VMT inventory is monthly and was temporalized to days of the week and then to hourly VMT through temporal profiles. The RPD processes require a speed profile (SPDPRO) that consists of vehicle speed by hour for a typical weekday and weekend day. Unlike other sectors, the temporal profiles and SPDPRO will impact not only the distribution of emissions through time but also the total emissions. Because SMOKE-MOVES (for RPD) calculates emissions from VMT, speed and meteorology, if one shifted the VMT or speed to different hours, it would align with different temperatures and hence different emission factors. In other words, two SMOKE-MOVES runs with identical annual VMT, meteorology, and MOVES emission factors, will have different total emissions if the temporalization of VMT changes. For RPH, the HOTELING inventory is monthly and was temporalized to days of the week and to hour of the day through temporal profiles. This is an analogous process to RPD except that speed is not included in the calculation of RPH.

In previous platforms, the diurnal profile for VMT[21] varied by road type but not by vehicle type (see Figure 3-20). These profiles were used throughout the nation.

Figure 3-20. Previous onroad diurnal weekday profiles for urban roads



Diurnal profiles that could differentiate by vehicle type as well as by road type and would potentially vary over geography were desired. In the development of the 2011v6.0[22] platform, the EPA updated these profiles to include information submitted by states in their MOVES county databases (CDBs). The 2011NEIv2 process provided an opportunity to update these diurnal profile with new information submitted by states, to supplement the data with additional sources, and to refine the methodology.

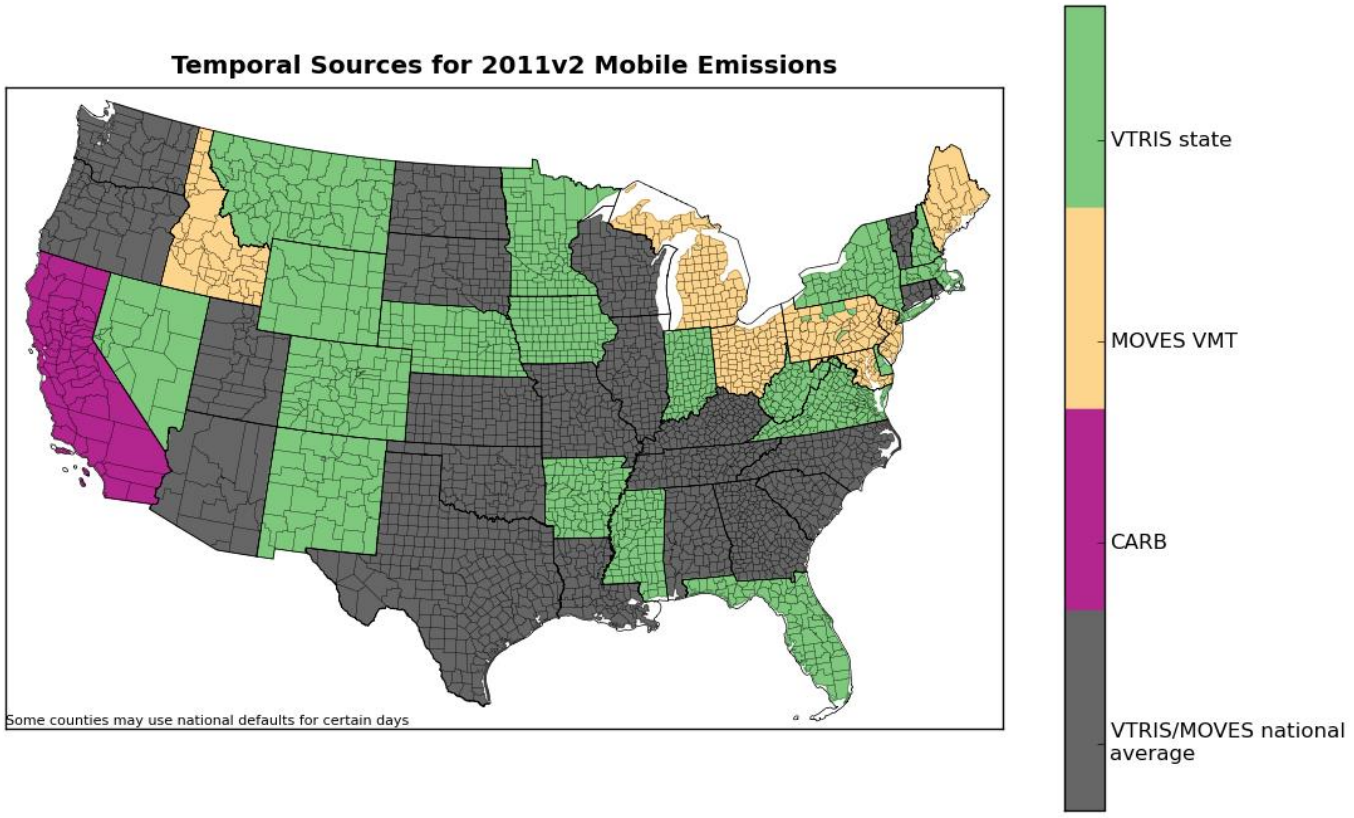
States submitted MOVES county databases (CDBs) that included information on the distribution of VMT by hour of day and by day of week[23] (see the 2011NEIv2 TSD for details on the submittal process for onroad). The EPA mined the state submitted MOVES CDBs for non-default diurnal profiles[24]. The list

[21] These profiles were used in the 2007 platform and proceeding platforms.
[22] These profiles that were generated from MOVES submittals only were used for the v6 and v6.1 platforms. See their respective TSDs for more details.
[23] The MOVES tables are the hourvmtfraction and the dayvmtfraction.
[24] Further QA was done to remove duplicates and profiles that were missing two or more hours. If they were missing a single hour, the missing hour could be calculated by subtracting all other hours fractions from 1.

of potential diurnal profiles was then analyzed to see whether the profiles varied by vehicle type, road type, weekday versus weekend, and by county within a state. For the MOVES diurnal profiles, the EPA only considered the state profiles that varied significantly by both vehicle and road types. Only those profiles that passed this criteria were used in that state or used in developing default temporal profiles. The Vehicle Travel Information System (VTRIS) is a repository for reported traffic count data to the Federal Highway Administration (FHWA). The EPA used 2012 VTRIS data to create additional temporal profiles for states that did not submit temporal information in their CDBs or where those profiles did not pass the variance criteria. The VTRIS data were used to create state specific diurnal profiles by HPMS vehicle and road type. The EPA created distinct diurnal profiles for weekdays, Saturday and Sunday along with day of the week profiles[25].

The EPA attempted to maximize the use of state and/or county specific diurnal profiles (either from MOVES or VTRIS). Where there was no MOVES or VTRIS data, then a new default profile would be used (see below for description of new profiles). This analysis was done separately for weekdays and for weekends and, therefore, some areas had submitted profiles for weekdays but defaults for weekends. The result was a set of profiles that varied geographically depending on the source of the profile and the characteristics of the profiles (see Figure 3-21).

Figure 3-21. Use of submitted versus new national default profiles

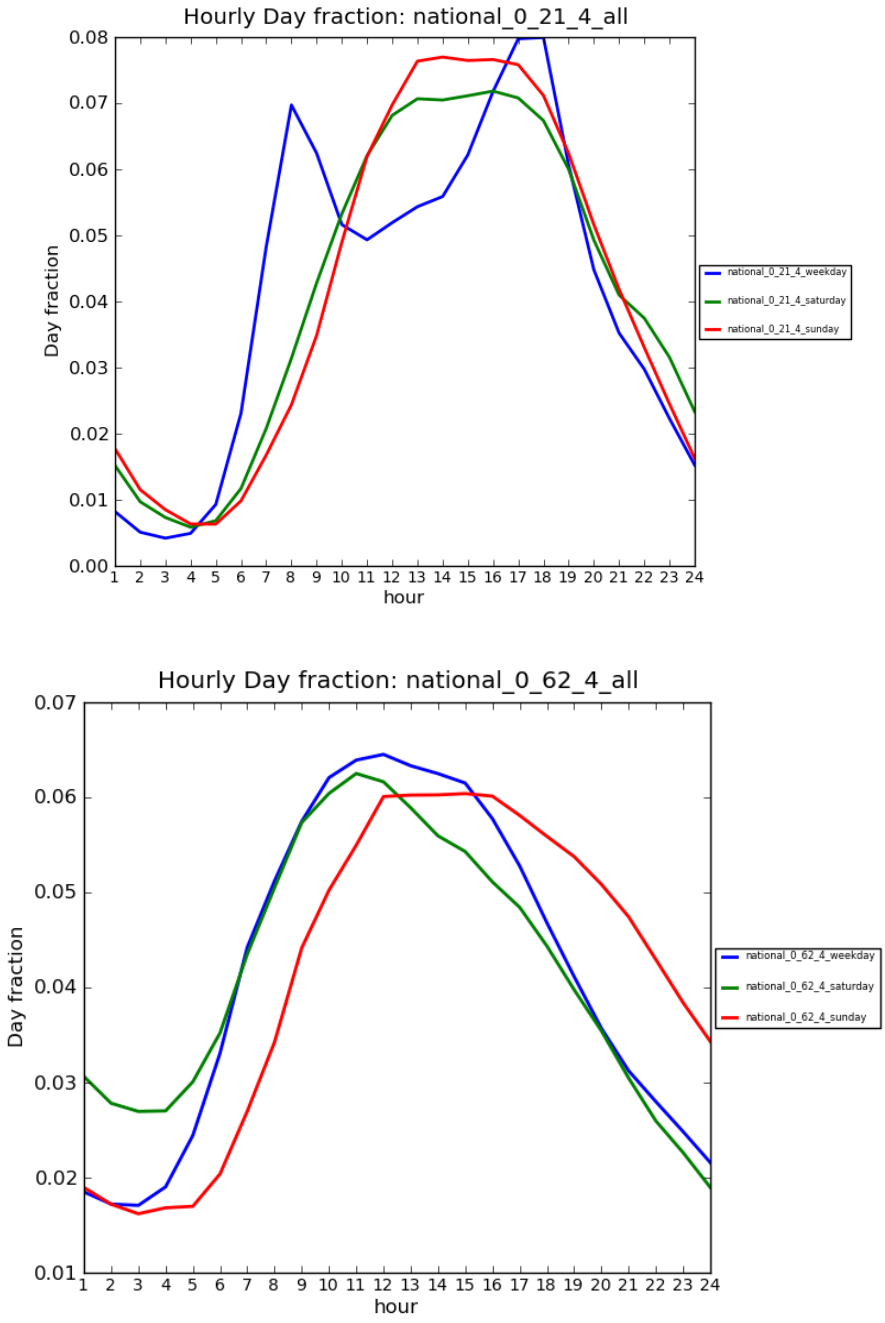


A new set of diurnal profiles was developed for the 2011v6.2 platform from the submitted profiles that varied by both vehicle type and road type. For the purposes of constructing the national default diurnal profiles, the EPA created individual profiles for each state (averaging over the counties within) to create a

[25] Note, the day of the week profiles (i.e., Monday vs Tuesday vs etc) are only from the VTRIS data. The MOVES CDBs only have weekday versus weekend profiles so they were not included in calculating a new national default day of the week profile.

single profile by state, vehicle type, road type, and the day (i.e., weekday versus Saturday versus Sunday). The source of the underlying profiles was either MOVES or VTRIS data (see Figure 3-21). The states individual profiles were averaged together to create a new default profile[26]. Figure 3-22 shows two new national default profiles for light duty gas vehicles (LDGV, SCC6 220121) and combination long-haul diesel trucks (HHDDV, SCC6 220262) on restricted urban roadways (interstates and freeways).

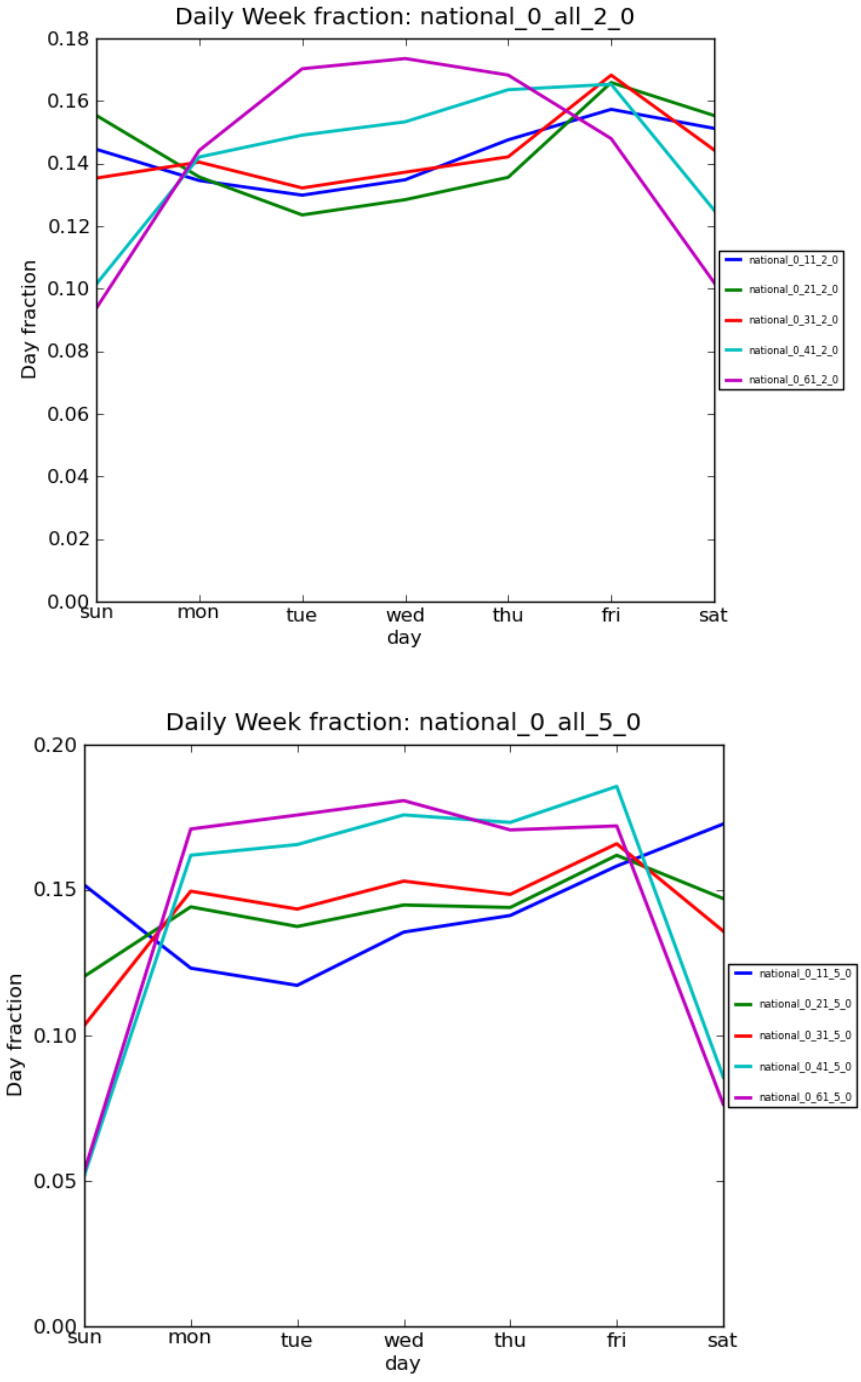
Figure 3-22. Updated national default profiles for LDGV vs. HHDDV, urban restricted



[26] Note that the states were weighted equally in the average independent of the size of the state or the variation in submitted county data.

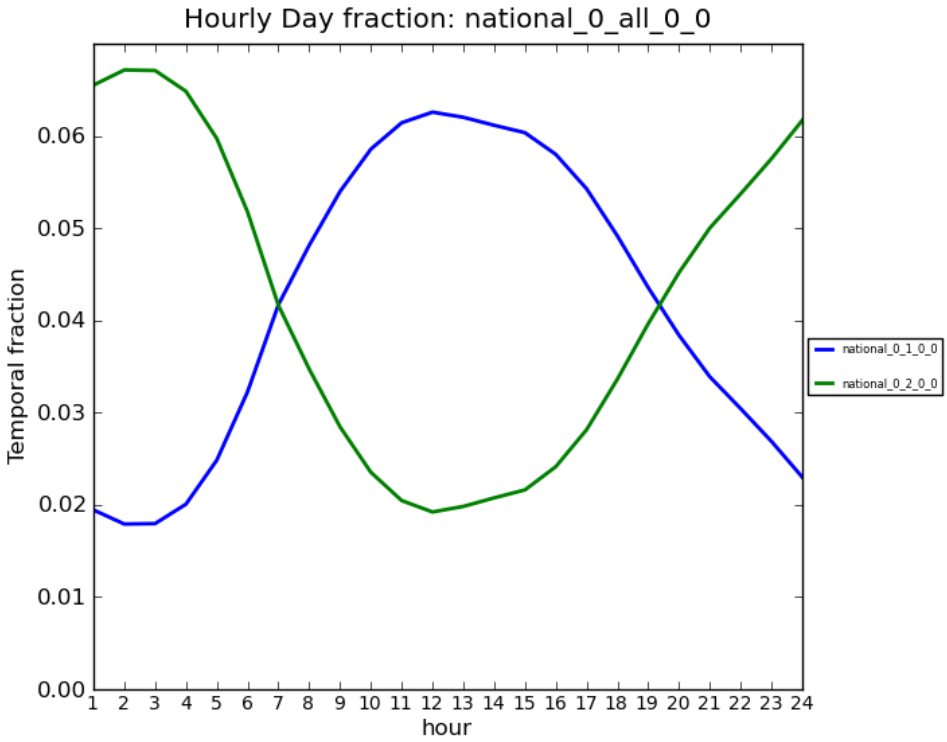
The blue lines of Figure Figure 3-22 indicate the weekday profile, the green the Saturday profile, and the red the Sunday profile. In comparison, the new default profiles for weekdays places more LDGV VMT (upper plot) in the rush hours while placing HHDDV VMT (lower plot) predominately in the middle of the day with a longer tail into the evening hours and early morning. In addition to creating diurnal profiles, the EPA developed day of week profiles using the VTRIS data. The creation of the state and national profiles was similar to the diurnal profiles (described above). Figure 3-23 shows a set of national default profiles for rural restricted roads (top plot) and urban unrestricted roads (lower plot). Each vehicle type is a different color on the plots.

Figure 3-23. Updated national default profiles for day of week



The EPA also developed a national profile for hoteling by averaging all the combination long-haul truck profiles on restricted roads (urban and rural) for weekdays to create a single national restricted profile (blue line in Figure 3-24). This was then inverted to create a profile for hoteling (green line in Figure 3-24). This single national profile was used for hoteling irrespective of location.

Figure 3-24. Combination long-haul truck restricted and hoteling profile



For California, CARB supplied diurnal profiles that varied by vehicle type, day of the week[27], and air basin. These CARB specific profiles were used in developing EPA estimates for California. Although the EPA adjusted the total emissions to match California's submittal to the 2011NEIv2, the temporalization of these emissions took into account both the state-specific VMT profiles and the SMOKE-MOVES process of incorporating meteorology. For more details on the adjustments to California's onroad emissions, see Section 2011 onroad mobile sources (onroad) and the 2011NEIv2 TSD.

3.3.7 Additional sector specific details (afdust, beis, cmv, rail, nonpt, ptnonipm, ptfire, np_oilgas)

For the afdust sector, meteorology is not used in the development of the temporal profiles, but it is used to reduce the total emissions based on meteorological conditions. These adjustments are applied through sector-specific scripts, beginning with the application of land use-based gridded transport fractions and then subsequent zero-outs for hours during which precipitation occurs or there is snow cover on the ground. The land use data used to reduce the NEI emissions explains the amount of emissions that are subject to transport. This methodology is discussed in (Pouliot et al., 2010) and in "Fugitive Dust Modeling for the 2008 Emissions Modeling Platform" (Adelman, 2012). The precipitation adjustment is

[27] California's diurnal profiles varied within the week. Monday, Friday, Saturday, and Sunday had unique profiles and Tuesday, Wednesday, Thursday had the same profile.

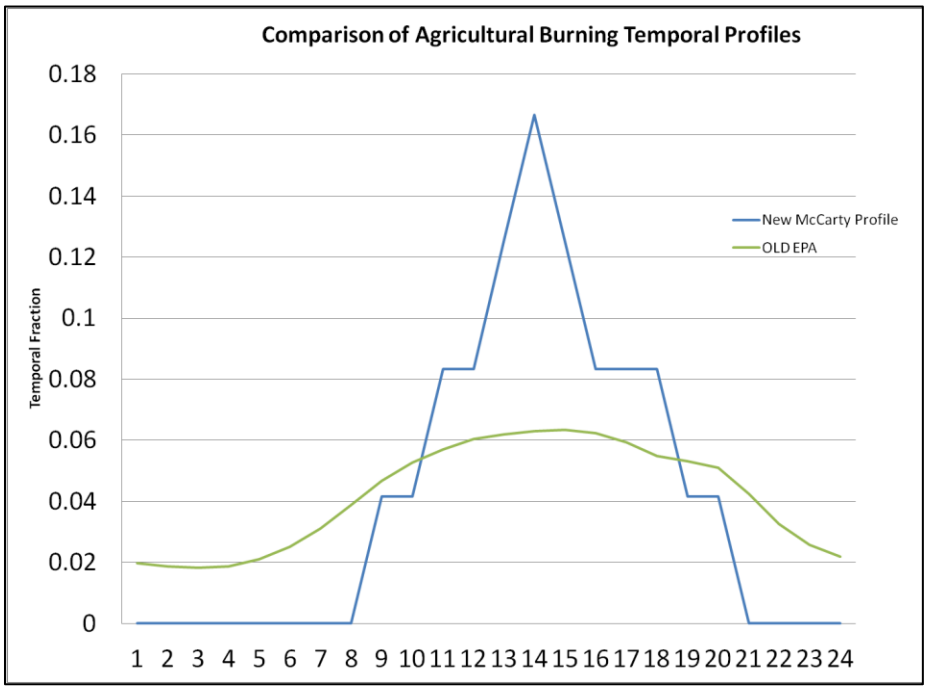
applied to remove all emissions for days where measureable rain occurs. Therefore, the afdust emissions vary day-to-day based on the precipitation and/or snow cover for that grid cell and day. Both the transport fraction and meteorological adjustments are based on the gridded resolution of the platform; therefore, somewhat different emissions will result from different grid resolutions. Application of the transport fraction and meteorological adjustments prevents the overestimation of fugitive dust impacts in the grid modeling as compared to ambient samples.

Biogenic emissions in the beis sector vary by every day of the year because they are developed using meteorological data including temperature, surface pressure, and radiation/cloud data. The emissions are computed using appropriate emission factors according to the vegetation in each model grid cell, while taking the meteorological data into account.

For the cmv and rail sectors, emissions are allocated with flat monthly and day of week profiles, and most emissions are also allocated with flat hourly profiles.

For the agfire sector, the emissions were allocated to months by adding up the available values for each day of the month. For all agricultural burning, the diurnal temporal profile used reflected the fact that burning occurs during the daylight hours - see Figure 3-25 (McCarty et al., 2009). This puts most of the emissions during the work day and suppresses the emissions during the middle of the night. A uniform profile for each day of the week was used for all agricultural burning emissions in all states, except for the following states that the EPA used state-specific day of week profiles: Arkansas, Iowa, Kansas, Louisiana, Minnesota, Missouri, Nebraska, Oklahoma, and Texas.

Figure 3-25. Agricultural burning diurnal temporal profile



Updates were made to temporal profiles for the ptnonipm sector in the 2011v6.2 platform based on comments and data review by EPA staff. Temporal profiles for small airports (i.e., non-commercial) were updated to eliminate emissions between 10pm and 6am due to a lack of tower operations. Industrial process that are not likely to shut down on Sundays such as those at cement plants were assigned to other

more realistic profiles that included emissions on Sundays. This also affected emissions on holidays because Sunday emissions are also used on holidays.

For the ptfire sectors, the inventories are in the daily point fire format ORL PTDAY. The ptfire sector is used in the model evaluation case (2011ek) and in the future base case (2017ek). The 2007 and earlier platforms had additional regulatory cases that used averaged fires and temporally averaged EGU emissions, but the 2011 platform uses base year-specific (i.e., 2011) data for both cases.

For the nonroad sector, while the NEI only stores the annual totals, the modeling platform uses monthly inventories from output from NMIM. For California, a monthly inventory was created from CARB's annual inventory using EPA-estimated NMIM monthly results to compute monthly ratios by pollutant and SCC7 and these ratios were applied to the CARB inventory to create a monthly inventory.

Some cross reference updates for temporalization of the np_oilgas sector were made in the 2011v6.2 and 2011v6.3 platform to assign np_oilgas sources to 24 hour per day, 7 days a week based on comments received.

3.3.8 Time zone corrections

Various time zone corrections/updates were made to the 2011v6.3 platform, which affects the hourly temporalization of emissions. Table 3-18 lists the time zone corrections for U.S. counties. Almost the entire country of Mexico needed to be corrected. Most of country is Central time zone with DST, except for the six northwesternmost states. In the 2011v6.2 platform, most of Mexico was Central time without DST. The time zone corrections made to Canada are the following:

- Quebec: Seven census divisions moved from Atlantic Time to Eastern Time. Only one Quebec census division remains in Atlantic Time zone.
- Manitoba: Daylight Saving Time (DST) added. (Only affects entire province FIPS; individual census divisions were already correct.)
- Saskatchewan: now Central time without DST; was previously a mix of Central time and Mountain Time with DST.
- Peace River, BC: changed from Pacific Time with DST to Mountain Time without DST.
- NW Territories: moved from Pacific Time to Mountain Time. (Only affects entire province FIPS; individual census divisions were already correct.)

Table 3-18. Time zone corrections for US counties in 2011v6.3 platform

FIPS	State	County	2011eh	2011ek
ALL	Indiana	ALL	some with no daylight saving time implemented (DST)	all changed to implementing DST
20093	Kansas	Kearny Co	MT	CT
21087	Kentucky	Green Co	ET	CT
21225	Kentucky	Union Co	ET	CT
21233	Kentucky	Webster Co	ET	CT
38057	North Dakota	Mercer Co	MT	CT
38059	North Dakota	Morton Co	MT	CT
38065	North Dakota	Oliver Co	MT	CT
38085	North Dakota	Sioux Co	MT	CT
46075	South Dakota	Jones Co	MT	CT
46095	South Dakota	Mellette Co	MT	CT
46121	South Dakota	Todd Co	MT	CT

3.4 Spatial Allocation

The methods used to perform spatial allocation are summarized in this section. For the modeling platform, spatial factors are typically applied by county and SCC. As described in Emissions Modeling Overview, spatial allocation was performed for a national 12-km domain. To accomplish this, SMOKE used national 12-km spatial surrogates and a SMOKE area-to-point data file. For the U.S., the EPA updated surrogates to use circa 2010-2011 data wherever possible. For Mexico and Canada, updated spatial surrogates were used as described below. The U.S., Mexican, and Canadian 12-km surrogates cover the entire CONUS domain 12US1 shown in Figure 3-1.

The changes to spatial allocation in the 2011el platform were limited to the addition of SCCs from the MOVES-Mexico inventory to the spatial cross reference for Canada and Mexico. The 2011en platform update introduced a new set of Canadian spatial surrogates, a new shipping lanes surrogate for U.S. emissions, and a new population surrogate in Mexico. Otherwise, the exception of some updates to the spatial surrogate cross reference, the spatial surrogates for the U.S. and Mexico used in the 2011v6.3 platform are the same as the surrogates used for the 2011v6.2 platform (EPA, 2015b). The details regarding how the 2011v6.2 platform surrogates were created are available from ftp://ftp.epa.gov/EmisInventory/2011v6/v2platform/spatial_surrogates/ in the files *US_SpatialSurrogate_Workbook_v072115.xlsx* and *US_SpatialSurrogate_Documentation_v070115.pdf*, and *SurrogateTools_Scripts_2014.zip* available. The remainder of this subsection provides further detail on the origin of the data used for the spatial surrogates and the area-to-point data.

3.4.1 Spatial Surrogates for U.S. Emissions

There are more than 100 spatial surrogates available for spatially allocating U.S. county-level emissions to the 12-km grid cells used by the air quality model. Table 3-19 lists the codes and descriptions of the surrogates. Surrogate names and codes listed in *italics* are not directly assigned to any sources for the 2011v6.3 platform, but they are sometimes used to gapfill other surrogates, or as an input for merging two surrogates to create a new surrogate that is used.

Many surrogates use circa 2010-based data, including: 2010 census data at the block group level; 2010 American Community Survey Data for heating fuels; 2010 TIGER/Line data for railroads and roads; the 2006 National Land Cover Database; 2011 gas station and dry cleaner data; and the 2012 National Transportation Atlas Data for rail-lines, ports and navigable waterways. The surrogate for ports (820) was developed based on the shapefile Ports_2014NEI while the Shipping Lane surrogate (808) was based on the Shapefile CMV_2013_Vessel_Density_CONUS1km based on 2013 shipping data from http://marinecdastre.gov. This data set included shipping lane data in the Atlantic, Pacific, Great Lakes and the Gulf of Mexico. The creation of surrogates and shapefiles for the U.S. was generated via the Surrogate Tool. The tool and documentation for it is available at https://www.cmascenter.org/sa-tools/documentation/4.2/SurrogateToolUserGuide_4_2.pdf.

Table 3-19. U.S. Surrogates available for the 2011 modeling platform.

Code	Surrogate Description	Code	Surrogate Description
N/A	Area-to-point approach (see 3.3.1.2)	507	Heavy Light Construction Industrial Land
100	Population	510	Commercial plus Industrial
110	*Housing*	515	Commercial plus Institutional Land
120	*Urban Population*	520	Commercial plus Industrial plus Institutional
130	Rural Population	*525*	*Golf Courses + Institutional +Industrial + Commercial*
137	*Housing Change*	526	Residential Non-Institutional
140	Housing Change and Population	527	Single Family Residential
150	Residential Heating - Natural Gas	*530*	*Residential - High Density*
160	*Residential Heating – Wood*	535	Residential + Commercial + Industrial + Institutional + Government
165	0.5 Residential Heating - Wood plus 0.5 Low Intensity Residential	540	Retail Trade
170	Residential Heating - Distillate Oil	545	Personal Repair
180	Residential Heating – Coal	*550*	*Retail Trade plus Personal Repair*
190	Residential Heating - LP Gas	555	Professional/Technical plus General Government
200	Urban Primary Road Miles	560	Hospitals
205	Extended Idle Locations	*565*	*Medical Offices/Clinics*
210	Rural Primary Road Miles	*570*	*Heavy and High Tech Industrial*
220	*Urban Secondary Road Miles*	575	Light and High Tech Industrial
221	Urban Unrestricted Roads	580	Food, Drug, Chemical Industrial
230	*Rural Secondary Road Miles*	585	Metals and Minerals Industrial
231	Rural Unrestricted Roads	590	Heavy Industrial
240	Total Road Miles	595	Light Industrial
250	Urban Primary plus Rural Primary	*596*	*Industrial plus Institutional plus Hospitals*
255	*0.75 Total Roadway Miles plus 0.25 Population*	600	Gas Stations
256	Off-Network Short-Haul Trucks	650	Refineries and Tank Farms
257	Off-Network Long-Haul Trucks	675	Refineries and Tank Farms and Gas Stations
258	Intercity Bus Terminals	680	Oil & Gas Wells circa 2005 (replaced by newer surrogates in Table 3-21. Spatial Surrogates for Oil and Gas Sources)
259	Transit Bus Terminals	710	Airport Points
260	Total Railroad Miles	711	Airport Areas
261	NTAD Total Railroad Density	*720*	*Military Airports*
270	*Class 1 Railroad Miles*	*800*	*Marine Ports*

Code	Surrogate Description	Code	Surrogate Description
271	NTAD Class 1, 2, 3 Railroad Density	*801*	*NEI Ports*
280	Class 2 and 3 Railroad Miles	*802*	*NEI Shipping Lanes*
300	Low Intensity Residential	806	Offshore Shipping NEI NOx
310	Total Agriculture	*807*	*Navigable Waterway Miles*
312	Orchards/Vineyards	808	2013 Shipping Density
320	Forest Land	*810*	*Navigable Waterway Activity*
330	Strip Mines/Quarries	*812*	*Midwest Shipping Lanes*
340	*Land*	820	Ports NEI2014 Activity
350	Water	850	Golf Courses
400	Rural Land Area	860	Mines
500	Commercial Land	870	Wastewater Treatment Facilities
505	Industrial Land	880	Drycleaners
506	Education	890	Commercial Timber

For the onroad sector, the on-network (RPD) emissions were spatially allocated to roadways. The refueling emissions were spatially allocated to gas station locations (surrogate 600). On-network (i.e., on-roadway) mobile source emissions were assigned to the following surrogates: rural restricted access to rural primary road miles (210); rural unrestricted access to 231; urban restricted access to urban primary road miles (200); and urban unrestricted access to 221. Off-network (RPP and RPV) emissions were spatially allocated according to the mapping in Table 3-20. Starting with the 2011v6.2 platform, emissions from the extended (i.e., overnight) idling of trucks were assigned to a new surrogate 205 that is based on locations of overnight truck parking spaces.

Table 3-20. Off-Network Mobile Source Surrogates

Source type	Source Type name	Surrogate ID
11	Motorcycle	535
21	Passenger Car	535
31	Passenger Truck	535
32	Light Commercial Truck	510
41	Intercity Bus	258
42	Transit Bus	259
43	School Bus	506
51	Refuse Truck	507
52	Single Unit Short-haul Truck	256
53	Single Unit Long-haul Truck	257
54	Motor Home	526
61	Combination Short-haul Truck	256
62	Combination Long-haul Truck	257

For the oil and gas sources in the np_oilgas sector, the spatial surrogates were updated to those shown in Table **3-21** using 2011 data consistent with what was used to develop the 2011NEI nonpoint oil and gas emissions. Note that the "Oil & Gas Wells, IHS Energy, Inc. and USGS" (680) is older and based on circa-2005 data. These surrogates were based on the same GIS data of well locations and related

attributes as was used to develop the 2011NEIv2 data for the oil and gas sector. The data sources include Drilling Info (DI) Desktop's HPDI database (Drilling Info, 2012) aggregated to grid cell levels, along with data from Oil and Gas Commission (OGC) websites. Well completion data from HPDI was supplemented by implementing the methodology for counting oil and gas well completions developed for the U.S. National Greenhouse Gas Inventory. Under that methodology, both completion date and date of first production from HPDI were used to identify wells completed during 2011. In total, over 1.08 million unique well locations were compiled from the various data sources. The well locations cover 33 states and 1,193 counties (ERG, 2014b).

Table 3-21. Spatial Surrogates for Oil and Gas Sources

Surrogate Code	Surrogate Description
681	Spud count - Oil Wells
682	Spud count - Horizontally-drilled wells
683	Produced Water at all wells
684	Completions at Gas and CBM Wells
685	Completions at Oil Wells
686	Completions at all wells
687	Feet drilled at all wells
688	Spud count - Gas and CBM Wells
689	Gas production at all wells
692	Spud count - All Wells
693	Well count - all wells
694	Oil production at oil wells
695	Well count - oil wells
697	Oil production at Gas and CBM Wells
698	Well counts - Gas and CBM Wells

Some spatial surrogate cross reference updates were made between the 2011v6.2 platform and the 2011v6.3 platform aside from the reworking of the onroad mobile source surrogates described above. These updates included the following:

- Nonroad SCCs using spatial surrogate 525 (50 percent commercial + industrial + institutional, 50 percent golf courses) were changed to 520 (100 percent commercial + industrial + institutional). The golf course surrogate 850, upon which 525 is partially based, is incomplete and subject to hot spots;
- Some nonroad SCCs for commercial equipment in New York County had assignments updated to surrogate 340;
- Commercial lawn and garden equipment was updated to use surrogate 520; and
- Some county-specific assignments for residential wood combustion (RWC) were updated to use surrogate 300.

For the 2011en update to the 2011v6.3 platform, the CMV underway emissions were changed to use surrogate 808. RWC fireplaces in all counties, and other RWC emissions in select counties, were changed to use surrogate 300.

Not all of the available surrogates are used to spatially allocate sources in the modeling platform; that is, some surrogates shown in Table 3-19 were not assigned to any SCCs, although many of the "unused" surrogates are actually used to "gap fill" other surrogates that are used. When the source data for a surrogate has no values for a particular county, gap filling is used to provide values for the surrogate in those counties to ensure that no emissions are dropped when the spatial surrogates are applied to the emission inventories. Table 3-22 shows the CAP emissions (i.e., ammonia (NH_3), NOx, $PM_{2.5}$, SO_2, and VOC) by sector, with rows for each sector listed in order of most emissions to least CAP emissions.

Table 3-22. Selected 2011en CAP emissions by sector for U.S. Surrogates*

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
afdust	130	Rural Population	0	0	1,089,422	0	0
afdust	140	Housing Change and Population	0	0	159,485	0	0
afdust	240	Total Road Miles	0	0	286,188	0	0
afdust	310	Total Agriculture	0	0	895,786	0	0
afdust	330	Strip Mines/Quarries	0	0	58,959	0	0
afdust	400	Rural Land Area	0	0	1	0	0
ag	310	Total Agriculture	3,502,246	0	0	0	0
agfire	310	Total Agriculture	3,287	45,594	100,174	17,001	79,615
agfire	312	Orchards/Vineyards	27	432	1,082	753	799
agfire	320	Forest Land	7	8	121	0	124
cmv_c1c2	808	2013 Shipping Density	332	510,868	16,326	7,352	12,309
cmv_c1c2	820	Ports NEI2011 NOx	23	61,823	2,072	2,354	1,883
nonpt	100	Population	4,137	0	0	0	1,196,465
nonpt	140	Housing Change and Population	3	23,423	65,897	29	134,887
nonpt	150	Residential Heating - Natural Gas	40,775	217,560	4,785	1,443	12,660
nonpt	170	Residential Heating - Distillate Oil	2,045	40,842	4,523	88,432	1,394
nonpt	180	Residential Heating - Coal	247	1,033	605	7,931	1,233
nonpt	190	Residential Heating - LP Gas	136	38,705	224	705	1,432
nonpt	240	Total Road Miles	0	27	602	0	32,152
nonpt	250	Urban Primary plus Rural Primary	0	0	0	0	102,207
nonpt	260	Total Railroad Miles	0	0	0	0	2,195
nonpt	300	Low Intensity Residential	3,847	18,334	90,706	3,048	40,003
nonpt	310	Total Agriculture	0	0	614	0	363,385
nonpt	312	Orchards/Vineyards	0	441	117	1,806	262
nonpt	320	Forest Land	0	85	287	0	97
nonpt	330	Strip Mines/Quarries	0	4	0	0	48
nonpt	400	Rural Land Area	2,855	0	0	0	0
nonpt	500	Commercial Land	2,367	2	85,404	585	26,183
nonpt	505	Industrial Land	35,360	195,282	124,150	112,016	114,391
nonpt	510	Commercial plus Industrial	4	178	27	109	224,110
nonpt	515	Commercial plus Institutional Land	1,408	177,903	18,637	58,798	21,710
nonpt	520	Commercial plus Industrial plus Institutional	0	0	0	0	14,965
nonpt	527	Single Family Residential	0	0	0	0	153,528

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
nonpt	535	Residential + Commercial + Industrial + Institutional + Government	23	366	1,283	0	327,986
nonpt	540	Retail Trade (COM1)	0	0	0	0	1,371
nonpt	545	Personal Repair (COM3)	0	0	93	0	60,289
nonpt	555	Professional/Technical (COM4) plus General Government (GOV1)	0	0	0	0	2,865
nonpt	560	Hospital (COM6)	0	0	0	0	10
nonpt	575	Light and High Tech Industrial (IND2 + IND5)	0	0	0	0	2,538
nonpt	580	Food, Drug, Chemical Industrial (IND3)	0	610	313	171	10,535
nonpt	585	Metals and Minerals Industrial (IND4)	0	23	140	8	443
nonpt	590	Heavy Industrial (IND1)	10	4,373	5,419	1,131	138,575
nonpt	595	Light Industrial (IND2)	0	1	244	0	79,169
nonpt	600	Gas Stations	0	0	0	0	416,448
nonpt	650	Refineries and Tank Farms	0	0	0	0	129,221
nonpt	675	Refineries and Tank Farms and Gas Stations	0	0	0	0	1,203
nonpt	711	Airport Areas	0	0	0	0	1,956
nonpt	801	Port Areas	0	0	0	0	12,469
nonpt	870	Wastewater Treatment Facilities	1,003	0	0	0	4,671
nonpt	880	Drycleaners	0	0	0	0	7,053
nonroad	100	Population	40	39,475	2,824	85	5,030
nonroad	140	Housing Change and Population	554	537,250	45,058	1,255	78,526
nonroad	261	NTAD Total Railroad Density	2	2,673	310	5	568
nonroad	300	Low Intensity Residential	106	26,637	4,324	138	202,928
nonroad	310	Total Agriculture	481	488,224	39,037	910	57,473
nonroad	350	Water	213	143,096	12,395	337	614,637
nonroad	400	Rural Land Area	157	25,658	16,711	194	620,786
nonroad	505	Industrial Land	452	146,871	5,809	411	32,978
nonroad	510	Commercial plus Industrial	382	131,572	9,888	348	139,291
nonroad	520	Commercial plus Industrial plus Institutional	205	70,541	16,361	288	255,836
nonroad	850	Golf Courses	12	2,394	112	17	7,092
nonroad	860	Mines	2	2,931	341	5	594
nonroad	890	Commercial Timber	19	12,979	1,486	38	8,680
np_oilgas	400	Rural Land Area	0	0	0	0	50
np_oilgas	680	Oil and Gas Wells	0	10	0	0	55
np_oilgas	681	Spud count - Oil Wells	0	0	0	0	6,700
np_oilgas	682	Spud count - Horizontally-drilled wells	0	5,526	208	9	349
np_oilgas	683	Produced Water at all wells	0	0	0	0	44,772
np_oilgas	684	Completions at Gas and CBM Wells	0	2,579	46	434	11,706
np_oilgas	685	Completions at Oil Wells	0	360	11	376	28,194
np_oilgas	686	Completions at all wells	0	45,044	1,742	106	101,803
np_oilgas	687	Feet drilled at all wells	0	44,820	1,449	119	9,714
np_oilgas	688	Spud count - Gas and CBM Wells	0	0	0	0	11,322
np_oilgas	689	Gas production at all wells	0	39,184	2,318	224	64,828

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
np_oilgas	692	Spud count - all wells	0	30,138	445	502	4,598
np_oilgas	693	Well count - all wells	0	23,437	436	93	48,205
np_oilgas	694	Oil production at oil wells	0	2,332	0	12,602	729,483
np_oilgas	695	Well count - oil wells	0	96,244	3,067	88	431,306
np_oilgas	697	Oil production at gas and CBM wells	0	3,579	183	34	465,478
np_oilgas	698	Well count - gas and CBM wells	0	373,808	6,428	2,644	525,201
onroad	200	Urban Primary Road Miles	27,650	972,477	36,555	5,698	166,352
onroad	205	Extended Idle Locations	792	287,139	6,085	102	68,756
onroad	210	Rural Primary Road Miles	12,380	812,492	24,653	2,665	81,013
onroad	221	Urban Unrestricted Roads	49,327	1,574,451	64,354	12,078	429,908
onroad	231	Rural Unrestricted Roads	30,711	1,271,368	42,148	6,577	232,468
onroad	256	Off-Network Short-Haul Trucks	0	13,769	305	13	17,456
onroad	257	Off-Network Long-Haul Trucks	0	458	38	2	1,421
onroad	258	Intercity Bus Terminals	0	168	3	0	39
onroad	259	Transit Bus Terminals	0	43	4	0	123
onroad	506	Education	0	633	31	1	1,037
onroad	507	Heavy Light Construction Industrial Land	0	558	10	0	157
onroad	510	Commercial plus Industrial	0	121,163	2,001	131	195,186
onroad	526	Residential - Non-Institutional	0	658	18	1	2,122
onroad	535	Residential + Commercial + Industrial + Institutional + Government	0	652,562	12,720	927	1,319,131
onroad	600	Gas Stations	0	0	0	0	198,012
rail	261	NTAD Total Railroad Density	2	16,536	379	260	925
rail	271	NTAD Class 1 2 3 Railroad Density	332	732,956	22,636	7,390	38,304
rail	280	Class 2 and 3 Railroad Miles	13	41,886	948	287	1,622
rwc	165	0.5 Residential Heating - Wood plus 0.5 Low Intensity Residential	15,162	27,530	318,442	7,900	385,325
rwc	300	Low Intensity Residential	4,520	6,883	62,481	1,049	56,858

3.4.2 Allocation Method for Airport-related Sources in the U.S.

There are numerous airport-related emission sources in the NEI, such as aircraft, airport ground support equipment, and jet refueling. The modeling platform includes the aircraft and airport ground support equipment emissions as point sources. For the modeling platform, the EPA used the SMOKE "area-to-point" approach for only jet refueling in the nonpt sector. The following SCCs use this approach: 2501080050 and 2501080100 (petroleum storage at airports), and 2810040000 (aircraft/rocket engine firing and testing). The ARTOPNT approach is described in detail in the 2002 platform documentation: http://www3.epa.gov/scram001/reports/Emissions%20TSD%20Vol1_02-28-08.pdf. The ARTOPNT file that lists the nonpoint sources to locate using point data were unchanged from the 2005-based platform.

3.4.3 Surrogates for Canada and Mexico Emission Inventories

The surrogates for Canada to spatially allocate the 2013 Canadian emissions have been updated in the 2011en platform. The spatial surrogate data came from Environment Canada, along with cross references. The surrogates they provided were outputs from the Surrogate Tool (previously referenced). The Canadian surrogates used for this platform are listed in Table 3-23. Surrogates for Mexico are circa 1999 and 2000 and were based on data obtained from the Sistema Municpal de Bases de Datos

(SIMBAD) de INEGI and the Bases de datos del Censo Economico 1999. Most of the CAPs allocated to the Mexico and Canada surrogates are shown in Table 3-24. The emissions in this table are from the othar, othon, and othafdust sectors.

Table 3-23. Canadian Spatial Surrogates based on 2013 Inventory

Code	Canadian Surrogate Description	Code	Description
100	Population	941	PAVED ROADS
101	total dwelling	942	UNPAVED ROADS
106	ALL_INDUST	945	Commercial Marine Vessels
113	Forestry and logging	950	Combination of Forest and Dwelling
115	Agriculture and forestry activities	955	UNPAVED_ROADS_AND_TRAILS
200	Urban Primary Road Miles	960	TOTBEEF
210	Rural Primary Road Miles	965	TOTBEEF_CD
212	Mining except oil and gas	966	TOTPOUL_CD
220	Urban Secondary Road Miles	967	TOTSWIN_CD
221	Total Mining	968	TOTFERT_CD
222	Utilities	970	TOTPOUL
230	Rural Secondary Road Miles	980	TOTSWIN
240	Total Road Miles	990	TOTFERT
308	Food manufacturing	996	urban_area
321	Wood product manufacturing	1211	Oil and Gas Extraction
323	Printing and related support activities	1212	OilSands
324	Petroleum and coal products manufacturing	1251	OFFR_TOTFERT
326	Plastics and rubber products manufacturing	1252	OFFR_MINES
327	Non-metallic mineral product manufacturing	1253	OFFR Other Construction not Urban
331	Primary Metal Manufacturing	1254	OFFR Commercial Services
412	Petroleum product wholesaler-distributors	1255	OFFR Oil Sands Mines
416	Building material and supplies wholesaler-distributors	1256	OFFR Wood industries CANVEC
448	clothing and clothing accessories stores	1257	OFFR Unpaved Roads Rural
562	Waste management and remediation services	1258	OFFR_Utilities
921	Commercial Fuel Combustion	1259	OFFR total dwelling
923	TOTAL INSTITUTIONAL AND GOVERNEMNT	1260	OFFR_water
924	Primary Industry	1261	OFFR_ALL_INDUST
925	Manufacturing and Assembly	1262	OFFR Oil and Gas Extraction
926	Distribtution and Retail (no petroleum)	1263	OFFR_ALLROADS
927	Commercial Services	1264	OFFR_OTHERJET
931	OTHERJET	1265	OFFR_CANRAIL
932	CANRAIL		

Table 3-24. CAPs Allocated to Mexican and Canadian Spatial Surrogates for 2011en

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
11	MEX 2015 Population	22,095	94,828	3,784	405	121,164
14	MEX Residential Heating - Wood	0	1,010	12,952	155	89,053

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
16	MEX Residential Heating - Distillate Oil	0	11	0	3	0
20	MEX Residential Heating - LP Gas	0	5,042	152	0	86
22	MEX Total Road Miles	2,154	306,924	8,198	4,305	68,105
24	MEX Total Railroads Miles	0	18,710	418	164	729
26	MEX Total Agriculture	146,737	105,222	22,250	5,106	8,400
32	MEX Commercial Land	0	61	1,343	0	19,436
34	MEX Industrial Land	3	1,055	1,626	0	98,577
36	MEX Commercial plus Industrial Land	0	1,559	26	4	83,144
38	MEX Commercial plus Institutional Land	2	1,427	64	3	42
40	MEX Residential (RES1-4)+Comercial+Industrial+Institutional+Government	0	4	9	0	63,022
42	MEX Personal Repair (COM3)	0	0	0	0	4,637
44	MEX Airports Area	0	2,521	68	319	796
46	MEX Marine Ports	0	8,291	526	4,150	84
50	MEX Mobile sources - Border Crossing - Mexico	4	136	1	2	252
100	CAN Population	593	50	585	11	263
101	CAN total dwelling	272	25,281	1,881	2,447	113,352
106	CAN ALL_INDUST	0	0	6,828	0	70
113	CAN Forestry and logging	268	1,693	0	77	5,056
115	CAN Agriculture and forestry activities	15	180	905	4	504
200	CAN Urban Primary Road Miles	1,460	65,668	2,918	261	8,929
210	CAN Rural Primary Road Miles	572	39,595	1,597	104	3,819
212	CAN Mining except oil and gas	0	0	2,108	0	0
220	CAN Urban Secondary Road Miles	2,713	98,357	5,484	553	21,628
221	CAN Total Mining	0	0	34,755	0	0
222	CAN Utilities	56	8,298	31,963	2,969	175
230	CAN Rural Secondary Road Miles	1,551	70,821	3,091	286	10,313
240	CAN Total Road Miles	31	58,110	2,036	66	93,692
308	CAN Food manufacturing	0	0	8,783	0	5,563
321	CAN Wood product manufacturing	182	1,613	0	85	5,802
323	CAN Printing and related support activities	0	0	0	0	10,739
324	CAN Petroleum and coal products manufacturing	0	529	645	238	2,268
326	CAN Plastics and rubber products manufacturing	0	0	0	0	16,066
327	CAN Non-metallic mineral product manufacturing	0	0	5,213	0	0
331	CAN Primary Metal Manufacturing	0	140	5,183	45	72
412	CAN Petroleum product wholesaler-distributors	0	0	0	0	29,688
448	CAN clothing and clothing accessories stores	0	0	0	0	81
562	CAN Waste management and remediation services	182	1,384	1,755	2,166	13,644
921	CAN Commercial Fuel Combustion	132	18,212	1,741	1,814	856
923	CAN TOTAL INSTITUTIONAL AND GOVERNEMNT	0	0	0	0	10,964
924	CAN Primary Industry	0	0	0	0	25,806
925	CAN Manufacturing and Assembly	0	0	0	0	56,437
926	CAN Distribution and Retail (no petroleum)	0	0	0	0	5,641
927	CAN Commercial Services	0	0	0	0	24,386
932	CAN CANRAIL	30	66,583	1,550	240	3,317

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
941	CAN PAVED ROADS	0	0	211,630	0	0
945	CAN Commercial Marine Vessels	77	63,283	2,338	14,649	3,598
950	CAN Combination of Forest and Dwelling	1,178	13,084	107,784	1,869	152,929
955	CAN UNPAVED_ROADS_AND_TRAILS	0	0	254,039	0	0
960	CAN TOTBEEF	0	0	791	0	164,199
965	CAN TOTBEEF_CD	177,624	0	0	0	0
966	CAN TOTPOUL_CD	20,316	0	0	0	0
967	CAN TOTSWIN_CD	59,387	0	0	0	0
968	CAN TOTFERT_CD	77,861	0	0	0	0
970	CAN TOTPOUL	0	0	156	0	209
980	CAN TOTSWIN	0	0	655	0	2,251
990	CAN TOTFERT	0	3,281	238,181	6,685	124
996	CAN urban_area	0	0	778	0	0
1211	CAN Oil and Gas Extraction	0	29	54,361	50	444
1212	CAN OilSands	0	0	0	0	0
1251	CAN OFFR_TOTFERT	71	77,251	5,715	52	7,079
1252	CAN OFFR_MINES	30	29,069	2,413	22	2,947
1253	CAN OFFR Other Construction not Urban	20	18,121	2,927	15	7,165
1254	CAN OFFR Commercial Services	28	14,606	1,803	23	18,293
1255	CAN OFFR Oil Sands Mines	0	0	0	0	0
1256	CAN OFFR Wood industries CANVEC	11	9,857	932	8	1,619
1257	CAN OFFR Unpaved Roads Rural	22	6,773	1,157	19	44,089
1258	CAN OFFR_Utilities	14	7,109	447	12	8,518
1259	CAN OFFR total dwelling	14	4,372	1,130	12	27,729
1260	CAN OFFR_water	2	603	93	3	5,663
1261	CAN OFFR_ALL_INDUST	3	3,671	238	3	749
1262	CAN OFFR Oil and Gas Extraction	0	509	31	0	101
1263	CAN OFFR_ALLROADS	1	931	65	1	399
1264	CAN OFFR_OTHERJET	1	781	65	1	66
1265	CAN OFFR_CANRAIL	0	65	6	0	11

4 Development of 2023 Base-Case Emissions

The emission inventories for the future year of 2023 have been developed using projection methods that are specific to the type of emission source. Future emissions are projected from the 2011 base case either by running models to estimate future year emissions from specific types of emission sources (e.g., EGUs, and onroad and nonroad mobile sources), or for other types of sources by adjusting the base year emissions according to the best estimate of changes expected to occur in the intervening years (e.g., non-EGU point and nonpoint sources). For some sectors, the same emissions are used in the base and future years, such as biogenic and fires. For the remaining sectors, rules and specific legal obligations that go into effect in the intervening years, along with changes in activity for the sector, are considered when possible.

Emissions inventories for neighboring countries used in our modeling are included in this platform, specifically 2011 and 2023 emissions inventories for Mexico, and 2013 and 2025 emissions inventories for Canada. The meteorological data used to create and temporalize emissions for the future year cases is held constant and represents the year 2011. With the exception of speciation profiles for mobile sources and temporal profiles for EGUs, the same ancillary data files are used to prepare the future year emissions inventories for air quality modeling as were used to prepare the 2011 base year inventories.

The approach for developing the EGU emissions **for 2023en** is described in Section 4.1. For 2023el, emission projections for EGUs were developed using IPM version 5.16 and are reflected in an air quality modeling-ready flat file taken from the EPA Base Case v.5.16. The NEEDS database is an important input to IPM in that contains the generation unit records used for the model plants that represent existing and planned/committed units in EPA modeling applications of IPM. NEEDS includes basic geographic, operating, air emissions, and other data on these generating units and has been updated for the EPA's version 5.16 power sector modeling platform. The EGU emission projections in the flat file format, the corresponding NEEDS database, and user guides and documentation are available with the information for the EPA's Power Sector Modeling Platform v.5.16 available from https://www.epa.gov/airmarkets/clean-air-markets-power-sector-modeling. The projected EGU emissions for 2023el included the Final Mercury and Air Toxics (MATS) rule announced on December 21, 2011, the Cross-State Air Pollution Rule (CSAPR) issued July 6, 2011, the CSAPR Update Rule issued October 26, 2016 and the Clean Power Plan (CPP), while the 2023en emissions include the other rules but do not include the CPP.

To project future emissions for onroad and nonroad mobile sources, the EPA used MOVES2014a and NMIM, respectively. The EPA obtained future year projected emissions for these sectors by running the MOVES and NMIM models using year-specific information about fuel mixtures, activity data, and the impacts of national and state-level rules and control programs. For this platform, the mobile source emissions for 2023 were generated by using year 2023 activity data coupled with emission factors for a MOVES run for the year 2023.

For non-EGU point and nonpoint sources, projections of 2023 emissions were developed by starting with the 2011 emissions inventories and applying adjustments that represent the impact of national, state, and local rules coming into effect in the intervening years, along with the impacts of planned shutdowns, the construction of new plants, specific information provided by states, and specific legal obligations resolving alleged environmental violations, such as consent decrees. Changes in activity are considered for sectors such as oil and gas, residential wood combustion, cement kilns, livestock, aircraft, commercial marine vessels and locomotives. Efforts were made to include some regional haze and state-reported local controls as part of a larger effort to include more local control information on stationary non-EGU sources.

The Mid-Atlantic Regional Air Management Association (MARAMA) provided projection and control data for year 2023 for most non-point and point sectors of the year 2011 inventory. The sectors affected are afdust, ag, cmv, nonpt, np_oilgas, pt_oilgas, ptnonipm, rail, rwc, and also portable fuel containers a subsector of nonpt. These MARAMA data consisted of projection and control packets used by EPA's Control Strategy Tool (CoST) and SMOKE to develop emissions for the following states: Virginia, North Carolina, New Hampshire, New York, Pennsylvania, New Jersey, West Virginia, Connecticut, Delaware, Vermont, Maine, Rhode Island, Maryland, Massachusetts, and District of Columbia. These MARAMA packets will be made available as part of the Data Files and Summaries found at https://www.epa.gov/air-emissions-modeling/2011-version-63-platform. They were developed using methods similar to those documented in the TSD Inventory Growth and Control Factors based on EPA 2011NEIv1 Emissions Modeling Platform (SRA, 2014)

The following bullets summarize the projection methods used for sources in the various sectors, while additional details and data sources are given in the following subsections and in Table 4-1.

- EGU sector (ptegu): 2023en included EGU emissions developed using an engineering analysis approach describe in Section 4.1 and did not include CPP, while 2023el used unit-specific estimates from IPM version 5.16, including CPP, CSAPR Update, CSAPR, MATS rule, Regional Haze rule, and the Cooling Water Intakes Rule.
- Non-IPM sector (ptnonipm): Closures, projection factors and percent reductions reflect comments received from the notices of data availability for the 2011, 2017, 2018, and 2023 emissions modeling platforms including closure updates from states in summer 2017, along with emission reductions due to national and local rules, control programs, plant closures, consent decrees and settlements. Projection for corn ethanol and biodiesel plants, refineries and upstream impacts take into account Annual Energy Outlook (AEO) fuel volume projections. Airport-specific terminal area forecast (TAF) data were used for aircraft to account for projected changes in landing/takeoff activity. The year represented for this sector is 2025, except that MARAMA factors for the year 2023 were used, where applicable.
- Point and nonpoint oil and gas sectors (pt_oilgas and np_oilgas): In 2023en, state projection factors were generated using historical oil and gas production data available for 2011 to 2015 from EIA and information from AEO 2017 projections to year 2023. For 2023el, regional projection factors were used (EPA, 2016b). Co-benefits of stationary engines CAP-cobenefit reductions (RICE NESHAP) and controls from New Source Performance Standards (NSPS) are reflected for select source categories. MARAMA factors for the year 2023 were used where applicable.
- Biogenic (beis): 2011 emissions are used for all future-year scenarios and are computed with the same "11g" meteorology as is used for the air quality modeling. The 2011en case included minor corrections to the BELD4.1 landuse that used as input into the BEIS3.61 modeling system.
- Fires sectors (ptfire, agfire): No growth or control – 2011 estimates are used directly.
- Agricultural sector (ag): Year 2023 projection factors for livestock estimates based on expected changes in animal population from 2005 USDA data, updated according to EPA experts in July 2012.
- Area fugitive dust sector (afdust): For livestock PM emissions, projection factors for dust categories related to livestock estimates based on expected changes in animal population. For unpaved and paved road dust, county-level VMT projections to 2023 were considered.
- Remaining Nonpoint sector (nonpt): Projection factors and percent reductions reflect comments received from the notices of data availability for the 2011, 2017, 2018, and 2023 emissions modeling platforms, along with emission reductions due to national and local rules/control programs. PFC projection factors reflecting impact of the final Mobile Source Air Toxics (MSAT2) rule. Upstream impacts from AEO fuel volume, including cellulosic ethanol plants, are reflected. The year represented for this sector is

2025, except that MARAMA factors for the year 2023 were used, where applicable. Changes in the 2023en case include the following:

  - The New York VOC change from 2011en case described in Section 2.2 was carried through to 2023en.
  - A new Boiler MACT packet for North Carolina was implemented: NCDAQ_CONTROL_2011v6_2_2023_BoilerMACT_POINT_051917.xlsx (This replaces MARAMA Boiler MACT controls in North Carolina used in 2023el)
  - The "nonpoint offsets" MARAMA inventory included in 2023el case were not used in the 2023en case as they were deemed inappropriate for national ozone transport modeling.

- Residential Wood Combustion (rwc): Year 2023 projection factors reflect assumed growth of wood burning appliances based on sales data, equipment replacement rates and change outs. These changes include the 2-stage NSPS for Residential Wood Heaters, resulting in growth in lower-emitting stoves and a reduction in higher emitting stoves.
- Locomotive, and non-Category 3 commercial marine sector (cmv and rail): Year 2023 projection factors for Category 1 and Category 2 commercial marine and locomotives reflect final locomotive-marine controls.
- Category 3 commercial marine vessel (cmv): Base-year 2011 emissions grown and controlled to 2023, incorporating controls based on Emissions Control Area (ECA) and International Marine Organization (IMO) global NOx and SO_2 controls.
- Nonroad mobile sector (nonroad): Other than for California and Texas, this sector uses data from a run of NMIM that utilized NONROAD2008a, using future-year equipment population estimates and control programs to 2023. The inputs were either state-supplied as part of the 2011NEIv2 process or using national level inputs, with only minor updates for 2011NEIv2. Final controls from the final locomotive-marine and small spark ignition rules are included. California data for 2023 were provided by the California Air Resources Board (CARB). For Texas, the Texas Commission on Environmental Quality (TCEQ) data were projected from 2011 to 2023 using trends based on NMIM data. For the 2023en case, temporal profile updates described in Section 3.3.2 for the 2011en case were carried forward for year 2023 modeling.
- Onroad mobile (onroad): MOVES2014a-based emissions factors for year 2023 were developed using the same representative counties, state-supplied data, meteorology, and procedures as were used to produce the 2011 emission factors. See section 4.3.1.1 for details about future year activity data used in generating emissions estimates.
- Onroad emissions data for California were provided by CARB.
- Other point (othpt), nonpoint/nonroad (othar, othafdust), onroad (othon): For Canada, year 2025inventories acquired from Environment Canada were used in the 2023en case for all of these sectors. In the 2023el case, the Canadian emissions were projected from the 2010 Environment Canada inventories for the othon and for the nonroad part of the othar sectors using projection factors derived from U.S. emissions changes from 2011 to 2023 by SCC and pollutant. In the othpt sector for the 2023el case, the Canadian point sources were modified by removing any remaining EGU facilities using coal. For Mexico, the othon inventory data in both cases were based on a 2023 run of MOVES-Mexico, while othar and othpt inventory data were interpolated to 2023 between 2018 and 2025. Offshore oil platform emissions were held constant at 2011 levels.

Table 4-1 summarizes the growth and control assumptions by source type that were used to create the U.S. 2023 base-case emissions from the base year inventories. The control, closures and projection packets (i.e., data sets) used to create the 2023 future year base-case scenario inventories from the 2011 base case are provided on the EMCH website and are discussed in more detail in the sections listed in Table 4-1. These packets were

processed through CoST to create future year emission inventories. CoST is described here: https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-analysis-modelstools-air-pollution and discussed in context to this emissions modeling platform in Section 4.2.1. The last column in Table 4-1 indicates the order of the CoST strategy used for the source/packet type. For some sectors (e.g., ptnonipm), multiple CoST strategies are needed to produce the future year inventory because the same source category may be subject to multiple projection or control packets. For example, the "Loco-marine" projection factors are applied in a second control strategy for the ptnonipm sector, while for the cmv and rail sectors, these same projection factors can be applied in the first (and only) control strategy. Thus, in Table 4-1, packets with a "1" in the CoST strategy column are applied in the first strategy, while packets with a "2" in the CoST strategy column are applied in a second strategy that is run on an intermediate inventory output from the first strategy.

The remainder of this section is organized by broad NEI sectors with further stratification by the types of packets (e.g., projection, control, closure packets) and whether emissions are projected via a stand-alone model (e.g., EGUs use the IPM model and onroad mobile uses MOVES), using CoST, or by other mechanisms. The EGU projections are discussed in Section 4.1. Non-EGU point and nonpoint sector projections (including all commercial marine vessels, locomotives and aircraft) are described in Section 4.2, along with some background on CoST. Onroad and nonroad mobile projections are discussed in Section 4.3. Finally, projections for all "other" sources, primarily outside the U.S., are described in Section 4.44. Section 5 contains summaries of the 2011 and 2023 emissions the emissions changes between the years for emissions both within and outside of the U.S.

Table 4-1. Growth and control methodologies used to create future year emissions inventories

Description of growth, control, closure data, or, new inventory	Sector(s)	Packet Type	CAPs impacted	Section(s)	CoST Strategy
Non-EGU Point (ptnonipm and pt_oilgas sectors) Growth and Control Assumptions					
Facility, unit and stack closures, primarily from the Emissions Inventory System (EIS)	ptnonipm, pt_oilgas	CLOSURE	All	4.2.2	1
"Loco-marine rule": Growth and control to years 2023 from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder: March, 2008	ptnonipm, cmv, rail	PROJECTION	All	4.2.3.3	2, 1
Upstream RFS2/EISA/LDGHG impacts on gas distribution, pipelines and refineries to future years	ptnonipm, pt_oilgas, nonpt	PROJECTION	All	4.2.3.4	2
AEO-based growth for industrial sources, including oil and gas regional projections	ptnonipm, pt_oilgas, nonpt, np_oilgas	PROJECTION	All	4.2.3.5	1
Aircraft growth via Itinerant (ITN) operations at airports	ptnonipm	PROJECTION	All	4.2.3.6	1
Corn Ethanol plants adjusted via AEO volume projections to 2025	ptnonipm	PROJECTION	All	4.2.3.8	1
NESHAP: Portland Cement projects. These results are from model runs associated with the NESHAP and NSPS analysis of August, 2013 and include closures and growth.	ptnonipm, nonpt	PROJECTION & new inventories for new kilns	All	4.2.3.7 & 4.2.5.4	1 & n/a
NESHAP: RICE (reciprocating internal combustion engines) with reconsideration amendments	ptnonipm, pt_oilgas, nonpt, np_oilgas	CONTROL	CO, NO_X, PM, SO_2, VOC	4.2.4.2	1
NSPS: oil and gas	pt_oilgas, np_oilgas	CONTROL	VOC	4.2.4.1	1

Description of growth, control, closure data, or, new inventory	Sector(s)	Packet Type	CAPs impacted	Section(s)	CoST Strategy
NSPS: RICE	ptnonipm, pt_oilgas, nonpt, np_oilgas	CONTROL	CO, NO_X, VOC	4.2.4.3	2
NSPS: Gas turbines	ptnonipm, pt_oilgas	CONTROL	NO_X	4.2.4.6	1
NSPS: Process heaters	ptnonipm, pt_oilgas	CONTROL	NO_X	4.2.4.7	1
Industrial/Commercial/Institutional Boiler MACT with Reconsideration Amendments + local programs	nonpt, ptnonipm, pt_oilgas	CONTROL	CO, NO_X, PM, SO_2, VOC	4.2.4.4	1
State fuel sulfur content rules for fuel oil – via 2018 NODA comments, effective only in most northeast states	nonpt, ptnonipm, pt_oilgas	CONTROL	SO_2	4.2.4.5	1
State comments: from previous platforms (including consent decrees) and NODAs	nonpt, ptnonipm, pt_oilgas	PROJECTION & CONTROL	All	4.2.3.5, 4.2.4.11	1
Commercial and Industrial Solid Waste Incineration (CISWI) revised NSPS	ptnonipm	CONTROL	SO2	4.2.4.9	1
Arizona Regional haze controls	ptnonipm	CONTROL	NO_X,SO_2	4.2.4.8	1
New biodiesel plants for year 2018	ptnonipm	new inventory	All	4.2.5.2	n/a
Nonpoint (afdust, ag, nonpt, np_oilgas and rwc sectors) Growth and Control Assumptions					
AEO-based VMT growth for paved and unpaved roads	afdust	PROJECTION	PM	4.2.3.1	1
Livestock emissions growth from year 2011 to year 2023	ag	PROJECTION	NH_3	4.2.3.2	1
Upstream RFS2/EISA/LDGHG impacts on gas distribution, pipelines and refineries to years 2018	ptnonipm, pt_oilgas, nonpt	PROJECTION	All	4.2.3.4	2
AEO-based growth: industrial sources, including oil and gas regional projections	ptnonipm, pt_oilgas, nonpt, np_oilgas	PROJECTION	All	4.2.3.5	1
NESHAP: RICE (reciprocating internal combustion engines) with reconsideration amendments	ptnonipm, pt_oilgas, nonpt, np_oilgas	CONTROL	CO, NO_X, PM, SO_2, VOC	4.2.4.2	1
NSPS: oil and gas	pt_oilgas, np_oilgas	CONTROL	VOC	4.2.4.1	1
NSPS: RICE	ptnonipm, pt_oilgas, nonpt, np_oilgas	CONTROL	CO, NO_X, VOC	4.2.4.3	2
Residential wood combustion growth and change-outs	rwc	PROJECTION	All	4.2.3.9	1
Industrial/Commercial/Institutional Boiler MACT with Reconsideration Amendments + local programs	nonpt, ptnonipm, pt_oilgas	CONTROL	CO, NO_X, PM, SO_2, VOC	4.2.4.4	1
State fuel sulfur content rules for fuel oil – via 2018 NODA comments, effective only in most northeast states	nonpt, ptnonipm, pt_oilgas	CONTROL	SO_2	4.2.4.5	1
State comments: from previous platforms (including consent decrees) and NODAs	nonpt, ptnonipm, pt_oilgas	PROJECTION & CONTROL	All	4.2.3.5, 4.2.4.11	1

Description of growth, control, closure data, or, new inventory	Sector(s)	Packet Type	CAPs impacted	Section(s)	CoST Strategy
MSAT2 and RFS2 impacts with state comments on portable fuel container growth and control from 2011 to years 2018	nonpt	new inventory	All	4.2.5.1	n/a
New cellulosic plants in year 2018	nonpt	new inventory	All	4.2.5.3	n/a
Onroad Mobile (onroad sector) Growth and Control Assumptions All national in-force regulations are modeled. The list includes recent key mobile source regulations but is not exhaustive.					
National Onroad Rules:					
All onroad control programs finalized as of the date of the model run, including most recently:	onroad	n/a	All	4.3	n/a
Tier-3 Vehicle Emissions and Fuel Standards Program: March, 2014					
2017 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions and Corporate Average Fuel Economy Standards: October, 2012					
Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles: September, 2011					
Regulation of Fuels and Fuel Additives: Modifications to Renewable Fuel Standard Program (RFS2): December, 2010					
Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards; Final Rule for Model-Year 2012-2016: May, 2010					
Final Mobile Source Air Toxics Rule (MSAT2): February, 2007					
Local Onroad Programs:					
California LEVIII Program	onroad	n/a	All	4.3	n/a
Ozone Transport Commission (OTC) LEV Program: January,1995					
Inspection and Maintenance programs					
Fuel programs (also affect gasoline nonroad equipment)					
Stage II refueling control programs					
Nonroad Mobile (cmv, rail, nonroad sectors) Growth and Control Assumptions All national in-force regulations are modeled. The list includes recent key mobile source regulations but is not exhaustive.					
National Nonroad Programs:					
All nonroad control programs finalized as of the date of the model run, including most recently:	nonroad	n/a	All	4.3.2	n/a
Emissions Standards for New Nonroad Spark-Ignition Engines, Equipment, and Vessels: October, 2008					
Growth and control from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder: March, 2008					
Clean Air Nonroad Diesel Final Rule – Tier 4: May, 2004					
Locomotives:					
Growth and control from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder: March, 2008	cmv, rail ptnonipm	PROJECTION	All	4.2.3.3	1, 2
Clean Air Nonroad Diesel Final Rule – Tier 4: May, 2004	cmv, rail	n/a	All	4.3.2	n/a
Commercial Marine:					
Category 3 marine diesel engines Clean Air Act and International Maritime Organization standards: April, 2010	cmv	PROJECTION	All	4.2.3.3	1

Description of growth, control, closure data, or, new inventory	Sector(s)	Packet Type	CAPs impacted	Section(s)	CoST Strategy
Growth and control from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder: March, 2008	cmv, rail, ptnonipm	PROJECTION	All	4.2.3.3	1, 2
Clean Air Nonroad Diesel Final Rule – Tier 4: May, 2004	nonroad	n/a	All	4.3.2	n/a

4.1 EGU sector projections (ptegu)

4.1.1 Engineering Analysis Estimates for 2023 Flat File

A flat file in a format that can be input to SMOKE was prepared for the 2023en case. The underlying data and calculations used in the development of this flat file, which are described below can be found in the workbook titled *Engineering_Analysis_2023_Unit_File.xlsx* available in the "Data Files and Summaries" on the 2011v6.3 platform web page https://www.epa.gov/air-emissions-modeling/2011-version-63-platform, more specifically it can be found in the FTP area ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/reports/2011en_and_2023en/. The following spreadsheets detail some of the computations described in this section are also available via FTP: *2023en_New_Unit_Capacity_Factor_Calcs.xlsx*, *2023en_Non_NOx_non_SO2_pollutants_for_eng_analysis.xlsx*, and *2023en_Generation_Surplus_Deficit_Calcs.xlsx*. The spreadsheet 2023en_egu_summer_emissions_comparison_30sep2017.xlsx provides a comparison of the 2023 summer EGU emissions with emissions in 2011 and 2016.

4.1.1.1 SO2 and NOx emissions for units reporting under Part 75 for EPA Acid Rain Program (ARP) and Cross State Air Pollution Rule (CSAPR)

EPA starts with 2016 reported, seasonal, historical emissions for each unit. This reflects the latest owner/operator reported data available at the time of EPA analysis. The emissions data for NO_x and SO_2 for units that report data to CAMD under either the Acid Rain Program (ARP) and/or the Cross-State Air Pollution Rule (CSAPR) are aggregated to the summer/ozone season period (May-September) and winter/non-ozone period (January-April and October-December).[27] Unit-level details such as plant name, unit ID, unit type, etc. are shown in columns A through F. Reported historical data for these units such as historical emissions, heat input, generation, etc. are shown in columns G through J. The 2016 historical emissions value is in column J. The projected 2023 emissions estimate is shown in column K, and reflects either the same emissions level as reported for 2016, or a modification of that value based on adjustments to the operational or pollution control status of that unit.[28] Because the 2016 data preceded implementation of certain NO_X reduction programs (e.g., CSAPR Update, Pennsylvania RACT, and Connecticut RACT), EPA made assumptions about how EGUs would adjust their operations and emissions in order to comply with such programs in 2023. With respect to the CSAPR Update, the agency made assumptions about EGU operations in steps four and five, below. CSAPR Update compliance is demonstrated through an ozone season NO_X allowance trading program, which provides flexibility for EGU owner/operators to determine their own compliance path. As such, the assumptions that EPA applies for the purpose of developing the 2023 EGU emission projection represent one reasonable compliance path, but not the only compliance path, for EGUs in CSAPR Update states. The modifications to operational or pollution control status are made due to:

1. *Retirements* - Emissions from units with upcoming confirmed retirement dates prior to 2023 are

[27] The EPA notes that historical state-level ozone season EGU NO_x emission rates are publically available and quality assured data. They are monitored using continuous emissions monitors (CEMs) data and are reported to the EPA directly by power sector sources. They are reported under Part 75 of the CAA.

[28] Based on data and changes known as of 8/11/2017.

adjusted to zero. Retirement dates are identified through a combination of sources including EIA 860, utility-announced retirements, and stakeholder feedback provided to EPA. The impact of retiring on emissions is shown in column K. These 269 retiring units are flagged in column L and noted as "Retiring" in column M.

	2016	2023
Unit X	10,000 mmBtu x .2 lb/mmBtu = 1 ton	**0 mmBtu** x .2 lb/mmBtu = **0 ton**

2. *Coal to Gas Conversion* – Emissions from units with scheduled conversion to natural gas fuel use by 2023 are adjusted to reflect reduced emission rates associated with natural gas. To reflect a given unit's conversion to gas, that unit's 2023 emission rates for NO_x are assumed to be half of its 2016 coal-fired emission rates, and the unit's SO_2 emissions rates are adjusted to zero while utilization levels are assumed to remain the same.[29] Therefore, the 2023 projected emissions for these converting units are estimated to be half of 2016 levels for NO_x, and zero for SO_2. Units expected to convert to gas are flagged using EIA 860 and stakeholder feedback. The impact of coal to gas conversion for 2023 is shown in column K, flagged in column L, and noted as "coal to gas conversion" in column M. The example below pertains to NO_x emission estimates.

	2016	2023
Unit X	10,000 mmBtu x .2 lb/mmBtu = 1 ton	10,000 mmBtu x **.1 lb/mmBtu** = **.5 ton**

3. *Retrofits* – Emissions from units with scheduled SCR, SNCR and/or FGD retrofits prior to 2023 are adjusted to reflect the emission rates expected with new SCR installation (.075 lb/mmBtu of NO_x), new SNCR (a 25% decrease in emission rate), and/or new FGD (0.06 lb/mmBtu of SO_2) and are assumed to operate at the same 2016 utilization levels.[30] These emission rates were multiplied by the affected unit's 2016 heat input to estimate the 2023 emission level. The impact of post-combustion control retrofits on 2023 emissions assumptions is shown in column K, flagged in column L, and noted as "New SCR", "New SNCR" or "New FGD" in column M.
For SCR:

	2016	2023
Unit X	10,000 mmBtu x .2 lb/mmBtu = 1 ton	10,000 mmBtu x **.075 lb/mmBtu = .38 ton**

For SNCR

	2016	2023
Unit X	10,000 mmBtu x .2 lbs/mmBtu = 1 ton	10,000 mmBtu * **.15 lbs/mmBtu = .75 ton**

4. *State-of-the- art combustion controls* – Emissions from units in the CSAPR update region that were operating in 2016 without state-of-the-art combustion controls were adjusted downwards to reflect assumed installation of these controls and their expected emission rate impact. EPA assumed a 2023 emission rate of 0.1549 lbs/mmBtu for units with dry bottom wall-fired boilers expected to install/upgrade combustion controls, and 0.139 lbs/mmBtu for tangentially-fired coal units expected to install upgrade combustion controls. These emission rates were multiplied by each unit's 2016 heat input to estimate its 2023 emission level. Details of EPA's assessment of state-of-the-art NO_x combustion controls and corresponding emission rates are provided in the EGU NO_x Mitigation Strategies Final Rule TSD.[31] The impact on state-of-the-art combustion controls on 2023 emission assumptions is shown in column K, flagged in column L, and noted as

[29] See NO_x Mitigation Strategy TSD available at https://www.epa.gov/sites/production/files/2017-05/documents/egu_nox_mitigation_strategies_final_rule_tsd.pdf
[30] *Ibid.*
[31] *Ibid.*

"Install state-of-the-art combustion controls" in column M. EPA identified 47 such units that it flagged as likely to receive such control upgrades.

	2016	2023
Unit X	10,000 mmBtu x .2 lb/mmBtu = 1 ton	10,000 mmBtu x **.139 lb/mmBtu = .7 ton**

5. *SCR optimization* – Emissions from units with existing SCRs in the CSAPR update region, but that operated at an emission rate greater than 0.10 lb/mmBtu in 2016, were adjusted downwards to reflect emissions when the SCR is operated to achieve a 0.10 lb/mmBtu emission rate. This emission rate was identified as achievable and regionally cost-effective under the CSAPR Update, and represents one reasonable compliance path for the purposes of this EGU projection.[32] The optimized emission rate is multiplied by 2016 heat input levels to arrive at the 2023 emissions estimate. For the 80 units affected by this adjustment, the impact on 2023 emission assumptions is shown in column K, flagged in column L, and noted as "Optimize SCR to 0.10 lb/mmBtu" in column M. Note, this assumption only applies to ozone-season NOx as that is the season in which the CSAPR Update compliance is required.

	2016	2023
Unit X	10,000 mmBtu x .2 lb/mmBtu = 1 ton	10,000 mmBtu x **.1 lb/mmBtu = .5 ton**

6. *New Units* – Emissions were adjusted up from 2016 levels of zero to reflect firm units that are under development (e.g., under construction units) greater than 25 MW that are expected to be in commercial operation by 2023. These assumed emission values for 156 new units are reflected in columns K, flagged in column L, and noted as "new unit > 25 MW" in column M". To obtain these emissions, EPA identified all new fossil-fired EGUs coming online after 2016 according to EIA Form 860 and stakeholder comments. EPA then identified the heat rate and capacity values for these units using EIA 860 and stakeholder-provided data. Next, EPA identified the 2016 average seasonal capacity factor for similar units that came online between 2011 and 2015. EPA used these seasonal capacity factors (e.g., 65% for NGCC in the summertime and 53.4% in the wintertime), the unit's capacity, the unit's heat rate, and the unit's estimated NO_x rate to estimate 2023 emissions (capacity factor × capacity × number of hours × heat rate × NO_x emission rate = NO_x emissions). The underlying data and calculations for these new unit emission estimates are available on EPA's website at the link provided in Section 1.

	2016	2023
Unit X	0 mmBtu x 0 lb/mmBtu = 0 ton	**100 MW x .65 x 8760 hours x 8000 Btu/KWh * 01 lb/mmBtu = 22 tons**

7. *Other* – EPA also made several unit-specific adjustments to 2016 emission levels to reflect forthcoming emission or emission rate requirements specified in consent decrees, BART requirements, and/or other revised permit limits. The impacts for 2023 emission assumptions are shown in column K, flagged in column L, and noted as such in column M (e.g., values of "CT RACT" mean that they were adjusted to reflect the impacts of the Connecticut Reasonably Available Control Technology (RACT) implementation).[33] EPA assumes that the the Pennsylvania RACT rule would result in units with existing SCRs operating at 0.12lb/mmBtu year-round. However, these same units are also adjusted to operate at 0.10lb/mmBtu during the ozone season in response to the CSAPR Update. Therefore, the Pennsylvania RACT does not

[32] 81 FR 74543

[33] EPA's adjustments to Connecticut EGU emissions for the purpose of representing compliance with Connecticut's RACT rule for 2023 reflect one potential compliance path, but not the only path, available under this state rule.

impact EPA's ozone-season emission assumptions for EGUs, but it does impact emission assumptions outside of the ozone season.

4.1.1.2 SO_2 and NO_x emissions for units not reporting under Part 75 for EPA ARP and CSAPR

All non-CAMD unit EGU SO_2 and NO_X emissions are taken directly from the 2011 NEI with the exception of 10 units known to be retired before 2023. These 10 units have emissions adjusted to zero. These units are Ben French (ORIS 3325 Unit 1), Chalk Cliff Cogen (ORIS 50003 Unit GEN1), Killen Station (ORIS 6031 GT1), James De Young (ORIS 1830 Unit 4), Prairie Creek (ORIS 1073 Units 1 and 2), Kennecott Power Plant (ORIS 56163 Unit 1, 2, 3), and Hutchinson Energy Center (ORIS 1248 Unit GT4).

4.1.1.3 Other pollutants

While NO_x and SO_2 are the primary pollutants of interest for the 2023 flat file when evaluating the 2008 ozone NAAQS, there are also air quality modeling inputs for other criteria pollutants including CO, NH3, PM_{10} filterable, PM_{10} primary, $PM_{2.5}$ filterable, $PM_{2.5}$ primary, PM Condensable, and VOC. For the units that do not report under CAMD programs, EPA used the 2011 NEI emission values (with the limited exceptions noted in section 2 for retirements). For units that do report data under an EPA emission program, EPA used 2011 NEI values, but made t adjustments to reflect most recent year (2016) utilization. For example, if heat input increased by 10% from 2011 to 2016 for the unit, then emissions were adjusted upwards by 10%. EPA also used source classification code (SCC)-based emission factors to adjust emissions for units that switched primary fuel between 2011 and 2016. Finally, EPA made limited modifications to emissions to reflect changes in control status. EPA flagged units that received a FGD between 2011 and 2023, for which EPA then adjusted emissions for PM_{10} and $PM_{2.5}$ based on emission rates for similarly controlled units.

4.1.1.4 Comparing future utilization and generation levels to regional load requirements

EPA analyzed and confirmed that assumed fleet operations in its emissions estimates were compatible with future load requirements by verifying that new units would provide enough generation, assuming technology-specific capacity factors, to replace the retiring generation expected to occur by 2023. EPA assessed generation adequacy at both the national level, Interconnect, and at the level of eight National Electric Reliability Council (NERC) regions.

- EPA identified the 2017 Energy Information Administration's Annual Energy Outlook (EIA AEO) growth projections from 2016 to 2023 electricity demand levels (195 TWh) from its No CPP reference case.
- Next, EPA identified the amount of retiring generation assumed in its engineering analysis (103 TWh).[34]
- EPA added these two values together (195 TWh + 103 TWh = 298 TWh) to identify the total amount of electricity generation that would need to be provided by new units assuming non-retiring units continued to collectively generate at 2016 levels.
- EPA then identified planned new capacity as that listed in EIA form 860 as "under construction", "testing", or "site prep". EPA also included other stakeholder-reported new capacity.

[34] This is *gross* generation, not *net*, and therefore slightly over-estimates the generation deficit created by retiring units. This is a conservative assumption for the analysis of determining if sufficient generation will exist to meet load.

- Using technology-specific capacity factors[35] based on past performance and IPM documentation, EPA anticipated 249 TWh from new generation already under construction. This left a remaining load of (298-249 = 49 TWh).

Primary Fuel	New Capacity (site prep, under construction, or testing phase) (MW)	Assumed Annual Capacity Factor	Annual Generation TWh
Gas (including CCs and CTs)	28,358	70%	173.9
Nuclear	4,434	90%	35.0
Other	231	10%	0.1
Petroleum	40	10%	0.04
Solar	2,840	21.6%	5.4
Wind	9,142	42.7%	34.2
Water	270	10%	0.2
Total	**45,315**		**248.9**

- EPA then identified additional expected new generation by looking at 1) "pending" and "permitted" generation from EIA 860, stakeholder comments, and data collection services which equaled 472 TWh if all constructed, and 2) applying the minimum expected continued build rate for new solar and wind forward from 2019 through 2022 (resulting in 169 TWh of additional generation).[3637] The expected continued build rate for solar and wind was equal to the solar and wind capacities for projects that had been identified as Application Pending, Permitted, Site Preparation, Under Construction, or Testing expected to come online in 2017. These build rates are 5,851 MW of solar and 11,074 MW of wind.[38]
- EPA combined the new generation that has been either "pending" or "permitted" along with the business as usual renewable capacity growth trends to identify up to 641 TWh of additional new generation.
- The potential new generation (641 TWh) is significantly greater than the 49 TWh generation gap identified in the bullet above, suggesting that available generation would easily exceed load requirements.
- EPA repeated this analysis at the three main interconnects and at the regional levels and found similar affirmation that potential generation levels consistent with these 2023 projections would significantly exceed demand levels.
- Finally, each state's projected 2023 emissions are compared to final CSAPR Update Rule state assurance levels to verify they do not exceed those levels.

4.1.1.5 NERC Region Generation Evaluation

EPA repeated the same analysis described in the previous section for each of the NERC Regions. First, the change in demand and generation lost from retiring units was calculated for each region as shown in Table 4-2,

[35] Assumed annual capacity factors are estimates of achievable and demonstrated capacity factors and are slightly different than the capacity factors used in the analysis to determine emissions from new EGUs. The results of this analysis do not change if these capacity factors slightly different.

[36] Because of relatively short build times for solar and wind facilities, it is unlikely that units coming on line post 2019 would be listed as "under construction" in current data sets.

[37] The total amount of new RE generation assumed in the exercise is conservative relative to AEO 2017 No CPP reference Case projections regarding RE generation growth by 2023. AEO projected an additional 349 TWh, while EPA assumes just 315 TWh.

[38] For example, in 2019, there are 1,762 MW of known solar projects in the pipeline. This calculation would add an additional 4,089 MW to equal the 2017 new build rate of 5,851 MW.

then, EPA calculated the "firm" new capacity being built in each region as shown in Table 4-3. The EPA also calculated the new capacity that was classified as permitted or application pending as shown in Table 4-4 and the expected generation from the "firm" new capacity as shown in Table 4-11.

Table 4-2. Change in demand and generation lost from retiring units for each region

NERC Region	Demand 2016 (TWh)	Demand 2023 (TWh)	Demand Change 2016 to 2023 (TWh)	Demand Change (percent)	mmBtu Retiring Units	Gen from retiring units (est. *gross*) (TWh)
ERCOT	351	380	29	8%	51,847,646	6
FRCC	208	208	0	0%	95,084,124	9
MRO	217	242	25	12%	27,582,891	2
NPCC	249	237	-12	-5%	32,217,183	3
RFC	931	928	-4	0%	280,926,895	29
SERC	1,015	1,076	61	6%	262,357,655	26
SPP	214	266	51	24%	50,532,303	5
WECC	710	755	45	6%	257,222,349	24
Total	**3,896**	**4,091**	**195**	**5%**	**1,057,771,045**	**103**

Table 4-3. "Firm" new capacity being built in each region: Site Prep, Under Construction, Testing (MW)

NERC Region	Gas (CCs and CTs)	Nuclear	Other	Petroleum	Solar	Wind	Water
ERCOT	3,866		28.6		207	2,386	
FRCC	1,640		15		80		
MRO	700		0		11	280	55
NPCC	2338		24.2	24.65	160	88	1.55
RFC	13,777		83.1	1	260	1,559	6
SERC	5,153	4,434	5	14.4	1,042		127.36
SPP			0			3,164	
WECC	884		75.432		1,080	1,665	80.3
Total	**28,358**	**4,434**	**231**	**40**	**2,840**	**9,142**	**270**

Table 4-4. New capacity classified as permitted or application pending

	Permitted, Application Pending (MW)						
NERC Region	Gas (including CCs and CTs)	Nuclear	Other	Petroleum	Solar	Wind	Water
ERCOT	240	19,804	2,716	317	1,004	4,114	
FRCC		2,140		0			
MRO	200	345		3	4	3,111	
NPCC		4,861		42	16	1,007	283
RFC	775	10,721		60	141	2,972	386
SERC		4,516	4,060	13	1,825	861	141

SPP	895	687		270	239	2,347	77
WECC		5,359		525	8,462	8,156	3,875
Total	**2,110**	**48,434**	**6,776**	**1,230**	**11,690**	**22,569**	**4,763**

Table 4-5. Expected generation from the "firm" new capacity

	Generation (TWh) from "Firm Units" (Site Prep, Under Construction, Testing)						
NERC Region	**Gas (including CCs and CTs)**	**Nuclear**	**Other**	**Petroleum**	**Solar**	**Wind**	**Water**
ERCOT	24	0	0	0	0	9	0
FRCC	10	0	0	0	0	0	0
MRO	4	0	0	0	0	1	0
NPCC	14	0	0	0	0	0	0
RFC	84	0	0	0	0	6	0
SERC	32	35	0	0	2	0	0
SPP	0	0	0	0	0	12	0
WECC	5	0	0	0	2	6	0
Total	**174**	**35**	**0**	**0**	**5**	**34**	**0**

The EPA also calculated the expected generation from the "permitted" and "application pending" generation as shown in Table 4-12. The EPA then combined this information to determine the surplus or deficit of generation in each NERC region. This was calculated twice, once considering only "firm" new generation, and again including generation that has a status of permitted or application pending as shown in Table 4-7. For the latter calculation, the EPA found that only two regions, MRO and SPP, had deficits of generation. The EPA also calculated the surplus or deficit for each region as a percentage of total 2023 demand as shown in Table 4-14.

Table 4-6. Expected generation from "permitted" and "application pending" units

	Generation (TWh) from Unit Permitted, Application Pending						
NERC Region	**Gas (including CCs and CTs)**	**Nuclear**	**Other**	**Petroleum**	**Solar**	**Wind**	**Water**
ERCOT	1	121	21	0	2	15	0
FRCC	0	13	0	0	0	0	0
MRO	1	2	0	0	0	12	0
NPCC	0	30	0	0	0	4	0
RFC	4	66	0	0	0	11	0
SERC	0	28	32	0	3	3	0
SPP	4	4	0	0	0	9	0
WECC	0	33	0	0	16	31	3
Total	**10**	**297**	**53**	**1**	**22**	**84**	**4**

Table 4-7. Review of surplus or deficit generation for each region (TWh)

NERC Region	2023 Demand	Demand Change from 2016	Gen from retiring units (est. *gross*)	New Gen.from "Firm Units" (Site Prep, under Construction, and Testing)	New Gen. from Permitted and Application Pending Units	Total New Generation	Increased Demand + Retiring Gen - New Firm Generation (Surplus or Deficit)	Increased Demand + Retiring Gen - New Total Generation (Surplus or Deficit)
ERCOT	380	29	6	33	162	195	2	-160
FRCC	208	0	9	10	13	23	-2	-15
MRO	242	25	2	5	15	20	21	7
NPCC	237	-12	3	15	34	49	-24	-58
RFC	928	-4	29	91	81	172	-66	-147
SERC	1,076	61	26	69	67	135	17	-49
SPP	266	51	5	12	18	30	44	26
WECC	755	45	24	14	83	97	56	-28
Total	**4,091**	**195**	**103**	**249**	**472**	**721**	**49**	**-424**

(for the last two columns, positive numbers are deficits, negative numbers are surpluses)

Table 4-8. Surplus or deficit generation as a fraction of total demand

NERC Region	Surplus/Deficit as a fraction of total demand (firm new units only)	Surplus/Deficit as a fraction of total demand (all new units)
ERCOT	0%	-42%
FRCC	-1%	-7%
MRO	9%	3%
NPCC	-10%	-24%
RFC	-7%	-16%
SERC	2%	-5%
SPP	17%	10%
WECC	7%	-4%
Total	**1%**	**-10%**

(positive numbers are deficits; negative numbers are surpluses)

Overall, EPA found that firm new units were close to being able to fill the gap created by increased demand and units expected to retire by 2023. Considering units that are either permitted or application pending, there is a significant surplus of generation. There was however some regional variation, with MRO and SPP having generation deficits when just considering all units permitted or with applications pending.

However, as described in the previous section, there are several additional sources of generation not captured in these projects, including additional solar and wind projects. Because of shorter construction times, not all RE generation expected to be online by 2023 is in the "under construction, testing, permitting, pending, site prep" phase. But assuming that new RE capacity build continues forward at levels greater than or equal to recent years, this additional generation would fill the deficits in these regions. For example, there were 2,505 MW of wind projects in the development pipeline (Application Pending, Permitted, Site Preparation, Under Construction, or Testing) expected to come online in SPP in 2017. If that rate of development continued in 2018

through 2022, an additional 9,519 MW of wind capacity that is not captured in this analysis would we added, resulting in an additional estimated 35.6 TWh of electricity. That generation would be sufficient to cover the 26 TWh deficit calculated for SPP. A similar dynamic in MRO would lead to an additional 3,007 MW and 11.2 TWh of generation from wind.[39]

In addition to increases in capacity, it is also possible that electricity could be transmitted from regions with surpluses to regions with deficits. The Eastern, Western, and Texas Interconnections all have generation surpluses in the tables above.

4.1.2 Connecticut Municipal Waste Combustor Reductions

The Connecticut Department of Energy and Environmental Protection provided comments on the 2011v6.3 platform NODA regarding reductions for municipal waste combustors in the state of Connecticut as a result of a MWC regulation in support of the Connecticut RACT certification (82 FR 35454, July 31, 2017; http://www.ct.gov/deep/cwp/view.asp?a=2684&q=546804). These requirements are effective as of August 2, 2017 and the resulting impacts due to a projected reduction in usage have been incorporated as shown in Table 4-9. These reductions, which are applied to all pollutants, were calculated from information found in the Revision to Connecticut's SIP (http://ct.gov/deep/lib/deep/air/ozone/ozoneplanningefforts/SouthwestConnecticutAttainmentSIPDRAFTFINAL.pdf), and include the closure of the Covanta Projects of Wallingford units. In addition, Connecticut tightened NOx emissions limits for most types of combustion equipment using a two-phased approach, with requirements for Phase 1 beginning in June, 2018 and phase 2 limits in June, 2023. The state provided some information on the Phase 1 impacts which are included in this modeling, but Phase 2 impacts were not quantified.

Table 4-9. Connecticut MWC Emission Reductions for 2023

Facility name	EIS Facility ID	EIS Unit ID	Emission Reduction (%)
Covanta Bristol, INC	588711	46157913	6.11
Covanta Bristol, INC	588711	46158013	6.11
Covanta Projects of Wallingford	589911	46137513	100
Covanta Projects of Wallingford	589911	46137613	100
Covanta Projects of Wallingford	589911	46137713	100
C R R A / Mid-Connecticut	715611	46362613	6.11
C R R A / Mid-Connecticut	715611	46362713	6.11
C R R A / Mid-Connecticut	715611	46362913	6.11
Wheelabrator Bridgeport LP	754411	46285513	36.38
Wheelabrator Bridgeport LP	754411	46285613	36.38
Wheelabrator Bridgeport LP	754411	46285713	36.38
Covanta Southeastern CT CO	754611	46284313	6.11
Covanta Southeastern CT CO	754611	46284413	6.11
Wheelabrator Lisbon INC (WM)	8501611	961813	6.11
Wheelabrator Lisbon INC (WM)	8501611	962013	6.11

[39] This may be a conservative estimate as it's based on MRO's 2017 wind build rate of 853 MW. However, in 2019, the build rate of projects in the pipeline is expected to be 2,132 MW.

4.2 Non-EGU Point and NEI Nonpoint Sector Projections

To project all U.S. non-EGU stationary sources, facility/unit closures information and growth (PROJECTION) factors and/or controls were applied to certain categories within the afdust, ag, cmv, rail, nonpt, np_oilgas, ptnonipm, pt_oilgas and rwc platform sectors. Some facility or sub-facility-level closure information was also applied to the point sources. There are also a handful of situations where new inventories were generated for sources that did not exist in the 2011 NEI (e.g., biodiesel and cellulosic plants, yet-to-be constructed cement kilns). This subsection provides details on the data and projection methods used for these sectors.

In recent platforms, the EPA has assumed that emissions growth for most industrial sources did not track with economic growth for most stationary non-IPM sources (EPA, 2006b). This "no-growth" assumption was based on an examination of historical emissions and economic data. Recently however, the EPA has received growth (and control) data from numerous states and regional planning organizations for many industrial sources, including the rapidly-changing oil and gas sector. The EPA provided a Notice of Data Availability for the 2011v6.0 emissions modeling platform and projected 2018 inventory in January, 2014 (Docket Id. No. EPA-HQ-OAR-2013-0809). The EPA requested comment on the future year growth and control assumptions used to develop the 2018 inventories. One of the most frequent comments the EPA received was to use the growth factors information that numerous states either provided or deferred to growth factors provided by broader region-level efforts. In an attempt to make the projections approach as consistent as possible across all states, the EPA decided to expand this effort to all states for some of the most-significant industrial sources (see Section 4.2.3).

Because much of the projections and controls data are developed independently from how the EPA defines its emissions modeling sectors, this section is organized primarily by the type of projections data, with secondary consideration given to the emissions modeling sector (e.g., industrial source growth factors are applicable to four emissions modeling sectors). The rest of this section is organized in the order that the EPA uses CoST in combination with other methods to produce future year inventories: 1) for point sources, apply plant (facility or sub-facility-level) closure information via CoST; 2) apply all PROJECTION packets via CoST (multiplicative factors that could cause increases or decreases); 3) apply all percent reduction-based CONTROL packets via CoST; and 4) append all other future-year inventories not generated via CoST. This organization allows consolidation of the discussion of the emissions categories that are contained in multiple sectors, because the data and approaches used across the sectors are consistent and do not need to be repeated. Sector names associated with the CoST packets are provided in parentheses.

4.2.1 Background on the Control Strategy Tool (CoST)

CoST is used to apply most non-EGU projection/growth factors, controls and facility/unit/stack-level closures to the 2011 NEI-based emissions modeling inventories to create future year inventories for the following sectors: afdust, ag, cmv, rail, nonpt, np_oilgas, ptnonipm, pt_oilgas and rwc. Information about CoST and related data sets is available from https://www.epa.gov/economic-and-cost-analysis-air-pollution-regulations/cost-analysis-modelstools-air-pollution.

CoST allows the user to apply projection (growth) factors, controls and closures at various geographic and inventory key field resolutions. Each of these CoST datasets, also called "packets" or "programs," provides the user with the ability to perform numerous quality assurance assessments as well as create SMOKE-ready future year inventories. Future year inventories are created for each emissions modeling sector via a CoST "strategy" and each strategy includes all base year 2011 inventories and applicable CoST packets. For reasons discussed later, some emissions modeling sectors require multiple CoST strategies to account for the compounding of

control programs that impact the same type of sources. There are also available linkages to existing and user-defined control measures databases and it is up to the user to determine how control strategies are developed and applied. The EPA typically creates individual CoST packets that represent specific intended purposes (e.g., aircraft projections for airports are in a separate PROJECTION packet from residential wood combustion sales/appliance turnover-based projections). CoST uses three packet types as described below:

1. CLOSURE: Applied first in CoST. This packet can be used to zero-out (close) point source emissions at resolutions as broad as a facility to as specific as a stack. The EPA uses these types of packets for known post-2011 controls as well as information on closures provided by states on specific facilities, units or stacks. This packet type is only used in the ptnonipm and pt_oilgas sectors.
2. PROJECTION: This packet allows the user to increase or decrease emissions for virtually any geographic and/or inventory source level. Projection factors are applied as multiplicative factors to the 2011 emissions inventories prior to the application of any possible subsequent CONTROLs. A PROJECTION packet is necessary whenever emissions increase from 2011 and is also desirable when information is based more on activity assumptions rather than known control measures. The EPA uses PROJECTION packet(s) in every non-EGU modeling sector.
3. CONTROL: These packets are applied after any/all CLOSURE and PROJECTION packet entries. The user has similar level of control as PROJECTION packets regarding specificity of geographic and/or inventory source level application. Control factors are expressed as a percent reduction (0 to 100) and can be applied in addition to any pre-existing inventory control, or as a replacement control where inventory controls are first backed out prior to the application of a more-stringent replacement control.

All of these packets are stored as data sets within the Emissions Modeling Framework and use comma-delimited formats. As mentioned above, CoST first applies any/all CLOSURE information for point sources, then applies PROJECTION packet information, followed by CONTROL packets. A hierarchy is used by CoST to separately apply PROJECTION and CONTROL packets. In short, in a separate process for PROJECTION and CONTROL packets, more specific information is applied in lieu of less-specific information in ANY other packets. For example, a facility-level PROJECTION factor will be replaced by a unit-level, or facility and pollutant-level PROJECTION factor. It is important to note that this hierarchy does not apply between packet types (e.g., CONTROL packet entries are applied irrespective of PROJECTION packet hierarchies). A more specific example: a state/SCC-level PROJECTION factor will be applied before a stack/pollutant-level CONTROL factor that impacts the same inventory record. However, an inventory source that is subject to a CLOSURE packet record is removed from consideration of subsequent PROJECTION and CONTROL packets.

The implication for this hierarchy and intra-packet independence is important to understand and quality assure when creating future year strategies. For example, with consent decrees, settlements and state comments, the goal is typically to achieve a targeted reduction (from the 2011NEI) or a targeted future-year emissions value. Therefore, as encountered with this future year base case, consent decrees and state comments for specific cement kilns (expressed as CONTROL packet entries) needed to be applied instead of (not in addition to) the more general approach of the PROJECTION packet entries for cement manufacturing. By processing CoST control strategies with PROJECTION and CONTROL packets separated by the type of broad measure/program, it is possible to show actual changes from the base year inventory to the future year inventory as a result of applying each packet.

Ultimately, CoST concatenates all PROJECTION packets into one PROJECTION dataset and uses a hierarchal matching approach to assign PROJECTION factors to the inventory. For example, a packet entry with Ranking=1 will supersede all other potential inventory matches from other packets. CoST then computes the projected emissions from all PROJECTION packet matches and then performs a similar routine for all

CONTROL packets. Therefore, when summarizing "emissions reduced" from CONTROL packets, it is important to note that these reductions are not relative to the 2011 inventory, but rather to the intermediate inventory ***after*** application of any/all PROJECTION packet matches (and CLOSURES). A subset of the more than 70 hierarchy options is shown in Table 4-10, although the fields in Table 4-10 are not necessarily named the same in CoST, but rather are similar to those in the SMOKE FF10 inventories. For example, "REGION_CD" is the county-state-county FIPS code (e.g., Harris county Texas is 48201) and "STATE" would be the 2-digit state FIPS code with three trailing zeroes (e.g., Texas is 48000). Table 4-4 includes corrections to matching hierarchy made in 2011v6.3 platform modeling. These corrections did cause emissions changes from the 2011v6.2 platform to 2011v6.3 platform for the np_oilgas, pt_oilgas, ptnonipm and nonpt sectors.

Table 4-10. Subset of CoST Packet Matching Hierarchy

Rank	Matching Hierarchy	Inventory Type
1	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, SCC, POLL	point
2	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, POLL	point
3	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, POLL	point
4	REGION_CD, FACILITY_ID, UNIT_ID, POLL	point
5	REGION_CD, FACILITY_ID, SCC, POLL	point
6	REGION_CD, FACILITY_ID, POLL	point
7	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, SCC	point
8	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID	point
9	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID	point
10	REGION_CD, FACILITY_ID, UNIT_ID	point
11	REGION_CD, FACILITY_ID, SCC	point
12	REGION_CD, FACILITY_ID	point
13	REGION_CD, NAICS, SCC, POLL	point, nonpoint
14	REGION_CD, NAICS, POLL	point, nonpoint
15	STATE, NAICS, SCC, POLL	point, nonpoint
16	STATE, NAICS, POLL	point, nonpoint
17	NAICS, SCC, POLL	point, nonpoint
18	NAICS, POLL	point, nonpoint
19	REGION_CD, NAICS, SCC	point, nonpoint
20	REGION_CD, NAICS	point, nonpoint
21	STATE, NAICS, SCC	point, nonpoint
22	STATE, NAICS	point, nonpoint
23	NAICS, SCC	point, nonpoint
24	NAICS	point, nonpoint
25	REGION_CD, SCC, POLL	point, nonpoint
26	STATE, SCC, POLL	point, nonpoint
27	SCC, POLL	point, nonpoint
28	REGION_CD, SCC	point, nonpoint
29	STATE, SCC	point, nonpoint
30	SCC	point, nonpoint
31	REGION_CD, POLL	point, nonpoint
32	REGION_CD	point, nonpoint
33	STATE, POLL	point, nonpoint
34	STATE	point, nonpoint
35	POLL	point, nonpoint

The contents of the controls, local adjustments and closures for the future year base case are described in the following subsections. Year-specific projection factors (PROJECTION packets) for the future year were used to create the future year base case, unless noted otherwise in the specific subsections. The contents of a few of

these projection packets (and control reductions) are provided in the following subsections where feasible. However, most sectors used growth or control factors that varied geographically and their contents could not be provided in the following sections (e.g., facilities and units subject to the Boiler MACT reconsideration has thousands of records). The remainder of Section 4.2 is divided into several subsections that are summarized in Table 4-5. Note that future year inventories were used rather than projection or control packets for some sources.

Table 4-11. Summary of non-EGU stationary projections subsections

Subsection	Title	Sector(s)	Brief Description
4.2.2	CoST Plant CLOSURE packet	ptnonipm, pt_oilgas	All facility/unit/stack closures information, primarily from Emissions Inventory System (EIS), but also includes information from states and other organizations.
4.2.3	CoST PROJECTION packets	All	Introduces and summarizes national impacts of all CoST PROJECTION packets to the future year.
4.2.3.1	Paved and unpaved roads VMT growth	afdust	PROJECTION packet: county-level resolution, based on VMT growth.
4.2.3.2	Livestock population growth	ag	PROJECTION packet: national, by-animal type resolution, based on animal population projections.
4.2.3.3	Locomotives	rail, ptnonipm	PROJECTION packet: Rail projections are by FIPS/SCC/poll for Calif. And SCC/poll for rest of US. NC rail projection packet was added for NODA, by FIPS/SCC/poll.
4.2.3.3	Category 1, 2, and 3 commercial marine vessels	cmv	PROJECTION packet: Category 1 & 2: CMV uses SCC/poll for all states except Calif. Category 3: region-level by-pollutant, based on cumulative growth and control impacts from rulemaking.
4.2.3.4	OTAQ upstream distribution, pipelines and refineries	nonpt, ptnonipm, pt_oilgas	PROJECTION packet: national, by-broad source category, based on upstream impacts from mobile source rulemakings.
4.2.3.5	Oil and gas and industrial source growth	nonpt, np_oilgas, ptnonipm, pt_oilgas	Several PROJECTION packets: varying geographic resolutions from state, county, to oil/gas play-level and by-process/fuel-type applications. Data derived from AEO2016 with several modifications.
4.2.3.6	Aircraft	ptnonipm	PROJECTION packet: by-airport for all direct matches to FAA Terminal Area Forecast data, with state-level factors for non-matching NEI airports.
4.2.3.7	Cement manufacturing	ptnonipm	PROJECTION packet: by-kiln projections based on Industrial Sectors Integrated Solutions (ISIS) model of demand growth and Portland Cement NESHAP.
4.2.3.8	Corn ethanol plants	ptnonipm	PROJECTION packet: national, based on 2014 AEO renewable fuel production forecast.
4.2.3.9	Residential wood combustion	rwc	PROJECTION packet: national with exceptions, based on appliance type sales growth estimates and retirement assumptions and impacts of recent NSPS.

Subsection	Title	Sector(s)	Brief Description
4.2.4	CoST CONTROL packets	nonpt, np_oilgas, ptnonipm, pt_oilgas	Introduces and summarizes national impacts of all CoST CONTROL packets in the future year.
4.2.4.1	Oil and gas NSPS	np_oilgas, pt_oilgas	CONTROL packet: national, oil and gas NSPS impacting VOC only for some activities.
4.2.4.2	RICE NESHAP	nonpt, np_oilgas, ptnonipm, pt_oilgas	CONTROL packet: national, reflects NESHAP amendments on compression and spark ignition stationary reciprocating internal combustion engines (RICE).
4.2.4.3	RICE NSPS	nonpt, np_oilgas, ptnonipm, pt_oilgas	CONTROL packet: state and county-level new source RICE controls, whose reductions by-definition, are a function of growth factors and also equipment retirement assumptions.
4.2.4.4	ICI Boilers	nonpt, ptnonipm, pt_oilgas	CONTROL packet: by-fuel, and for point sources, by-facility-type controls impacting Industrial and Commercial/Institutional boilers from rulemaking and state-provided information.
4.2.4.5	Fuel sulfur rules	nonpt, ptnonipm, pt_oilgas	CONTROL packet: state and MSA-level fuel sulfur control programs provided by several northeastern U.S. states.
4.2.4.6	Natural gas turbines NSPS	ptnonipm, pt_oilgas	CONTROL packet: state and county-level new source natural gas turbine controls, whose reductions by-definition, are a function of growth factors and also equipment retirement assumptions.
4.2.4.7	Process heaters NSPS	ptnonipm, pt_oilgas	CONTROL packet: state and county-level new source process heaters controls, whose reductions by-definition, are a function of growth factors and also equipment retirement assumptions.
4.2.4.8	Arizona Regional Haze	ptnonipm	CONTROL packet: Regional haze controls for Arizona provided by Region 9.
4.2.4.9	CISWI	ptnonipm	CONTROL packet reflecting EPA solid waste rule cobenefits.
4.2.4.11	Data from comments on previous platforms	nonpt, ptnonipm, pt_oilgas	CONTROL packets for all other programs, including Regional Haze, consent decrees/settlements, and other information from states/other agencies in prior platforms.
4.2.5	Stand-alone future year inventories	nonpt, ptnonipm	Introduction to future-year inventories not generated via CoST strategies/packets.
4.2.5.1	Portable fuel containers	nonpt	Reflects impacts of Mobile Source Air Toxics (MSAT2) on PFCs.
4.2.5.2	Biodiesel plants	ptnonipm	Year 2018 new biodiesel plants provided by OTAQ reflecting planned sited-plants production volumes.
4.2.5.3	Cellulosic plants	nonpt	Year 2018 new cellulosic ethanol plants based on cellulosic biofuel refinery siting provided by OTAQ and 2018 NODA.

Subsection	Title	Sector(s)	Brief Description
4.2.5.4	New cement plants	nonpt, ptnonipm	Year 2018 policy case-derived new cement kilns, permitted (point) and model-generated based on shifted capacity from some closed units to open units (nonpt)

4.2.2 CoST Plant CLOSURE Packet (ptnonipm, pt_oilgas)

Packet: "CLOSURES_2011v6_2_v5_18aug2017_nf_v1"

The CLOSURES packet contains facility, unit and stack-level closure information derived from the following sources:

1. Emissions Inventory System (EIS) facilities report from August 1, 2017 with closure status equal to "PS" (permanent shutdown);
2. input on closures provided by states in summer 2017 including Georgia, Illinois, Kansas, Michigan, Missouri, Minnesota, North Carolina, Ohio, Virginia, West Virginia, and Wisconsin;
3. concatenation of all 2011v6.0 closures information; see Section 4.2.11.3 from the 2011v6.0 platform TSD;
4. comments from states and regional planning organizations on the 2011v6.2 platform for states including Oklahoma; and
5. closures provided by MARAMA with 2011v6.3 2023 CoST packets.

The 2011v6.3 closure information is from a concatenation of previous facility and unit-level closure information used in the 2008 NEI-based emissions modeling platform used for 2007 air quality modeling. In addition, comments on the 2011v6.0 emissions modeling platform received by states and other agencies indicated that some previously specified closures should remain open. Ultimately, all data were updated to match the SMOKE FF10 inventory key fields, with all duplicates removed, and a single CoST packet was generated. The cumulative reductions in emissions for ptnonipm are shown in Table 4-12.

Table 4-12. Reductions from all facility/unit/stack-level closures for 2023en.

Pollutant	ptnonipm	pt_oilgas
CO	108,767	10,744
NH3	1,902	0
NOX	41,274	19,287
PM10	11,382	502
PM2.5	8,319	488
SO2	96,571	1,753
VOC	26,085	7,033

4.2.3 CoST PROJECTION Packets (afdust, ag, cmv, rail, nonpt, np_oilgas, ptnonipm, pt_oilgas, rwc)

As previously discussed, for point inventories, after application of any/all CLOSURE packet information, the next step in running a CoST control strategy is the application of all CoST PROJECTION packets. Regardless of inventory type (point or nonpoint), the PROJECTION packets applied prior to the CoST packets. For several emissions modeling sectors (i.e., afdust, ag, cmv, rail and rwc), there is only one CoST PROJECTION packet. For all other sectors, there are several different sources of PROJECTIONS data and, therefore, there are multiple PROJECTION packets that are concatenated and quality-assured for duplicates and applicability to the inventories in the CoST strategy. The PROJECTION (and CONTROL) packets were separated into a few "key" control program types to allow for quick summaries of these distinct control programs. The remainder of this section is broken out by CoST packet, with the exception of discussion of the various packets used for oil and gas and industrial source projections; these packets are a mix of different sources of data that targeted similar sources.

MARAMA provided PROJECTION and CONTROL packets for year 2023 for states including: Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New York, New Jersey, North Carolina, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Maine, and the District of Columbia. MARAMA only provided pt_oilgas and np_oilgas packets for Rhode Island, Maryland and Massachusetts. For states not covered by the MARAMA packets, projection factors for 2023 were generated by interpolating from the 2017 and 2025 packets, except for the nonpt and ptnonipm sectors that represent 2025 levels. The 2025 CoST packets are documented in the TSD Preparation of Emissions Inventories for the Version 6.2, 2011 Emissions Modeling Platform (USEPA, 2015b).

4.2.3.1 Paved and unpaved roads VMT growth (afdust)

Packet:

" PROJECTION_2011el_2023el_AFDUST_VMT_CPP_19sep2016_v0.txt"
"BETA_Projections_AFDUST_2023_21jul2016_emf_csv_02sep2016_v0.txt" (MARAMA)

These packets consist of county-level VMT projection factors for paved/unpaved roads and are based on county comparison of projected year 2023 VMT versus year 2011 VMT. The method for projecting VMT to year 2023 can be found in section 4.3.

We received comments from the 2018 NODA (search for 'EPA-HQ-OAR-2013-0809' at www.regulations.gov) suggesting we grow emissions from paved and unpaved road dust as a function of VMT. The resulting national sector-total increase from year 2011 to 2023 in $PM_{2.5}$ emissions are provided in Table 4-13. Note that this packet does not impact any other sources of fugitive dust emissions in the afdust sector (e.g., no impact on construction dust, mining and quarrying, etc.).

Table 4-13. Increase in total afdust $PM_{2.5}$ emissions from VMT projections

2011 Emissions	2023 Emissions	Percent Increase in 2023
2,510,246	2,753,900	9.71%

4.2.3.2 Livestock population growth (ag)

Packet:

"PROJECTION_2011_2023_ag_2011v6_2_no_RFS2_31aug2016_v0.txt"
"BETA_Projections_AG_2023_21jul2016" (MARAMA)

The EPA estimated animal population growth in NH_3 emissions from livestock in the ag sector. Except for dairy cows and turkey production, the animal projection factors are derived from national-level animal population projections from the USDA and the Food and Agriculture Policy and Research Institute (FAPRI). This methodology was initiated in 2005 for the 2005 NEI, but was updated on July 24, 2012, in support of the 2007v5 platform (EPA, 2012). For dairy cows, the EPA assumed that there would be no growth in emissions based on little change in U.S. dairy cow populations from years 2011 through 2023, according to linear regression analyses of the FAPRI projections. This assumption was based on an analysis of historical trends in the number of such animals compared to production rates. Although productions rates have increased, the number of animals has declined. Based on this analysis, the EPA concluded that production forecasts do not provide representative estimates of the future number of cows and turkeys; therefore, these forecasts were not used for estimating future-year emissions from these animals. In particular, the dairy cow population is projected to decrease in the future as it has for the past few decades; however, milk production will be increasing over the same period. Note that the NH_3 emissions from dairies are not directly related to animal population, but also nitrogen excretion. With the cow numbers going down and the production going up, the excretion value will change, but no change was assumed because a quantitative estimate was not available.

The national projection factors by animal category and ag sector total impacts are provided in Table 4-14, while the projection factors for MARAMA states varied by state. As discussed below, dairy cows are assumed to have no growth in animal population and, therefore, the projection factor for these animals is 1.0 (no growth). Impacts from the renewable fuels mandate are not included in projections for this sector. The overall average factor was 1.037 resulting in a 2.47% increase over 2011 and total emissions of 3,609,331 tons.

Table 4-14. NH_3 projection factors and total impacts to years 2023 for animal operations

Animal Category	Projection Factors
Dairy Cow	1.000
Beef	0.978
Pork	1.106
Broilers	1.119
Turkeys	0.927
Layers	1.087
Poultry Average	1.078

4.2.3.3 Locomotives and category 1, 2, & 3 commercial marine vessels (cmv, rail, ptnonipm, othpt)

Packets for rail, cmv and ptnonipm:

"PROJECTION_2011v6_3_2023_c1c2rail_BASE_02sep2016_v0.txt"
"PROJECTION_2011_2023_C3_CMV_ECA_IMO_2011v6_3_02sep2016_v0.txt"
"BETA_Projections_C1C2RAIL_2023_21jul2016_emf_csv_02sep2016_v0.txt" (MARAMA)

There are two components used to create projection factors for year 2023. The first component of the future year cmv and rail inventories is the non-California data projected from the 2011 base case. The second component is the CARB-supplied year 2011 and 2023 data for California.

For all states outside of California, national projection factors by SCC and pollutant between 2011 and future years reflect the May 2004 "Tier 4 emissions standards and fuel requirements" (https://nepis.epa.gov/Exe/ZyPDF.cgi/P100K5U2.PDF?Dockey=P100K5U2.PDF) as well as the March 2008 "Final locomotive-marine rule" controls (https://nepis.epa.gov/Exe/ZyPDF.cgi/P100094D.PDF?Dockey=P100094D.PDF). The future-year cmv and rail

emissions account for increased fuel consumption based on Energy Information Administration (EIA) fuel consumption projections for freight, and emissions reductions resulting from emissions standards from the Final Locomotive-Marine rule (EPA, 2009d)[40]. For locomotives, the EPA applied HAP factors for VOC HAPs by using VOC projection factors to obtain 1,3-butadiene, acetaldehyde, acrolein, benzene, and formaldehyde. Similar to locomotives, C1/C2 VOC HAPs were projected based on the VOC factor. C1/C2 diesel emissions were projected based on the Final Locomotive Marine rule national-level factors. These non-California projection ratios are provided in Table 4-15. Note that projection factors for "…Yard Locomotives" (SCC=2285002010) are applied to the ptnonipm (point inventory) "yard locomotives" (SCC=28500201) reported by a couple of states in the 2011 NEI. Note that the factors for MARAMA states are similar to those below, but county-specific factors were provided for North Carolina and those are not reflected in the table.

Table 4-15. Non-California projection factors for locomotives and Category 1 and Category 2 CMV Emissions

SCC	Description	Poll	2023 Factor
2280002XXX	Marine Vessels, Commercial; Diesel; Underway & port emissions	CO	0.955
2280002XXX	Marine Vessels, Commercial; Diesel; Underway & port emissions	NO_X	0.603
2280002XXX	Marine Vessels, Commercial; Diesel; Underway & port emissions	PM	0.546
2280002XXX	Marine Vessels, Commercial; Diesel; Underway & port emissions	SO_2	0.091
2280002XXX	Marine Vessels, Commercial; Diesel; Underway & port emissions	VOC	0.596
2285002006	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations	CO	1.212
2285002006	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations	NO_X	0.676
2285002006	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations	PM	0.522
2285002006	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations	SO_2	0.035
2285002006	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations	VOC	0.486
2285002007	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations	CO	1.212
2285002007	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations	NO_X	1.062
2285002007	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations	PM	1.015
2285002007	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations	SO_2	0.035
2285002007	Railroad Equipment; Diesel; Line Haul Locomotives: Class II / III Operations	VOC	1.212
2285002008	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)	CO	1.101
2285002008	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)	NO_X	0.519
2285002008	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)	PM	0.418
2285002008	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)	SO_2	0.032
2285002008	Railroad Equipment; Diesel; Line Haul Locomotives: Passenger Trains (Amtrak)	VOC	0.356
2285002009	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines	CO	1.101
2285002009	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines	NO_X	0.519
2285002009	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines	PM	0.418
2285002009	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines	SO_2	0.032
2285002009	Railroad Equipment; Diesel; Line Haul Locomotives: Commuter Lines	VOC	0.356
2285002010	Railroad Equipment; Diesel; Yard Locomotives	CO	1.212

[40] This rule lowered diesel sulfur content and tightened emission standards for existing and new locomotives and marine diesel emissions to lower future-year PM, SO_2, and NOx, and is documented at: http://www.epa.gov/otaq/marine.htm#2008final.

SCC	Description	Poll	2023 Factor
2285002010	Railroad Equipment; Diesel; Yard Locomotives	NO_X	0.873
2285002010	Railroad Equipment; Diesel; Yard Locomotives	PM	0.845
2285002010	Railroad Equipment; Diesel; Yard Locomotives	SO_2	0.035
2285002010	Railroad Equipment; Diesel; Yard Locomotives	VOC	0.812

For California projections, the CARB provided to the EPA the locomotive, and C1/C2 commercial marine emissions used to reflect years 2011 and 2023. These CARB inventories included nonroad rules reflected in the December 2010 Rulemaking Inventory (http://www.arb.ca.gov/regact/2010/offroadlsi10/offroadisor.pdf), those in the March 2011 Rule Inventory, the Off-Road Construction Rule Inventory for "In-Use Diesel," cargo handling equipment rules in place as of 2011 (see http://www.arb.ca.gov/ports/cargo/cargo.htm), and the 2007 and 2010 regulations to reduce emissions diesel engines on commercial harbor craft operated within California waters and 24 nautical miles (nm) of the California baseline.

The California C1/C2 CMV and locomotive year-specific 2023 emissions were obtained from the CARB in the form of Excel workbooks. These data were converted to SMOKE FF10 format. These emissions were developed using Version 1 of the CEPAM, which supports various California off-road regulations. Documentation of the CARB off-road methodology, including cmv and rail sector data, is provided here: http://www.arb.ca.gov/msei/categories.htm#offroad_motor_vehicles.

The non-California projection factors were applied to all "offshore" C1 and C2 CMV emissions. These offshore emissions, in the 2011 NEI, start at the end of state waters and extend out to the EEZ. A summary of the national impact for the U.S. (including California) and rail and offshore C1 &C2 cmv sector emissions are provided in Table 4-16.

Table 4-16. Difference in Category 1& 2 cmv and rail sector emissions between 2011en and 2023en

Region	Pollutant	2011	2023	Difference 2023 – 2011
U.S. CMV	CO	70,408	76,265	5,857
U.S. CMV	NO_X	413,314	280,626	-132,688
U.S. CMV	PM_{10}	19,629	7,513	-12,116
U.S. CMV	$PM_{2.5}$	18,099	7,039	-11,060
U.S. CMV	SO_2	91,045	6,811	-84,234
U.S. CMV	VOC	12,578	12,880	302
Offshore CMV	CO	66,395	63,421	-2,974
Offshore CMV	NO_X	326,631	197,021	-129,610
Offshore CMV	PM_{10}	10,795	5,894	-4,901
Offshore CMV	$PM_{2.5}$	10,471	5,717	-4,754
Offshore CMV	SO_2	4,014	366	-3,648
Offshore CMV	VOC	7,472	4,453	-3,019
U.S. rail	CO	122,703	145,627	22,924
U.S. rail	NO_X	791,381	563,382	-227,999
U.S. rail	PM_{10}	25,898	14,236	-11,662
U.S. rail	$PM_{2.5}$	23,963	13,165	-10,798

U.S. rail	SO_2	7,936	340	-7,596
U.S. rail	VOC	40,851	21,384	-19,467

As discussed in Section 2.4.1 of the 2011v6.3 platform TSD, the EPA estimates for C3 CMV, emissions data were developed for year 2002 and projected to year 2011 for the 2011 base case, and used where states did not submit data to Version 2 of the 2011 NEI. Pollutant and geographic-specific projection factors to year 2011 were applied, along with projection factors to years 2023 that reflect assumed growth and final ECA-IMO controls. These emissions estimates reflect the EPA's coordinated strategy for large marine vessels. More information on the EPA's coordinated strategy for large marine vessels can be found in our Category 3 Marine Diesel Engines and Fuels regulation published in April 2010. That rule, as well as information about the North American and U.S. Caribbean Sea ECAs, designated by amendment to MARPOL Annex VI, can be found at: https://www.epa.gov/regulations-emissions-vehicles-and-engines/international-standards-reduce-emissions-marine-diesel.

Projection factors for creating the year 2023 cmv inventory from the 2011 base case are provided in Table 4-17. For more information on the mapping of the states to each EEZ, see Section 2.4.1 of the 2011v6.3 platform TSD. For example, Washington state emissions are grown the same as all North Pacific offshore emissions.

Table 4-17. Growth factors to project the 2011 ECA-IMO inventory to 2023

Region	**EEZ (offshore) FIPS**	**CO**	**NO_X**	**PM_{10}**	**PM_{25}**	**SO_2**	**VOC**
North Pacific (NP)	85001	1.49	0.85	0.2	0.2	0.06	1.49
South Pacific (SP)	85002	1.86	0.95	0.26	0.26	0.07	1.86
East Coast (EC)	85004	1.71	0.89	0.23	0.23	0.06	1.71
Gulf Coast (GC)	85003	1.42	0.75	0.19	0.19	0.05	1.42
Great Lakes (GL)	n/a	1.23	0.95	0.16	0.16	0.04	1.23
Outside ECA	98001	1.72	1.39	0.63	0.63	0.58	1.72

Packet for othpt:

"PROJECTION_2011_2023_C3_CMV_ECA_IMO_2011v6_3_02sep2016_v0.txt"

Note that the MARAMA packet provided in BETA_Projections_C3Marine_2023_20feb2016_emf_csv_02sep2016_v0.txt was not used because the offshore emissions were not in a MARAMA state. As discussed in Section 2.4.2 of the 2011v6.3 platform TSD, emissions outside the 3 to 10-mile coastal boundary, but within the approximately 200 nm EEZ boundaries, were projected to year 2023 using the same regional adjustment factors as the U.S. emissions; however, the FIPS codes were assigned as "EEZ" FIPS and these emissions are processed in the "othpt" sector. Note that state boundaries in the Great Lakes are an exception, extending through the middle of each lake such that all emissions in the Great Lakes are assigned to a U.S. county or Ontario. The classification of emissions to U.S. and Canadian FIPS codes is needed to avoid double-counting of Canadian-provided C3 CMV emissions in the Great Lakes.

The cumulative impact of these ECA-IMO projections and controls to the U.S. + near-offshore (cmv sector) and far-offshore emissions (othpt sector) in 2023 is provided in Table 4-18.

Table 4-18. Difference in Category 3 cmv sector and othpt C3 CMV emissions between 2011 and 2023

Region	Pollutant	2011 emissions	2023 emissions	Difference 2023 - 2011
Offshore to EEZ*	CO	133,574	173,938	40,364
Offshore to EEZ*	NOX	798,258	728,724	-69,534
Offshore to EEZ*	PM10	28,451	6,854	-21,597
Offshore to EEZ*	PM2_5	26,113	6,293	-19,820
Offshore to EEZ*	SO2	222,113	16,509	-205,604
Offshore to EEZ*	VOC***	81,593	98,753	17,160
Non-US SECA C3	CO	187,439	321,978	134,539
Non-US SECA C3	NOX	2,209,800	3,078,374	868,574
Non-US SECA C3	PM10	187,587	118,375	-69,212
Non-US SECA C3	PM2_5	172,580	108,413	-64,167
Non-US SECA C3	SO2	1,391,702	803,736	-587,966
Non-US SECA C3	VOC***	79,575	136,692	57,117

* - Offshore to EEZ includes both c3marine, and the offshore oil rigs/etc from the US point inventory
*** - INCLUDES pre-speciated inventory VOC in Canada, so post-SMOKE VOC_INV < VOC

4.2.3.4 Upstream distribution, pipelines and refineries (nonpt, ptnonipm, pt_oilgas)

Packet:

ptnonpim and nonpt sectors only:
"PROJECTION_2011_2025_OTAQ_upstream_GasDist_pipelines_refineries_2011v6_2_05feb2015_05feb2015_v0.txt"
pt_oilgas sector only: "PROJECTION_2011v6_2025_pipelines_refineries
"BETA_Projections_OTAQ_Upstream_GasDist_2023_20feb2016_emf_csv_02sep2016_v0.txt" (MARAMA)

To account for projected increases in renewable fuel volumes due to the Renewable Fuel Standards (RFS2)/EISA (EPA, 2010a) and decreased gasoline volumes due to RFS2 and light-duty greenhouse gas standards as quantified in AEO 2014 (http://www.eia.gov/forecasts/archive/aeo14/), the EPA developed county-level inventory adjustments for gasoline and gasoline/ethanol blend transport and distribution. Here, for non-MARAMA states, year 2025 factors are used for year 2023. MARAMA provided year 2023-specific factors. These adjustments account for losses during truck, rail and waterways loading/unloading and intermodal transfers such as highway-to-rail, highways-to-waterways, and all other possible combinations of transfers. Adjustments for 2018 only account for impacts of RFS2, and the 2025 adjustments also account for additional impacts of greenhouse gas emission standards for motor vehicles (EPA, 2012b) on transported volumes. These emissions are entirely evaporative and, therefore, limited to VOC.

A 2018 inventory that included impacts of the EISA mandate was developed by applying adjustment factors to the 2011NEIv2 inventory. These adjustments were made using an updated version of the EPA's model for upstream emission impacts, developed for the RFS2 rule[41]. The methodology used to make these adjustments is described in a 2014 memorandum included in the docket for the EPA Tier 3 rule (EPA, 2014)[42].

[41] U.S. EPA. 2013. Spreadsheet "upstream_emissions_rev T3.xls.
[42] U. S. EPA. Development of Air Quality Reference Case Upstream and Portable Fuel Container Inventories for the Tier 3 Final Rule. Memorandum from Rich Cook, Margaret Zawacki and Zoltan Jung to the Docket. February 25, 2014. Docket EPA-HQ-OAR-2011-0135.

Ethanol emissions were estimated in SMOKE by applying the ethanol to VOC ratios from headspace profiles to VOC emissions for E10 and E15, and an evaporative emissions profile for E85. These ratios are 0.065 for E10, 0.272 for E15, and 0.61 for E85. The E10 and E15 profiles were obtained from an ORD analysis of fuel samples from EPAct exhaust test program[43] and were submitted for incorporation into the EPA's SPECIATE database. The E85 profile was obtained from data collected as part of the CRC E-80 test program (Environ, 2008) and was also submitted into the EPA's SPECIATE database. For more details on the change in speciation profiles between the base and future years, see Section 3.2 of the 2011v6.3 platform TSD.

Pipeline usage and refinery emissions were adjusted to account for impacts of the 2017-2025 light duty vehicle greenhouse gas emission standards, as well as renewable fuel volume projections. These adjustments were developed by the EPA's OTAQ and impact processes such as process heaters, catalytic cracking units, blowdown systems, wastewater treatment, condensers, cooling towers, flares and fugitive emissions. Calculation of the emission inventory impacts of decreased gasoline and diesel production, due to renewable fuel volume projections, on nationwide refinery emissions was done in the EPA's spreadsheet model for upstream emission impacts (EPA, 2009b). Emission inventory changes reflecting these impacts were used to develop adjustment factors that were applied to inventories for each petroleum refinery in the U.S. These impacts of decreased production were assumed to be spread evenly across all U.S. refineries. Toxic emissions were estimated in SMOKE by applying speciation to VOC emissions. It should be noted that the adjustment factors are estimated relative to that portion of refinery emissions associated with gasoline and diesel fuel production. Production of jet fuel, still gas and other products also produce emissions. If these emissions were included, the adjustment factors would not be as large.

The resulting adjustments for pipelines, refineries and the gasoline distribution processes (RBT, BPS and BTP) are provided in Table 4-19. Separate adjustments were applied to refinery to bulk terminal (RBT), bulk plant storage (BPS), and bulk terminal to gasoline dispensing pump (BTP) components. Emissions for the BTP component are greater than the RBT and BPS components. An additional adjustment was applied for 2025 at a national scale to account for impacts of gasoline volume reductions of the 2017-2025 light-duty greenhouse gas rule.

Notice that the "2011 Emissions" are not the same in Table 4-19. This is because these "2011" emissions are actually an intermediate set up projections applied after a first CoST strategy used to apply most other PROJECTION and CONTROL packets. We decided to first apply these other packets because we have multiple PROJECTION and CONTROL programs that impact the same emission sources. For this example, we applied year-specific industrial sector AEO-based growth (discussed in the next section) with our first CoST strategy, then applied these "EISA" adjustments on the results of this first CoST strategy. Similarly, we have RICE existing NESHAP, as well as NSPS, controls that need to be applied in separate strategies. Alternatively, we could have made "compound" CoST packets that combine these PROJECTION (and CONTROL) factors, but preferred to keep these packets separate for transparency. If we tried to process the multiple packets affecting the same sources in a single CoST strategy, CoST would either fail if the packet entries were the same key-field resolution (duplicate error), or, if packets were at a different key-field resolution, CoST would only apply the packet entry with higher priority according to Table 4-10.

Table 4-19. Petroleum pipelines & refineries and production storage and transport factors and reductions

Poll	Year	Factors		Reduction	

[43] U.S. EPA. 2011. Hydrocarbon Composition of Gasoline Vapor Emissions from Enclosed Fuel Tanks. Office of Research and Development and Office of Transportation and Air Quality. Report No. EPA-420-R-11-018. EPA Docket EPA-HQ-OAR-2011-0135.

		Pipelines & Refineries	RBT	BTP/BPS	2011 Emissions		Percent Reduction
CO	2023	0.9445	n/a	n/a	53,501	2,969	5.55%
NOX	2023	0.9348	n/a	n/a	68,354	4,454	6.52%
PM10	2023	0.9668	n/a	n/a	24,484	813	3.32%
PM2.5	2023	0.9679	n/a	n/a	21,599	694	3.21%
SO2	2023	0.9517	n/a	n/a	78,944	3,815	4.83%
VOC	2023	0.9650	n/a	n/a	750,025	26,266	3.50%

4.2.3.5 Oil and gas and industrial source growth (nonpt, np_oilgas, ptnonipm, pt_oilgas)

Packets:

ptnonipm and nonpt sectors:

"PROJECTION_2011v6_2_2025_SCC_POINT_LADCO_09dec2014_09dec2014_v0.txt"
"PROJECTION_2011v6_2_2025_NAICS_SCC_SCA_orig_NEI_matched_CAPPED2_5_04dec2014_04dec2014_v0.txt"
"PROJECTION_2011v6_2_2025_SCC_POINT_SCA_orig_CAPPED_09dec2014_04feb2015_v1.txt"
"PROJECTION_2011v6_2_2025_SRAcapped_POINT_05dec2014_05dec2014_v0.txt"
'PROJECTION_TCEQ_ptnonipm_NAICS_comments_2011v6_2025_revised_16jul2015_v0.txt"
"PROJECTION_2011v6_2_2025_SCC_NONPOINT_LADCO_09dec2014_09dec2014_v0.txt"
"PROJECTION_2011v6_2_2025_SCC_NONPOINT_SCA_orig_CAPPED_09dec2014_09dec2014_v0.txt"
"PROJECTION_2011v6_2_2025_nonpoint_SCC_SRAcapped_05dec2014_05dec2014_v0.txt"
"PROJECTION_2011_2025_aircraft_ST_and_by_airport_22jan2015"
"PROJECTION_VA_ME_TCEQ_AL_comments_2011v6_2019_04dec2013_v0.txt"
"PROJECTION_2011v6_3__2017_Oklahoma_source_NODA_11jan2016_v1.txt"
"PROJECTION_2011v6_2_2025_TCEQ_v6_leftovers_NONPOINT_30jan2015_30jan2015_v0.txt"

np_oilgas sectors:

np_oilgas_offshore_coalbed_2011_2023en_projection_packet_03aug2017_v0.txt
np_oilgas_TCEQ_2014_2023_projection_packet_03aug2017_v0.txt
np_oilgas_2011_2023en_projection_packet_03aug2017_v0.txt

pt_oilgas sector:

OK_pt_oil_gas_projection_csv_06jan2016_v0.txt
PROJECTION_2011_2023_NAICS_SCC_SCA_orig_NEI_matched_CAPPED2_5_csv_04oct2016_v1.txt
PROJECTION_2011v6_2_2023_SCC_POINT_LADCO_csv_04oct2016_v0.txt
PROJECTION_2011v6_2_2023_SCC_POINT_SCA_orig_CAPPED_09dec2014_04oct2016_v0.txt
PROJECTION_2011v6_2_2023_SRAcapped_POINT_05dec2014_04oct2016_v0.txt
PROJECTION_TCEQ_ptnonipm_NAICS_comments_2011v6_2023_04dec2013_04oct2016_v0.txt
pt_oilgas_2011_2023en_projection_packet_03aug2017_v0.txt
PROJECTION_2011v6_2025_pipelines_refineries_26mar2014_v0.txt

MARAMA states: "BETA_Projections_NP_OILGAS_2023_22apr2016_emf.csv" (MARAMA: PA only)
"BETA_Projections_PT_OILGAS_2023_24aug2016_emf.csv" (MARAMA: PA only)
"BETA_Projections_PT_NonERTAC_2023_24aug2016_emf.csv" (MARAMA)
"BETA_Projections_PT_Small_EGU_2023_25jul2016_emf.csv" (MARAMA)
"BETA_Projections_NonPoint_2023_2016_08_24_emf.csv" (MARAMA)
"BETA_Projections_NONPT_REFUELING_2023_25jul2016_emf.csv" (MARAMA)
"BETA_Projections_Aircraft_Engine_GSE_APU_2023_10aug2016_emf.csv" (MARAMA)

The EPA provided a NODA (search for the docket 'EPA-HQ-OAR-2013-0809' on *regulations.gov*) for the 2011v6.0 emissions modeling platform and projected 2018 inventory in January, 2014. A significant number of the comments were about the EPA's "no growth" assumption for industrial stationary sources and about the current projection approach for oil and gas sources that was applied similarly to five broad geographic (NEMS) regions and limited to only oil and gas drilling activities.

With limited exceptions, the EPA used a no-growth assumption for all industrial non-EGU emissions since the 2005 NEI-based emissions modeling platform (EPA, 2006). However, comments provided to the EPA for this platform (via the NODA) and for previous modeling platforms suggested that this approach was insufficient. In addition, the NO_x Budget program, which had a direct impact on post-2002 emissions reductions, is in full compliance in the 2011 NEI. This means that additional large-scale industrial reductions should not be expected beyond 2011 in the absence of on-the-books state and federal rules.

In response to the comments about the EPA's no-growth and previous approaches, the EPA developed industrial sector activity-based growth factors. In response to the NODA, many states have additionally provided detailed activity-based projection factors for industrial sources, including oil and gas sources. To develop the methods described here, we have blended the state-provided growth factors with the EPA-developed industrial sector growth factors. This approach has attempted to balance using the specific information that is available with the EPA's interest in consistency for a given sector and technical credibility. Table 4-14 lists the new resulting data sources for industrial sector non-EGU growth factors that the EPA applied to estimate year 2023 emissions for this emissions modeling platform. Ultimately, there were three broad sources of projection information for industrial sources, including oil and gas; these sources are referenced as the following for simplicity:

1) EPA:
    a. **(NEW)** Reflects EPA-generated factors based on EIA state historical production data and AEO2017 reference case production data (label dated "03aug2017").
    b. Reflects EPA-sponsored data provided by a contractor (SC&A, 2014a; SC&A, 2014b). Packet file names for these data include "SCA."
2) MARAMA:
    a. Reflects data submitted on behalf of Atlantic seaboard states from North Carolina through Maine, and extending west through Pennsylvania and West Virginia. Packet file names for these data include "SRA" (SRA, 2014).
    b. Reflects data submitted on behalf of Atlantic seaboard states from North Carolina through Maine, and extending west through Pennsylvania and West Virginia. Packet file names that begin with "BETA" (MARAMA, 2016).
3) LADCO: Reflects data submitted on behalf of Lake Michigan Air Directors Consortium (LADCO) states (MN, WI, MI, IL, IN, OH). Projection data from this data source are reflected in packet names containing "LADCO" (Alpine Geophysics, 2014).

Table 4-20. Sources of new industrial source growth factor data for year 2023 in the 2011v6.3 platform

Abbrev.	Source	Geographic Resolution	Inventory Resolution	Use/Caveat
MARAMA "BETA" packets	MARAMA/states using 2015 AEO data and other data sources	State or county for nonpoint and facility and below for most point sources	Facility and sub-facility for point, SCC-level for nonpoint	Provided by MARAMA (2016) for year-2023 specific projection purposes.

Abbrev.	Source	Geographic Resolution	Inventory Resolution	Use/Caveat
EPA New projection packets for 2023en case: "np_oilgas_offshore_coalbed_2011_2023en_projection_packet_03aug2017_v0.txt" "np_oilgas_TCEQ_2014_2023_projection_packet_03aug2017_v0.txt" "np_oilgas_2011_2023en_projection_packet_03aug2017_v0.txt" "pt_oilgas_2011_2023en_projection_packet_03aug2017_v0.txt"	Non-MARAMA states using EIA historical production state data and 2017 AEO Crude Oil Production and Natural Gas Production data	EIA Supply Region	State or county/ SCC	Impacts both point and nonpoint oil and gas sectors as well as some non-EGU point sources not in the pt_oilgas sector.

Table 4-20 above lists only the new projection packets used to estimate year 2023 emissions for this modeling effort. MARAMA provided year-2023 specific factors for all sectors mentioned in this section. The EPA generated factors using AEO2017 data were also year-2023 specific emissions. The previous TSDs for 2011v6.2 and 2011v6.3 describe the other packets mentioned earlier in this section. Specifically, year 2025 packets mentioned in this section are described in the 2011v6.2 TSD (EPA, 2015b).

Natural Gas Consumption and Crude Oil Production

In the 2023el case, the AEO 2016 reference case data (http://www.eia.gov/outlooks/aeo/tables_ref.cfm) was used to project production-related oil and gas sources. The AEO2016 tables used include the National Oil and Gas Supply Table #14, Lower 48 Crude Oil Production Table #60, and Lower 48 Natural Gas Production Table #61. These AEO2016 tables were used to project emissions related to oil and gas production for the six EIA Supply Regions (Figure 4-1) plus offshore regions. These projection factors were applied to appropriate production related SCCs in the NEI2011v2 inventory. In cases where a SCC description listed both oil and gas production processes may be involved, an average projection factor was used for that EIA Supply Region. For more details on the 2023el case approach, see the *Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the year 2023* technical support document (EPA, 2016b).

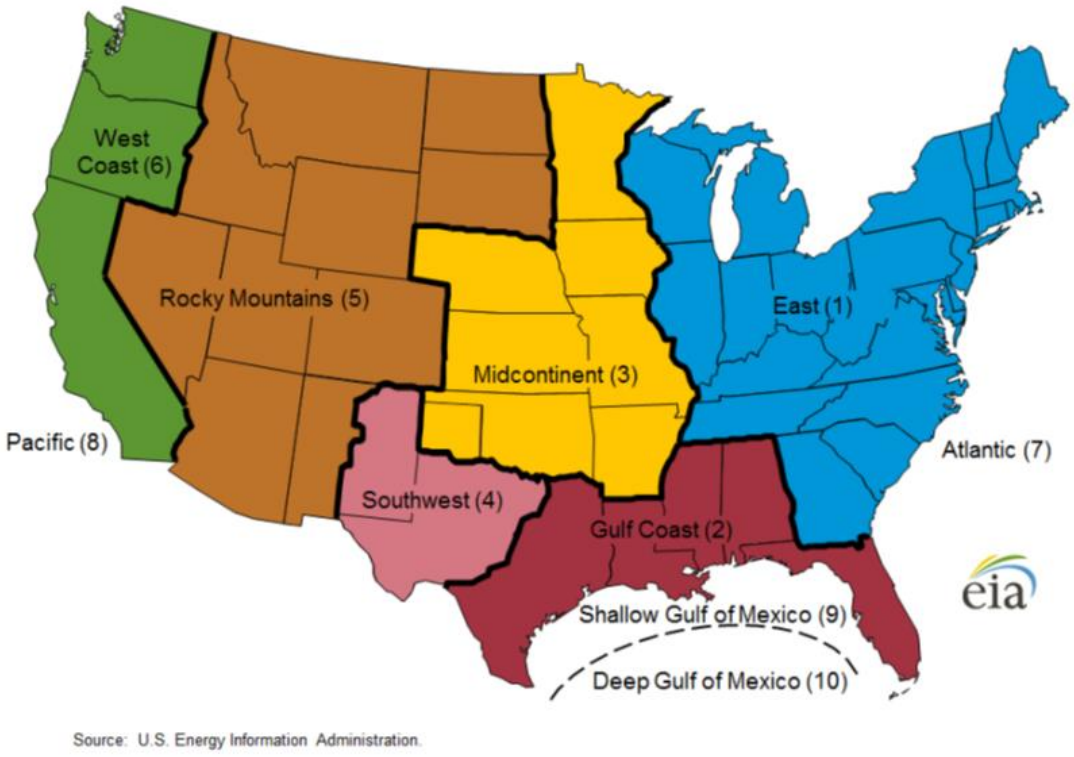
The method used in the 2023el case was released in a Notice of Data Availability (NODA), (82 FR 1733, Docket No. EPA-HQ-OAR-2016-0751). Comments on the methodology were solicited with the NODA. Some states and other stakeholders recommended future methodology updates for oil and gas projections. In particular, some commenters expressed strong interest in enhancing the methodology to better account for how states in a given multi-state region can have notably different trends in oil and gas production. In response to these comments, EPA updated the projection method in the 2023en case for production-related oil and gas emission sources to better account for differences in both historical and projected state oil and gas production trends.

In the 2023en case, updated state-specific 2011-2023 projection factors were generated and applied. The projection factors used in the 2023en case are the products of multiplying historic (2011-2015) state-level factors by regional projection factors that represent 2015 to 2023.

- The 2011-2015 factors are based on historic state oil and gas production data published by EIA.
    - Crude oil production data
        - http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm

- Dry natural gas estimated production data
  - http://www.eia.gov/dnav/ng/ng_sum_lsum_a_epg0_r20_bcf_a.htm
- The 2015-2023 factors are based on projected oil and gas production in EIA's 2017 Annual Energy Outlook (AEO) Reference Case without the Clean Power Plan for the six EIA Supply Regions (Figure 4-1)

Figure 4-1. Oil and Gas NEMS Regions



To better differentiate state trends within each region, the following three assumptions were implemented which cause the projection factors to vary based on historic oil and gas production:

1. States without EIA oil and gas production data for 2011-2015 have their factor set to 1.0 for 2011-2015; a factor of 1.0 indicates that there is no growth from 2011-2015.
2. States without EIA oil and gas production data for 2011-2015 have 2015-2023 projection factors set to 1.0, unless the region containing the state has a 2015-2023 factor less than 1.0, in which case the lower regional factor will be applied.
3. If a state has a 2011-2015 projection factor less than 1.0 and its associated 2015-2023 regional factor is greater than 1.0, then the 2015-2023 factor is set to 1.0.

There were some states for which the approach had to be somewhat modified for various reasons. For example, in New Mexico which has counties falling into two different EIA Supply Regions in the 2017 AEO data, the 2011-2015 factors are state-specific and the 2015-2023 factors are region-specific. For Texas, which has counties falling into three different EIA Supply Regions in the 2017 AEO data, a 2014 emissions inventory provided in response to the NODA was paired with 2014-2023 projection factors that are region-specific. For Pennsylvania, the 2023el projection factors for the np_oilgas sector were used in the 2023en case. The net impacts of these projection factors for each of the modeling sectors is provided in Table 4-21. Specific

projection factors for each state are available on the Projection Factors tab of the spreadseheet *2011_2023en_oil_gas_projections_082517.xlsx* available with the reports for the 2011v6.3 platform area of the FTP site: ftp://ftp.epa.gov/EmisInventory/2011v6/v3platform/reports/2011en_and_2023en/.

Table 4-21. Industrial source projections net impacts for 2023en

Pollutant	Sector	2011 Emissions Subject to projection	Intermediate Projected Emissions	Difference (Future - 2011)	% Difference (Future - 2011)
CO	nonpt	733,239	790,635	57,396	8%
CO	np_oilgas	669,611	861,154	191,544	29%
CO	pt_oilgas	235,236	290,468	55,232	23%
CO	ptnonipm	1,028,175	1,152,841	124,666	12%
CO	**Total**	**2,666,261**	**3,095,098**	**428,837**	**16%**
NH_3	nonpt	18,381	18,830	449	2%
NH_3	pt_oilgas	266	237	-29	-11%
NH_3	ptnonipm	12,645	13,473	828	7%
NH_3	**Total**	**31,291**	**32,540**	**1,248**	**4%**
NO_X	nonpt	499,419	517,606	18,187	4%
NO_X	np_oilgas	707,212	942,919	235,707	33%
NO_X	pt_oilgas	541,483	592,903	51,419	9%
NO_X	ptnonipm	713,372	799,033	85,662	12%
NO_X	**Total**	**2,461,486**	**2,852,461**	**390,975**	**16%**
PM_{10}	nonpt	280,933	315,788	34,856	12%
PM_{10}	np_oilgas	18,082	24,783	6,702	37%
PM_{10}	pt_oilgas	15,101	16,500	1,399	9%
PM_{10}	ptnonipm	140,965	159,778	18,812	13%
PM_{10}	**Total**	**455,081**	**516,849**	**61,768**	**14%**
$PM_{2.5}$	nonpt	224,860	254,129	29,268	13%
$PM_{2.5}$	np_oilgas	16,618	21,789	5,171	31%
$PM_{2.5}$	pt_oilgas	14,790	16,159	1,369	9%
$PM_{2.5}$	ptnonipm	114,104	130,535	16,431	14%
$PM_{2.5}$	**Total**	**370,372**	**422,612**	**52,239**	**14%**
SO_2	nonpt	253,885	237,039	-16,846	-7%
SO_2	np_oilgas	29,058	48,014	18,956	65%
SO_2	pt_oilgas	59,322	59,264	-58	0%
SO_2	ptnonipm	481,022	482,098	1,076	0%
SO_2	**Total**	**823,287**	**826,415**	**3,128**	**0%**
VOC	nonpt	1,133,960	1,189,481	55,520	5%
VOC	np_oilgas	2,563,018	3,849,332	1,286,314	50%

Pollutant	Sector	2011 Emissions Subject to projection	Intermediate Projected Emissions	Difference (Future - 2011)	% Difference (Future - 2011)
VOC	pt_oilgas	146,969	175,377	28,408	19%
VOC	ptnonipm	177,442	203,905	26,463	15%
VOC	**Total**	**4,021,389**	**5,418,095**	**1,396,706**	**35%**

4.2.3.6 Aircraft (ptnonipm)

Packet:

"PROJECTION_2011_2025_aircraft_ST_and_by_airport_22jan2015_v0.txt"
"BETA_Projections_Aircraft_Engine_GSE_APU_2023_10aug2016_emf.csv" (MARAMA)

Aircraft emissions are contained in the ptnonipm inventory. These 2011 point-source emissions are projected to future years by applying activity growth using data on ITN operations at airports. The ITN operations are defined as aircraft take-offs whereby the aircraft leaves the airport vicinity and lands at another airport, or aircraft landings whereby the aircraft has arrived from outside the airport vicinity. The EPA used projected ITN information available from the Federal Aviation Administration's (FAA) Terminal Area Forecast (TAF) System: https://www.faa.gov/data_research/aviation/taf/ (publication date March, 2014). This information is available for approximately 3,300 individual airports, for all years up to 2040. The methods that the FAA used for developing the ITN data in the TAF are documented in: http://www.faa.gov/about/office_org/headquarters_offices/apl/aviation_forecasts/taf_reports/media/TAF_Summary_Report_FY2013-2040.pdf.

None of our aircraft emission projections account for any control programs. The EPA considered the NOx standard adopted by the International Civil Aviation Organization's (ICAO) Committee on Aviation Environmental Protection (CAEP) in February 2004, which is expected to reduce NOx by approximately 3 percent by 2020. However, this rule has not yet been adopted as an EPA (or U.S.) rule and, therefore, its effects were not included in the future-year emissions projections.

The EPA developed two sets of projection factors for aircraft. The first set was a simple state-level aggregation, used primarily for airports with very little activity, by ITN operation type (commercial, general aviation, military and air taxi) to be used as a default method for projecting from 2011 to future years. The second set of projection factors was by airport, where the EPA projects emissions for each individual airport with significant ITN activity.

Where NEI facility identifiers were not matched to FAA airport identifiers, we simply summed the ITN operations to state totals by year and aircraft operation and computed projection factors as future-year ITN to year-2011 ITN. The EPA assigned factors to inventory SCCs based on the operation type shown in Table 4-22.

Table 4-22. NEI SCC to FAA TAF ITN aircraft categories used for aircraft projections

SCC	Description	FAA ITN Type
2265008005	Commercial Aircraft: 4-stroke Airport Ground Support Equipment	Commercial
2267008005	Commercial Aircraft: LPG Airport Ground Support Equipment	Commercial
2268008005	Commercial Aircraft: CNG Airport Ground Support Equipment	Commercial

SCC	Description	FAA ITN Type
2270008005	Commercial Aircraft: Diesel Airport Ground Support Equipment	Commercial
2275000000	All Aircraft Types and Operations	Commercial
2275001000	Military Aircraft, Total	Military
2275020000	Commercial Aviation, Total	Commercial
2275050011	General Aviation, Piston	General
2275050012	General Aviation, Turbine	General
2275060011	Air Taxi, Total: Air Taxi, Piston	Air Taxi
2275060012	Air Taxi, Total: Air Taxi, Turbine	Air Taxi
2275070000	Commercial Aircraft: Aircraft Auxiliary Power Units, Total	Commercial
27501015	Internal Combustion Engines; Fixed Wing Aircraft L & TO Exhaust; Military; Jet Engine: JP-5	Military
27502011	Internal Combustion Engines; Fixed Wing Aircraft L & TO Exhaust; Commercial; Jet Engine: Jet A	Commercial
27505001	Internal Combustion Engines; Fixed Wing Aircraft L & TO Exhaust; Civil; Piston Engine: Aviation Gas	General
27505011	Internal Combustion Engines; Fixed Wing Aircraft L & TO Exhaust; Civil; Jet Engine: Jet A	General

Most NEI airports matched FAA TAF identifiers and, therefore, use airport-specific projection factors. We applied a cap on projection factors of 2.0 (100 percent increase) for state-level defaults and 5.0 for airport-specific entries. None of the largest airports/larger-emitters had projection factors close to these caps. A national summary of aircraft emissions between 2011 and future year 2023 are provided in Table 4-23.

Table 4-23. National aircraft emission projection summary for 2023en

	Emissions		Difference	% Difference
	2011	2025	2025-2011	2025
CO	489,854	559,783	69,930	14.28%
NO_X	120,968	157,610	36,642	30.29%
PM_{10}	9,164	10,039	874	9.54%
$PM_{2.5}$	7,891	8,709	818	10.37%
SO_2	14,207	18,139	3,932	27.67%
VOC	32,023	38,077	6,054	18.90%

4.2.3.7 Cement manufacturing (ptnonipm)

Packet:

"PROJECTION_2011_2025_ISIS_cement_by_CENSUS_DIVISION.txt"

As indicated in Table 4-1, the Industrial Sectors Modeling Platform (ISMP) (EPA, 2010b) was used to project the cement industry component of the ptnonipm emissions modeling sector to 2025; we used year 2025 emissions for year 2023. This approach provided reductions of criteria and select hazardous air pollutants. The

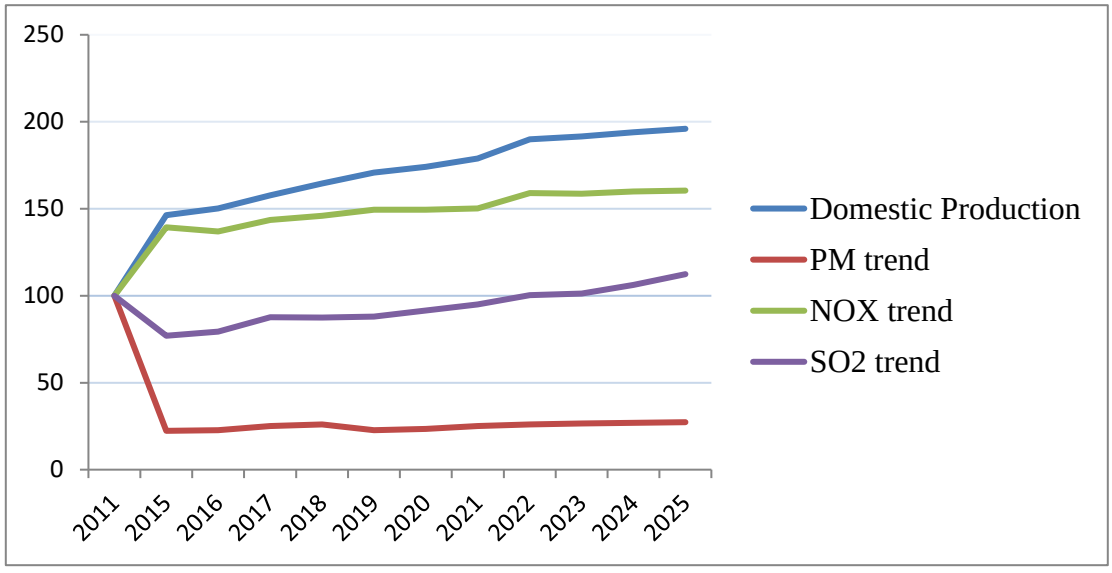
ISMP cement emissions were developed in support for the Portland Cement NESHAPs and the NSPS for the Portland cement manufacturing industry.

The ISMP model produced a Portland Cement NESHAP policy case of multi-pollutant emissions for individual cement kilns (emission inventory units) that were relevant for years 2015 through 2030. These ISMP-based emissions are reflected using a CoST packet for all existing kilns that are not impacted by more local information from states (or consent decrees). ISMP also generates new cement kilns that are permitted (point inventory) and not-permitted, but generated based on ISMP assumptions on demand and infrastructure (nonpt inventory). These new cement kilns are discussed in Section 4.2.5.4.

The PROJECTION packets contain U.S. census division level based projection factors for each NEI unit (kiln) based on ISMP updated policy case emissions at existing cement kilns. The units that closed before 2025 are included in the 2025 base case but are included in other CoST packets that reflect state comments and consent decrees (discussed in Section 4.2.4.11).

The ISMP model, version August 2013, was used for these projections. Recent data updates include updated matching of kilns to better capture recent retirements, capacity additions and projections of capacity additions from Portland Cement Association (PCA) Plant Information Summary of December 31, 2010, and feedback from Portland Cement NESHAP reconsideration comments. Updated cement consumption projections are based on a post-recession (July 2012) PCA long-term cement consumption outlook. Updated emissions controls in 2015 from the NESHAP are also reflected. Overall, as seen in Figure 4-2, domestic production of cement grows significantly between 2011 and 2015, then more slowly through 2018. Meanwhile, emissions from NESHAP-regulated pollutants such as PM and SO_2 drop significantly based on regulated emissions rates. Emissions for NOx increase, though not as much as production because the ISMP model continues the recent trend in the cement sector of the replacement of lower capacity, inefficient wet and long dry kilns with bigger and more efficient preheater and precalciner kilns.

Figure 4-2. Cement sector trends in domestic production versus normalized emissions



Multiple regulatory requirements such as the NESHAP and NSPS currently apply to the cement industry to reduce CAP and HAP emissions. Additionally, state and local regulatory requirements might apply to individual cement facilities depending on their locations relative to ozone and $PM_{2.5}$ nonattainment areas. The ISMP model provides the emission reduction strategy that balances: 1) optimal (least cost) industry operation;

2) cost-effective controls to meet the demand for cement; and 3) emission reduction requirements over the time period of interest.

The first step in using ISMP 2025 projected emissions is matching the kilns in future years to those in the 2011 NEI. While ISMP provides by-kiln emissions for each future year, the EPA cement kilns experts preferred that the agency project existing cement kilns based on a more-smooth geographic approach to reduce the "on/off" switching that ISMP assigns to each kiln based on production and capacity demands. It would be inefficient and unrealistic to project existing cement kilns to operate as essentially 0 percent or 100 percent capacity based strictly on ISMP output. Therefore, the EPA developed a U.S. Census Division approach where ISMP emissions in 2011 and future years, that matched the 2011 NEI (e.g., not new ISMP kilns), were aggregated by pollutant for each year within each of the nine census divisions in the contiguous U.S. (http://www.eia.gov/consumption/commercial/images/cendivco.gif). These aggregate emissions were used to create 2025/2011 emissions ratios for each pollutant and geographic area. The projection ratios, provided in Table 4-24, were then applied to all 2011 NEI cement kilns, except for kilns where specific local information (e.g., consent decrees/settlements/local information) was available.

Table 4-24. U.S. Census Division ISMP-based projection factors for existing kilns

Region	Division	NOx	PM	SO_2	VOC
		2025	2025	2025	2025
Midwest	East North Central	2.053	0.144	3.034	0.67
Midwest	West North Central	1.279	0.673	1.262	0.492
Northeast	Middle Atlantic	1.221	0.119	0.867	0.569
Northeast	New England	2.56	0.004	3.563	0.713
South	East South Central	0.999	0.109	0.402	0.323
South	South Atlantic	1.077	0.339	0.936	0.42
South	West South Central	1.526	0.174	0.664	0.252
West	Mountain	1.321	1.032	1.366	0.345
West	Pacific	1.465	0.006	0.251	0.29

Table 4-25 shows the magnitude of the ISMP census division based projected cement industry emissions at existing NEI facilities from 2011 to future year 2025; we use 2025 projected emissions for year 2023. Additional new kiln emissions generated by ISMP are discussed in Section 4.2.5.4. There are some local exceptions where the EPA did not use ISMP-based projections for cement kilns where local information from consent decrees/settlements and state comments were used instead. Cement kilns projected using these non-ISMP information are not reflected here in Table 4-25.

Table 4-25. ISMP-based cement industry projected emissions for 2023en

	Emissions		Tons Difference	% Difference
	2011	2025	2025	2025
NO_X	47,270	67,856	20,586	43.6%
PM_{10}	2,743	967	-1,776	-64.8%

$PM_{2.5}$	1,523	598	-925	-60.7%
SO_2	11,520	21,534	10,014	86.9%
VOC	2,329	940	-1,390	-59.7%

4.2.3.8 Corn ethanol plants (ptnonipm)

Packet:

"PROJECTION_2011_2025_Corn_Ethanol_Plants_AEO2014_Table17_2011v6.2_19feb2015_v0.txt"

We used the AEO 2014 renewable forecast projections of "From Corn and Other Starch" to compute national year 2025 growth in ethanol plant production. Per OTAQ direction, we exempted two facilities ('Highwater Ethanol LLC' in Redwood county MN and 'Life Line Foods LLC-St. Joseph' in Buchanan county MO) from these projections; future year emissions were equal to their 2011 NEI v2 values for these two facilities.

The 2011 corn ethanol plant emissions were projected to account for the change in domestic corn ethanol production between 2011 and future years, from approximately 13.9 Bgal (billion gallons) in 2011 to 13.2 Bgal by 2025 based on AEO 2014 projections. The projection was applied to all pollutants and all facilities equally. Table 4-26 provides the summaries of estimated emissions for the corn ethanol plants in 2011 and future year 2025.

Table 4-26. 2011 and 2025 corn ethanol plant emissions [tons]

	Emissions		**Difference**	**% Change**
	2011	**2025**	**2025**	**2025**
CO	877	831	-46	-5.19%
NO_x	1,328	1,259	-69	-5.19%
PM_{10}	1,259	1,194	-65	-5.19%
$PM_{2.5}$	302.243	286.545	-16	-5.19%
SO_2	9.52755	9.03272	0	-5.19%
VOC	3,084	2,924	-160	-5.19%

4.2.3.9 Residential wood combustion (rwc)

Packet:

"PROJECTION_2011_2023_RWC_2011v6.3.csv"
"BETA_Projections_RWC_2023_18apr2016_emf.csv" (MARAMA)

The EPA applied the recently-promulgated national NSPS for wood stoves to the RWC projections methodology for this platform. To learn more about the strengthened NSPS for residential wood heaters, see http://www2.epa.gov/residential-wood-heaters/regulatory-actions-residential-wood-heaters. The EPA projected RWC emissions to year 2017 and 2025 based on expected increases and decreases in various residential wood burning appliances. The EPA linearly interpolated these factors to year 2023 for this modeling platform. As newer, cleaner woodstoves replace ***some*** older, higher-polluting wood stoves, there will be an overall reduction of the emissions from older "dirty" stoves but an overall increase in total RWC due to population and sales trends in all other types of wood burning devices such as indoor furnaces and outdoor hydronic heaters (OHH). It is important to note that our RWC projection methodology does not explicitly account for state or local

residential wood control programs. There are a number more-stringent state and local rules in place in 2011, specifically in California, Oregon and Washington. However, at this time, the EPA does not have enough detailed information to calculate state specific or local area growth rates. Therefore, with the exception of California, Oregon and Washington, the EPA is using national level growth rates for each RWC SCC category. After discussions with California air districts, regional office contacts and EPA experts, the EPA decided to hold RWC emissions flat (unchanged) for all SCCs in California, Oregon and Washington.

Assumed Appliance Growth and Replacement Rates

The development of projected growth in RWC emissions to year 2017 and 2025 starts with the projected growth in RWC appliances derived from year 2012 appliance shipments reported in the Regulatory Impact Analysis (RIA) for Proposed Residential Wood Heaters NSPS Revision Final Report (EPA, 2013b), also available at: http://www2.epa.gov/sites/production/files/2013-12/documents/ria-20140103.pdf. The 2012 shipments are based on 2008 shipment data and revenue forecasts from a Frost & Sullivan Market Report (Frost & Sullivan, 2010). Next, to be consistent with the RIA (EPA, 2013b), growth rates for new appliances for certified wood stoves, pellet stoves, indoor furnaces and OHH were based on forecasted revenue (real GDP) growth rate of 2.0 percent per year from 2013 through 2025 as predicted by the U.S. Bureau of Economic Analysis (BEA, 2012). While this approach is not perfectly correlated, in the absence of specific shipment projections, the RIA assumes the overall trend in the projection is reasonable. The growth rates for appliances not listed in the RIA (fireplaces, outdoor wood burning devices (not elsewhere classified) and residential fire logs) are estimated based on the average growth in the number of houses between 2002 and 2012, about 1 percent (U.S. Census, 2012).

In addition to new appliance sales and forecasts extrapolating beyond 2012, assumptions on the replacement of older, existing appliances are needed. Based on long lifetimes, no replacement of fireplaces, outdoor wood burning devices (not elsewhere classified) or residential fire logs is assumed. It is assumed that 95 percent of new woodstoves will replace older non-EPA certified freestanding stoves (pre-1988 NSPS) and 5 percent will replace existing EPA-certified catalytic and non-catalytic stoves that currently meet the 1988 NSPS (Houck, 2011).

The EPA RWC NSPS experts assume that 10 percent of new pellet stoves and OHH replace older units and that because of their short lifespan, that 10 percent of indoor furnaces are replaced each year; these are the same assumptions used since the 2007 emissions modeling platform (EPA, 2012d). The resulting growth factors for these appliance types varies by appliance type and also by pollutant because the emission rates, from EPA RWC tool (EPA, 2013rwc), vary by appliance type and pollutant. For EPA certified units, the projection factors for PM are lower than those for all other pollutants. The projection factors also vary because the total number of existing units in 2011 varies greatly between appliance types.

NSPS Overview

The residential wood heaters NSPS final rule was promulgated on February 3, 2015. This rule does not affect existing woodstoves or other wood burning devices; however, it does provide more stringent emissions standards for new woodstoves, outdoor hydronic heaters and indoor wood-burning forced air furnaces. New "Phase 1" less-polluting heater standards began in 2015, with even more-stringent Phase 2 standards beginning in 2020. The associated reduced emission rates for each appliance type (SCC) are applied to all new units sold, some of which are assumed to replace retired units, since year 2015.

Currently the 1988 NSPS limits primary $PM_{2.5}$ emissions from adjustable burn rate stoves, including fireplace inserts and freestanding woodstoves, to 7.5 grams/hour (g/hr) for non-catalytic stoves and 4.1 g/hr for catalytic stoves. The final NSPS limits $PM_{2.5}$ emissions for room heaters, which include adjustable and single burn rate

stoves and pellet stoves to 4.5 g/hr in 2015 and 1.3 g/hr in 2020. In addition, the final NSPS limits $PM_{2.5}$ emissions from hydronic heaters to 0.32 lb/MMBtu heat output in 2015, and 0.06 lb/MMBtu in 2020. The final NSPS limits $PM_{2.5}$ emissions from indoor furnaces to 0.93 lb/MMBtu in 2015 and 0.06/MMBtu in 2020.

Emission factors were estimated from the 2011v2 NEI based on tons of emissions per appliance for $PM_{2.5}$, VOC and CO. This calculation was based on estimated appliance (SCC) population and total emissions by SCC. EPA-certified wood stove emission factors are provided in the wood heaters NSPS RIA Tables 4-3, 4-7 and 4-11 for $PM_{2.5}$, VOC and CO, respectively. For all RWC appliances subject to the NSPS, baseline RIA emission factors, when lower than the computed emission factors (2011 NEI), are used for new appliances sold between 2012 and 2014. Starting in 2015, Phase 1 emission limits are 60 percent stronger (0.45 g/hr / 0.75 g/hr) than the RIA baseline emission factors. There are also different standards for catalytic versus non-catalytic EPA-certified stoves. Similar calculations are performed for Phase 2 emission limits that begin in 2020 and for different emission rates for different appliance types. Because the 2011NEI and RIA baseline (2012-2014) emission factors vary by pollutant, all RWC appliances subject to the NSPS have pollutant-specific "projection" factors. We realize that these "projection" factors are a composite of growth, retirements and potentially emission factors in 4 increments. More detailed documentation on the EPA RWC Projection Tool, including information on baseline, new appliances pre-NSPS, and Phase 1 and Phase 2 emission factors, is available upon request.

Caveats and Results

California, Oregon and Washington have state-level RWC control programs, including local burn bans in place. Without an ability to incorporate significant local RWC control programs/burn bans for a future year inventory, the EPA left RWC emissions unchanged in the future for all three states. The RWC projections factors for states other than California, Oregon and Washington are provided in Table 4-27. VOC HAPs use the same projection factors as VOC; PM_{10} uses the same factor as $PM_{2.5}$; and all other pollutants use the CO projection factor. Note that appliance types not subject to the wood heaters NSPS (e.g., fire pits, fire logs) have pollutant-independent projection factors because there is no assumed change in future year emission factors.

Table 4-27. Non-West Coast RWC projection factors, including NSPS impacts

SCC	Description	Default if pollutant not defined	PM	VOC and VOC HAPs	CO and remaining CAPs
2104008100	Fireplace: general	1.127			
2104008210	Woodstove: fireplace inserts; non-EPA certified	0.791			
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic	1.238	1.103		
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic	1.281	1.128		
2104008310	Woodstove: freestanding, non-EPA certified	0.829	0.828	0.842	0.829
2104008320	Woodstove: freestanding, EPA certified, non-catalytic	1.238	1.103		
2104008330	Woodstove: freestanding, EPA certified, catalytic	1.281	1.129		
2104008400	Woodstove: pellet-fired, general	1.852	1.898		

SCC	Description	Default if pollutant not defined	PM	VOC and VOC HAPs	CO and remaining CAPs
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	0.277	0.318	0.276	0.277
2104008610	Hydronic heater: outdoor	1.044	1.079		
2104008700	Outdoor wood burning device, NEC	1.127			
2104009000	Residential Firelog Total: All Combustor Types	1.127			

National emission summaries for the RWC sector in 2011 and 2023 are provided in Table 4-**28**. For direct PM, the NSPS emission factor reductions mostly offset the growth in appliances by year 2023.

Table 4-28**.** Cumulative national RWC emissions from growth, retirements, and NSPS impacts

Pollutant	Emissions		Difference	% Difference
	2011	2023	2023 - 2011	2023- 2011
CO	2,526,548	2,376,924	149,624	5.92%
NH_3	19,759	18,560	1,199	6.07%
NO_X	34,518	35,000	-483	-1.40%
PM_{10}	382,754	364,067	18,687	4.88%
$PM_{2.5}$	382,528	363,818	18,710	4.89%
SO_2	8,975	7,926	1,049	11.68%
VOC	444,269	417,315	26,954	6.07%

4.2.4 CoST CONTROL Packets (nonpt, np_oilgas, ptnonipm, pt_oilgas)

The final step in a CoST control strategy, after application of any/all CLOSURE packet(s) (point inventories only) and any/all PROJECTION packet(s) is the application of CoST CONTROL packets. While some controls are embedded in our PROJECTION packets (e.g., NSPS controls for RWC and loco-marine controls for rail and commercial marine vessels), we attempted to separate out the control (program) component in our modeling platform where feasible. In our platform, CoST control packets only impact the nonpt, np_oilgas, ptnonipm and pt_oilgas sectors.

There are several different sources of CONTROL data that are concatenated and quality-assured for duplicates and applicability to the inventories in the CoST strategies. We broke up the CONTROL (and PROJECTION) packets into a few "key" control program types to allow for quick summaries of these distinct control programs. The remainder of this section is broken out by CoST packet, with the exception of discussion of the various packets gathered from previous versions of the emissions modeling platform; these packets are a mix of different sources of data, only some of which have not been replaced by more recent information gathered for this platform.

For future-year NSPS controls (oil and gas, RICE, Natural Gas Turbines, and Process Heaters), we attempted to control only new sources/equipment using the following equation to account for growth and retirement of existing sources and the differences between the new and existing source emission rates.

$$Qn = Qo \{ [(1 + Pf)^t - 1] Fn + (1 - Ri)^t \, Fe + [1 - (1 - Ri)^t] Fn \} \quad \textit{Equation 1}$$

where:

Qn = emissions in projection year
Qo = emissions in base year
Pf = growth rate expressed as ratio (e.g., 1.5=50 percent cumulative growth)
t = number of years between base and future years
Fn = emission factor ratio for new sources
Ri = retirement rate, expressed as whole number (e.g., 3.3 percent=0.033)
Fe = emission factor ratio for existing sources

The first term in Equation 1 represents new source growth and controls, the second term accounts for retirement and controls for existing sources, and the third term accounts for replacement source controls. For computing the CoST % reductions (Control Efficiency), the simplified Equation 2 was used for 2023 projections:

$$Control\_Efficiency_{2023}(\%) = 100 * (1- [(Pf_{2023}-1)*Fn + (1-Ri)^{12} + (1-(1-Ri)^{12})*Fn]/ Pf_{2023}) \quad \text{Equation 2}$$

Here, the existing source emissions factor (Fe) is set to 1.0, 2023 (future year) minus 2011 (base year) is 12, and new source emission factor (Fn) is the ratio of the NSPS emission factor to the existing emission factor. Table 4-29 shows the values for Retirement rate and new source emission factors (Fn) for new sources with respect to each NSPS regulation and other conditions within; this table also provides the subsection where the CONTROL packets are discussed.

Table 4-29. Assumed retirement rates and new source emission factor ratios for various NSPS rules

NSPS Rule	TSD Section	Retirement Rate years (%/year)	Pollutants Impacted	Applied where?	New Source Emission Factor (Fn)
Oil and Gas	4.2.4.1	No assumption	VOC	Storage Tanks: 70.3% reduction in growth-only (>1.0)	0.297
				Gas Well Completions: 95% control (regardless)	0.05
				Pneumatic controllers, not high-bleed >6scfm or low-bleed: 77% reduction in growth-only (>1.0)	0.23
				Pneumatic controllers, high-bleed >6scfm or low-bleed: 100% reduction in growth-only (>1.0)	0.00
				Compressor Seals: 79.9% reduction in growth-only (>1.0)	0.201
				Fugitive Emissions: 60% Valves, flanges, connections, pumps, open-ended lines, and other	0.40
				Pneumatic Pumps: 71.3% Oil and Gas	0.287
RICE	4.2.4.3	40, (2.5%)	NO_X	Lean burn: PA, all other states	0.25, 0.606
				Rich Burn: PA, all other states	0.1, 0.069
				Combined (average) LB/RB: PA, other states	0.175, 0.338
			CO	Lean burn: PA, all other states	1.0 (n/a), 0.889

				Rich Burn: PA, all other states	0.15, 0.25
				Combined (average) LB/RB: PA, other states	0.575, 0.569
			VOC	Lean burn: PA, all other states	0.125, n/a
				Rich Burn: PA, all other states	0.1, n/a
				Combined (average) LB/RB: PA, other states	0.1125, n/a
Gas Turbines	4.2.4.6	45 (2.2%)	NO_X	California and NO_X SIP Call states	0.595
				All other states	0.238
Process Heaters	4.2.4.7	30 (3.3%)	NO_X	Nationally to Process Heater SCCs	0.41

4.2.4.1 Oil and Gas NSPS (np_oilgas, pt_oilgas)

Packet:
"oilgas_2011_2023en_control_packet_NSPS_27jul2017_07aug2017_v0"
"CONTROL_2023_OILGAS_VOC_NSPS_csv_07aug2017_v2"
"BETA_Controls_OilGas_NSPS_2023_29apr2016.csv" (MARAMA)

For oil and gas NSPS controls, with the exception of gas well completions (a 95 percent control), the assumption of no equipment retirements through year 2023 dictates that NSPS controls are applied to the growth component only of any PROJECTION factors. For example, if a growth factor is 1.5 for storage tanks (indicating a 50 percent increase activity), then, using Table 4-29, the 70.3 percent VOC NSPS control to this new growth will result in a 23.4 percent control: 100 *(70.3 * (1.5 -1) / 1.5); this yields an "effective" growth rate (combined PROJECTION and CONTROL) of 1.1485, or a 70.3 percent reduction from 1.5 to 1.0. The impacts of all non-drilling completion VOC NSPS controls are therefore greater where growth in oil and gas production is assumed highest. Conversely, for oil and gas basins with assumed negative growth in activity/production, VOC NSPS controls will be limited to well completions only. Because these impacts are so geographically varying, we are providing the VOC NSPS reductions by each of the 6 broad NEMS regions, with Texas and New Mexico aggregated because these states include multiple NEMS regions (see Figure 4-1). These reductions are year-specific because projection factors for these sources are year-specific.

Table 4-30. NSPS VOC oil and gas reductions from projected pre-control 2023en grown values

Region	Pre-NSPS emissions	Post-NSPS emissions	NSPS Reductions	NSPS % reductions
Gulf Coast	1,066	53	1,013	95%
Midcontinent	72,774	58,883	13,891	19%
New Mexico/Texas*	1,250,016	914,867	335,149	27%
Northeast	291,465	123,494	167,970	58%
Rocky Mountains	753,719	388,716	365,002	48%
West Coast	358	30	328	92%
Overall	2,369,397	1,486,043	883,354	37%

4.2.4.2 RICE NESHAP (nonpt, np_oilgas, ptnonipm, pt_oilgas)

Packet:

"CONTROL_2011v6.2_RICE_NESHAP_v2_30jan2015_v0.txt"
"BETA_Controls_RICE_NESHAP_29apr2016" (MARAMA)

There are two rulemakings for National Emission Standards for Hazardous Air Pollutants (NESHAP) for Reciprocating Internal Combustion Engines (RICE). These rules reduce HAPs from existing and new RICE sources. In order to meet the standards, existing sources with certain types of engines will need to install controls. In addition to reducing HAPs, these controls have co-benefits that also reduce CAPs, specifically, CO, NOx, VOC, PM, and SO_2. In 2014 and beyond, compliance dates have passed for both rules and are thus included in emissions projections. These RICE reductions also reflect the Reconsideration Amendments (proposed in January, 2012), which result in significantly less stringent NOx controls (fewer reductions) than the 2010 final rules.

The rules can be found at https://www.epa.gov/stationary-engines and are listed below:

- National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines; Final Rule (FR 9648) published 03/03/10.

- National Emission Standards for Hazardous Air Pollutants for Reciprocating Internal Combustion Engines; Final Rule (75 FR 51570) published 08/20/2010.

The difference among these two rules is that they focus on different types of engines, different facility types (major for HAPs, versus area for HAPs) and different engine sizes based on horsepower. In addition, they have different compliance dates, though both are after 2011 and fully implemented prior to 2017. The EPA projects CAPs from the 2011NEIv2 RICE sources, based on the requirements of the rule for existing sources only because the inventory includes only existing sources. The EPA estimates the NSPS (new source) impacts from RICE regulations in a separate CONTROL packet and CoST strategy; the RICE NSPS is discussed in the next section.

The "Regulatory Impact Analysis (RIA) for the Reconsideration of the Existing Stationary Compression Ignition (CI) Engines NESHAP: Final Report" (EPA, 2013ci) is available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/RICE_NESHAPreconsideration_Compression_Ignition_Engines_RIA_final2013_EPA.pdf. The "Regulatory Impact Analysis (RIA) for Reconsideration of the Existing Stationary Spark Ignition (SI) RICE NESHAP: Final Report" (EPA, 2013si) is available at: http://www.epa.gov/ttn/ecas/regdata/RIAs/NESHAP_RICE_Spark_Ignition_RIA_finalreconsideration2013_EPA.pdf. Together, the EPA calls these the RICE NESHAP amendment RIA's for SI and CI engines. From these RICE NESHAP RIA documents, the EPA obtained cumulative RICE reductions for all SCCs represented by CI and SI engines. These aggregate reductions and percent reductions from baseline emissions (not the 2011NEIv2) are provided in Table 4-31. This table reflects the impacts of both the MARAMA and non-MARAMA packets.

Table 4-31. Summary RICE NESHAP SI and CI percent reductions prior to 2011NEIv2 analysis

	CO	**NO_X**	**PM**	**SO_2**	**VOC**
RIA Baseline: SI engines	637,756	932,377			127,170
RIA Reductions: SI engines	22,211	9,648			9,147
RIA Baseline: CI engines	81,145		19,369	11,053	79,965

	CO	NO_X	PM	SO_2	VOC
RIA Reductions: CI engines	14,238		2,818	5,100	27,142
RIA Cumulative Reductions	36,449	9,638	2,818	5,100	36,289
SI % reduction	3.5%	1.0%	n/a	n/a	7.2%
CI % reduction	17.5%	n/a	14.5%	46.1%	33.9%

These RIA percent reductions were used as an ***upper-bound*** for reducing emissions from RICE SCCs in the 2011NEIv2 point and nonpoint modeling sectors (ptnonipm, nonpt, pt_oilgas and np_oilgas). To begin with, the RIA inventories are based on the 2005 NEI, so the EPA wanted to ensure that our 2011 reductions did not exceed those in the RICE RIA documents. For the 2011 platform, the EPA worked with EPA RICE NESHAP experts and developed a fairly simple approach to estimate RICE NESHAP reductions. Most SCCs in the inventory are not broken down by horsepower size range, mode of operation (e.g., emergency mode), nor major versus area source type. Therefore, the EPA summed NEI emissions nationally by SCC for RICE sources and also for sources that were at least partially IC engines (e.g., "Boiler and IC engines"). Then, the EPA applied the RIA percent reductions to the 2011NEIv2 for SCCs where national totals exceeded 100 tons; the EPA chose 100 tons as a threshold, assuming there would be little to no application of RICE NESHAP controls on smaller existing sources.

Next, the EPA aggregated these national reductions by engine type (CI vs. SI) and pollutant and compared these to the RIA reductions. As expected, for most pollutants and engine types, the cumulative reductions were significantly less than those in the RIA. The only exception was for SO_2 CI engines, where the EPA scaled the RIA percent reduction from 46.1 percent to 14.4 percent for four broad nonpoint SCCs that were not restricted to only RICE engines. These four SCCs were the "Boilers and IC Engines" or "All processes" that would presumably contain some fraction of non-RICE component. This had minimal impact as sulfur content in distillate fuel for many IC engine types has decreased significantly since 2005. Reducing the SO_2 percent reduction for these four SCCs resulted in slightly less than 5,100 tons of SO_2 reductions overall from only RICE NESHAP controls. However, more specific CoST projection packets would later override these RICE NESHAP reductions for SO_2. Recall the CoST hierarchy discussed earlier; these RICE NESHAP reductions are national by pollutant and SCC and thus easily overridden by more-specific information such as state-level fuel sulfur rules (discussed in the next section).

Additional comments from the NODA were also implemented; specifically, CO controls were modified for a couple of distillate-fueled industrial/commercial boiler sources. Impacts of the RICE NESHAP controls on nonpt, ptnonipm, pt_oilgas and np_oilgas sector emissions are provided in Table 4-32. This table reflects the impacts of both the MARAMA and non-MARAMA packets.

Table 4-32. National by-sector reductions from RICE Reconsideration controls for 2023en (tons)

Pollutant	Year	Nonpoint Oil & Gas (np_oilgas)	Point Oil & Gas (pt_oilgas)	Nonpoint (nonpt)	Point (ptnonipm)	Total
CO	2023	11,051	5,452	3,505	6,357	26,365
NOX	2023	3,008	2,238	216	83	5,545
PM10	2023	0	8	1,038	306	1,352
PM2.5	2023	0	8	913	289	1,210
SO2	2023	0	11	2,951	307	3,269
VOC	2023	2,192	3,723	622	934	7,471

4.2.4.3 RICE NSPS (nonpt, np_oilgas, ptnonipm, pt_oilgas)

Packet:

"oilgas_2011_2023en_control_packet_RICE_NSPS_27jul2017_07aug2017_v0"
"CONTROL_2011v6_3_2023_RICE_NSPS_18oct2016_07aug2017_v1:

"BETA_Controls_RICE_NSPS_2023_30jul2016_csv_07aug2017_v1" (MARAMA)

Controls for existing RICE source emissions were discussed in the previous section. This section discusses control for new equipment sources, NSPS controls that impact CO, NOx and VOC. The EPA emission requirements for stationary engines differ according to whether the engine is new or existing, whether the engine is located at an area source or major source, and whether the engine is a compression ignition or a spark ignition engine. Spark ignition engines are further subdivided by power cycle, two versus four stroke, and whether the engine is rich burn or lean burn.

RICE engines in the NOx SIP Call area are covered by state regulations implementing those requirements. EPA estimated that NOx emissions within the control region were expected to be reduced by about 53,000 tons per 5month ozone season in 2007 from what they would otherwise be without this program. Federal rules affecting RICE included the NESHAP for RICE (40 CFR part 63, Subpart ZZZZ), NSPS for Stationary Spark Ignition IC engines (40 CFR part 60, Subpart JJJJ), and NSPS for Compression Ignition IC engines (40 CFR part 60, Subpart IIII). SI engine operators were affected by the NSPS if the engine was constructed after June 12, 2006, with some of the smaller engines affected by the NSPS 1-3 years later. The recommended RICE equipment lifetime is 30 to 40 years depending on web searches. We chose 40 years as a conservative estimate.

The 2011 estimates of the RICE engine average emission rates for lean burn and rich burn engines was developed using the stationary engine manufacturers data submitted to the EPA for the NSPS analysis (Parise, 2005). Emission factors by pollutant for engines 500-1200 horsepower (hp) were used to develop the average emission rates. The analysis was organized this way because lean versus rich burn engine type is such a significant factor in the NOx emissions rate. Any state emission regulations that require stationary RICE engines to achieve emission levels lower than the 2012 NSPS could be included by using lower new source emission ratios that account for the additional emission reductions associated with having more stringent state permit rules. Information is provided for Pennsylvania in Table 4-33. That information shows that the Pennsylvania regulations have different emission standards for lean burn versus rich burn engines, and that the emission limits also vary by engine size (100-500 hp or greater than 500 hp). While some of the newer RICE SCCs (oil and gas sector in particular) allow states to indicate whether engines are lean versus rich burn, some SCCs lump these two together. None of the RICE point source SCCs have information about engine sizes. However, the EPA RIA for the RICE NSPS and NESHAP analysis (RTI, 2007) provides a table that shows the NOx (CO, NMHC and HAP emission estimates are provided as well) emissions in 2015 by engine size, along with engine populations by size. In the future, more rigorous analysis can use this table to develop computations of weighted average emission reductions by rated hp to state regulations like Pennsylvania's.

Table 4-33. RICE NSPS Analysis and resulting 2011v6.2 emission rates used to compute controls

Engine type & fuel	Max Engine Power	Geographic Applicability	Emission standards g/HP-hr		
			NO_X	CO	VOC
2011 pop lean burn	500-1200 hp		1.65	2.25	0.7
2011 pop rich burn	500-1200 hp		14.5	8	0.45
Non-Emerg. SI NG and Non-E. SI Lean Burn LPG (except LB 500≤HP<1,350)	HP≥100	2006 NSPS	2.0	4.0	1.0
Non-Emerg. SI NG and Non-E. SI Lean Burn LPG (except LB 500≤HP<1,350)	HP≥100	2012 NSPS	1.0	2.0	0.7
	HP≥100	PA (Previous GP-5)	2.0	2.0	2.0
New NG Lean Burn	100<HP<500	PA (New GP-5)	1.0	2.0	0.7
New NG Lean Burn	HP >500	PA (New GP-5)	0.5	2.0	0.25
New NG Rich Burn	100<HP<500	PA (New GP-5)	0.25	0.3	0.2
New NG Rich Burn	HP >500	PA (New GP-5)	0.2	0.3	0.2
	HP≥100	Maryland	1.5		
	HP>7500	Colorado	1.2 - 2		
		Wyoming	None	None	None
Notes: the above table compares the criteria pollutant emission standards from the recent NSPS with the emission limits from selected states for stationary IC engines to determine whether future year emission rates are likely to be significantly lower than for the existing engine population. States in the NO_X SIP Call region instituted NO_X emission limits for large engines well before 2011. Most of the values in the above table come from an analysis posted on the PA DEP website. The state emission limits listed above are those in place prior to 2011. Some states (like PA) have instituted tougher RICE emission limits for new and modified engines more recently.					
Note 2: Wyoming exempts all but the largest RICE engines from emission limits.					
Note 3: PA has had a size limit for new RICE engines of 1500 hp until recently (i.e., not engines bigger than 1500 hp can be installed). Their new General Permit-5 removed the engines size cap, but requires new or modified larger engines to be cleaner (i.e., has emission limits lower than the NSPS). PA expects that the new emission limits will result in an increase in larger engines being installed, and bringing the average emission rate much lower than it is currently.					
New source Emissions Rate (Fn): Controls % =100 * (1-Fn)			**NO_X**	**CO**	**VOC**
Pennsylvania	NG-Comb. LB & RB		0.175	0.575	0.113
All other states	NG-Comb. LB & RB		0.338	0.569	1.278
Pennsylvania	NG-lean burn		0.250	1.000	0.125
All other states	NG-lean burn		0.606	0.889	1.000
Pennsylvania	NG-rich burn		0.100	0.150	0.100
All other states	NG-rich burn		0.069	0.250	1.556

We applied NSPS reduction for lean burn, rich burn and "combined" (not specified). We also computed scaled-down (less-stringent) NSPS controls for SCCs that were "IC engines + Boilers" because boiler emissions are not subject to RICE NSPS. For these SCCs, we used the 2011NEIv2 point inventory to aggregate eligible (fuel and type) boiler and IC engine emissions for each pollutant. We found that for CI engines, almost all emissions were boiler-related; therefore, there are no CI engine RICE NSPS reductions for "IC engines + Boilers." For SI engines, we found that approximately 9 percent of NOx, 10 percent of CO and 19 percent of VOC "IC engines + Boilers" were IC engines; these splits were then applied to the NSPS reductions in Table 4-33. Finally, we limited RICE NSPS-eligible sources (SCCs) to those that have at least 100 tons nationally for NOx, CO or VOC, and ignored resulting controls that were under 1 percent.

Pennsylvania DEP staff note that until recently they have limited RICE engines to a maximum of 1500 hp. That cap is lifted under the new General Permit-5 regulations. With that cap lifting, Pennsylvania expects that new applications will choose to install larger engines which have lower emission limits. However, that potential effect will be difficult to capture with no information about how this might occur. These controls were then plugged into *Equation 2* (see Section 4.2.4) as a function of the projection factor. Resulting controls greater than or equal to 1 percent were retained. Note that where new emissions factors >=1.0 (uncontrolled, as represented by red cells at the bottom of Table 4-33), no RICE NSPS controls were computed. National RICE NSPS reductions from projected pre-NSPS 2023 inventory is shown in Table 4-34. This table reflects the impacts of both the MARAMA and non-MARAMA packets.

Table 4-34. National by-sector reductions from RICE NSPS controls for 2023en (tons)

Pollutant	Year	Nonpoint Oil & Gas (np_oilgas)	Point Oil & Gas (pt_oilgas)	Nonpoint (nonpt)	Point (ptnonipm)	Total NSPS reductions	Pre-NSPS total emissions	NSPS % reduction
CO	2023	37,637	45,012	2,278	1,344	86,270	396,892	22%
NOX	2023	42,141	108,925	3,903	2,027	156,997	574,683	27%
VOC	2023	2,641	689	0	2	3,332	5,528	60%

4.2.4.4 ICI boilers (nonpt, ptnonipm, pt_oilgas)

Packets:

CONTROL_2011v6.2_20xx_BoilerMACT_POINT_v2_30jan2015_v0.txt
CONTROL_2011v6.2_20xx_BoilerMACT_NONPT_08jan2015_11jan2016_nf_v1.txt
NCDAQ_CONTROL_2011v6_2_2017_BoilerMACT_POINT_revised_07jan2016_v0.txt
BETA_Controls_BOILER_MACT_24aug2016.csv (MARAMA)

The Industrial/Commercial/Institutional Boilers and Process Heaters MACT Rule, hereafter simply referred to as the "Boiler MACT," was promulgated on January 31, 2013, based on reconsideration. Background information on the Boiler MACT can be found at: https://www.epa.gov/stationary-sources-air-pollution/clean-air-act-standards-and-guidelines-energy-engines-and. The Boiler MACT promulgates national emission standards for the control of HAPs (NESHAP) for new and existing industrial, commercial, and institutional (ICI) boilers and process heaters at major sources of HAPs. The expected cobenefit for CAPs at these facilities is significant and greatest for SO_2 with lesser impacts for direct PM, CO and VOC. These packets address only the expected cobenefits to existing ICI boilers. MARAMA supplied their own control packet that covers the MACT Rule impacts for their states.

Boiler MACT reductions were computed from a non-NEI database of ICI boilers. As seen in the Boiler MACT Reconsideration RIA (see docket item EPA-HQ-OAR-2002-0058-3876 on http://regulations.gov, EPA 2011c), this Boiler MACT Information Collection Request (ICR) dataset computed over 558,000 tons of SO_2 reductions by year 2015. However, the Boiler MACT ICR database and reductions are based on the assumption that if a unit *could* burn oil, it *did* burn oil, and often to capacity. With high oil prices and many of these units also able to burn cheaper natural gas, the 2011NEIv2 inventory has a lot more gas combustion and a lot less oil combustion than the boiler MACT database. For this reason, the EPA decided to target units that potentially could be subject to the Boiler MACT and compute preliminary reductions for several CAPs prior to building a control packet.

Step 1: Extract facilities/sources potentially subject to Boiler MACT

This step is only applicable to point inventory sources. The EPA did not attempt to map each ICR unit to the NEI units, instead choosing to use a more general approach to extract NEI sources that would be potentially subject to, and hence have emissions reduced by the Boiler MACT. The NEI includes a field that indicates whether a facility is a major source of HAPs and/or CAPs. This field in our FF10 point inventory modeling file is called "FACIL_CATEGORY_CODE" and the possible values for that field are shown in Table 4-35.

Table 4-35. Facility types potentially subject to Boiler MACT reductions

Code	Facility Category	Subject to Boiler MACT?	Description
CAP	CAP Major	N	Facility is Major based upon 40 CFR 70 Major Source definition paragraph 2 (100 tpy any CAP. Also meets paragraph 3 definition, but NOT paragraph 1 definition).
HAP	HAP Major	Y	Facility is Major based upon only 40 CFR 70 Major Source definition paragraph 1 (10/25 tpy HAPs).
HAPCAP	HAP and CAP Major	Y	Facility meets both paragraph 1 and 2 of 40 CFR 70 Major Source definitions (10/25 tpy HAPs and 100 tpy any CAP).
HAPOZN	HAP and O3 n/a Major	Y	Facility meets both paragraph 1 and 3 of 40 CFR 70 Major Source definitions (10/25 tpy HAPs and Ozone n/a area lesser tons for NO_X or VOC).
NON	Non-Major	N	Facility's Potential to Emit is below all 40 CFR 70 Major Source threshold definitions without a FESOP.
OZN	O3 n/a Major	N	Facility is Major based upon only 40 CFR 70 Major Source definition paragraph 3 (Ozone n/a area lesser tons for NO_X or VOC).
SYN	Synthetic non-Major	N	Facility has a FESOP which limits its Potential To Emit below all three 40 CFR 70 Major Source definitions.
UNK	Unknown	N	Facility category per 40 CFR 70 Major Source definitions is unknown.

Because the Boiler MACT rule applies to only major sources of HAPs, the EPA restricted the universe of facilities potentially subject to the Boiler MACT to those classified as HAP major or unknown (UNK). The third column indicates whether the facility was a candidate for extraction as being potentially subject to the Boiler MACT.

Step 2: Merge control information with 2011 NEI and apply state NODA comments

The EPA analyzed the SCCs in the OTC 2007 inventories and tweaked the SCC mapping of these ICI boiler adjustments to map to those in the 2011 NEI point and nonpoint inventory with non-zero emissions. The EPA also removed some duplicate and incorrect mappings and expanded the SCC mapping in some cases to SCCs that were in the NEI, but not the OTC inventory (and thus missing from the analysis).

Some states commented on the 2011v6.0 ICI boiler controls via the 2018 NODA (docket # EPA-HQ-OAR-2013-0809 on http://www.regulations.gov). Wisconsin provided alternative SO_2, VOC and HCl controls for stoker and pulverized coal fueled units. The national-level and Wisconsin-specific ICI boiler adjustments, applied at the unit-level for point sources and by SCC (and state for Wisconsin) are provided in Table 4-36; note that we applied the same national-level adjustments to CO, NOx and PM for coal units in Wisconsin. New York and New Jersey, via the MARAMA comment/data to the 2018 NODA, provided boiler rule NOx reductions that also supersede these nationally-applied factors. The New Jersey and New York factors are provided in Table 4-37; note that New Jersey controls apply only to nonpoint sources and that New York controls vary by fuel for point sources.

Table 4-36. National-level, with Wisconsin exceptions, ICI boiler adjustment factors by base fuel type

Unit/Fuel Type	Default % Reduction (Adjustments)					
	CO	NOX	PM	SO2	VOC	HCl
Stoker Coal	98.9	70.7	96	97.4	98.9	95
Pulverized Coal	98.9	60.6	72.2	73	98.9	95
Residual Oil	99.9	57	92.4	97.1	99.9	95
Distillate Oil	99.9	38.8	68.4	99.9	99.9	88.6
Wisconsin: Stoker Coal	98.9	70.7	96	30	0	45
Wisconsin: Pulverized Coal	98.9	60.6	72.2	30	0	45

Table 4-37. New York and New Jersey NO_X ICI Boiler Rules that supersede national approach

NJ and NY Boiler Rule controls	NOX % Reduction
New Jersey Small Boiler Rule (nonpoint only): Default for Distillate, Residual, natural gas and LPG	25
New York Small Boiler Rule (nonpoint only): Default for Distillate, Residual, natural gas and LPG	10
NY Boiler Rule: Industrial /Distillate Oil /< 10 Million Btu/hr	10
NY Boiler Rule: Industrial /Residual Oil /10-100 Million Btu/hr	33.3
NY Boiler Rule: Electric Gen /Residual Oil /Grade 6 Oil: Normal Firing	40
NY Boiler Rule: Electric Gen /Natural Gas /Boilers, < 100 Million Btu/hr except Tangent	50
NY Boiler Rule: Electric Gen /Natural Gas /Boilers, 100 Million Btu/hr except Tangent	60
NY Boiler Rule: Industrial /Bitum Coal /Cyclone Furnace	66.7
NY Boiler Rule: Industrial /Natural Gas /> 100 Million Btu/hr	70
NY Boiler Rule: Electric Gen /Bituminous Coal /Pulverized Coal: Dry Bottom	73.3

The impacts of these ICI boiler reductions are provided in Table 4-38. This table reflects the impacts of both the MARAMA and non-MARAMA packets. Overall, the CO and $PM_{2.5}$ reductions are reasonably close to the year-2015 expected reductions in the Boiler MACT Reconsideration RIA (see docket item EPA-HQ-OAR-2002-0058-3876 on http://regulations.gov). It is worth noting that the SO_2 reductions in the preamble for the Boiler MACT Reconsideration (76 FR 80532; https://www.epa.gov/stationary-sources-air-pollution/industrial-commercial-and-institutional-boilers-and-process-heaters) were estimated at 442,000 tons; the additional SO_2 reductions in the reconsideration are from an additional co-benefit from more stringent HCl controls. The 2011NEIv2 SO_2 emissions are actually less than the estimated Boiler MACT reductions, likely a result of numerous units undergoing fuel switching from coal or oil to natural gas.

Table 4-38. Summary of ICI Boiler reductions for 2023en

Year	Pollutant	Emissions Eligible for Control	Controlled (Final) Emissions	Reductions (tons)	% Reductions
CO	2023	20,568	3,760	16,808	81.7%
NOX	2023	65,430	31,226	34,204	52.3%
PM10	2023	9,050	2,140	6,910	76.4%
PM2.5	2023	6,540	1,601	4,939	75.5%

SO2	2023	142,660	25,677	116,983	82.0%
VOC	2023	1,222	187	1,035	84.7%

4.2.4.5 Fuel sulfur rules (nonpt, ptnonipm, pt_oilgas)

Packet:

"CONTROL_2011v6.2_20xx_Fuel_Sulfur_Rules_09jan2015_v0.txt"
"BETA_Controls_MANEVU_SULFUR_2016_08_24.csv" (MARAMA)

Fuel sulfur rules, based on web searching and the 2011 emissions modeling NODA comments, are currently limited to the following states: Connecticut, Delaware, Maine, Massachusetts, New Jersey, New York, Pennsylvania, Rhode Island and Vermont. The fuel limits for these states are incremental starting after year 2012, but are fully implemented by July 1, 2018, in all of these states.

A summary of all fuel sulfur rules provided back to the EPA by the 2011 emissions modeling NODA comments is provided in Table 4-39. State-specific control factors were computed for distillate, residual and #4 fuel oil using each state's baseline sulfur contents and the sulfur content in the rules. For most states, the baseline sulfur content was 3,000 ppm (0.3 percent) for distillate oil, and 2.25 percent for residual and #4 oil. However, many states had lower baseline sulfur contents for residual oil, which varied by state and county. The SRA used state- or county-specific baseline residual oil sulfur contents to calculate a state- or county-specific control factors for residual oil (SRA, 2014).

A summary of the sulfur rules by state, with emissions reductions is provided in Table 4-40. This table reflects the impacts of the MARAMA packet only, as these reductions are not estimated in non-MARAMA states. Most of these reductions (98+ percent) occur in the nonpt sector; a small amount of reductions occur in the ptnonipm sector, and a negligible amount of reductions occur in the pt_oilgas sector. Note that these reductions are based on intermediate 2023 inventories, those grown from 2011 to the specific future years.

Table 4-39. State Fuel Oil Sulfur Rules data provided by MANE-VU

State	Reference
Connecticut	Section 22a-174-19a. Control of sulfur dioxide emissions from power plants and other large stationary sources of air pollution: Distillate and Residual: 3000 ppm effective April 15, 2014. Section 22a – 174 - 19b. Fuel Sulfur Content Limitations for Stationary Sources (except for sources subject to Section 22a-174-19a). Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 Residual: 1.0% effective July 1, 2014; 0.3% effective July 1, 2018 Connecticut General Statute 16a-21a. Sulfur content of home heating oil and off-road diesel fuel. Number 2 heating oil and off-road diesel fuel: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 See: http://www.ct.gov/deep/cwp/view.asp?a=2684&Q=322184&deepNav_GID=1619
Delaware	1108 Sulfur Dioxide Emissions from Fuel Burning Equipment Distillate: 15 ppm effective July 1, 2017 Residual: 0.5% effective July 1, 2017 #4 Oil: 0.25% effective July 1, 2017 See: http://regulations.delaware.gov/AdminCode/title7/1000/1100/1108.shtml
Maine	Chapter l06: Low Sulfur Fuel Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 Residual: 0.5% effective July 1, 2018 See: http://www.mainelegislature.org/legis/bills/bills_124th/billpdfs/SP062701.pdf.
Massachusetts	310 CMR 7.05 (1)(a)1: Table 1 : Sulfur Content Limit of Liquid Fossil Fuel Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 Residual: 1.0% effective July 1, 2014; 0.5% effective July 1, 2018 See: http://www.mass.gov/eea/docs/dep/service/regulations/310cmr07.pdf
New Jersey	Title 7, Chapter 27, Subchapter 9 Sulfur in Fuels

State	Reference
	Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2016 Residual: 0.5% or 0.3%, depending on county, effective July 1, 2014 #4 Oil: 0.25% effective July 1, 2014 See: http://www.nj.gov/dep/aqm/rules27.html
New York	Subpart 225-1 Fuel Composition and Use - Sulfur Limitations Distillate: 15 ppm effective July 1, 2016 Residual: 0.3% in New York City effective July 1, 2014; 0.37% in Nassau, Rockland and Westchester counties effective July 1, 2014; 0.5% remainder of state effective July 1, 2016 See: http://www.nyc.gov/html/dep/html/news/dep_stories_p3-109.shtml and http://green.blogs.nytimes.com/2010/07/20/new-york-mandates-cleaner-heating-oil/?_r=1 and http://switchboard.nrdc.org/blogs/rkassel/governor_paterson_signs_new_la.html
Pennsylvania	§ 123.22. Combustion units Distillate: 500 ppm effective July 1, 2016 Residual: 0.5% effective July 1, 2016 #4 Oil: 0.25% effective July 1, 2016 See: http://www.pacode.com/secure/data/025/chapter123/s123.22.html
Rhode Island	Air Pollution Control Regulations No. 8 Sulfur Content of Fuels Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 Residual: 0.5% effective July 1, 2018 See: http://www.dem.ri.gov/pubs/regs/regs/air/air08_14.pdf
Vermont	5-221(1) Sulfur Limitations in Fuel Distillate: 500 ppm effective July 1, 2014; 15 ppm effective July 1, 2018 Residual: 0.5% effective July 1, 2018 #4 Oil: 0.25% effective July 1, 2018 See: http://www.epa.gov/region1/topics/air/sips/vt/VT_Section5_221.pdf

Table 4-40. Summary of fuel sulfur rule impacts on SO_2 emissions for 2023en

Year	Emissions Eligible for Control	Controlled (Final) Emissions	Reductions	% Reductions
2023	90,764	10,035	80,729	88.9%

4.2.4.6 Natural gas turbines NOx NSPS (ptnonipm, pt_oilgas)

Packet:
"CONTROL_2011v6.2_2025_NOX_GasTurbines_16dec2014_v0.txt"
"BETA_Controls_GasTurbines_NSPS_2023_30jul2016.csv" (MARAMA)

These controls were generated based on examination of emission limits for stationary combustion turbines that are not in the power sector. In 2006, the EPA promulgated standards of performance for new stationary combustion turbines in 40 CFR part 60, subpart KKKK. The standards reflect changes in NOx emission control technologies and turbine design since standards for these units were originally promulgated in 40 CFR part 60, subpart GG. The 2006 NSPSs affecting NOx and SO_2 were established at levels that bring the emission limits up-to-date with the performance of current combustion turbines. Stationary combustion turbines were also regulated by the NOx SIP (State Implementation Plan) Call, which required affected gas turbines to reduce their NOx emissions by 60 percent.

Table 4-41 compares the 2006 NSPS emission limits with the NOx RACT regulations in selected states within the NOx SIP Call region. The map showing the states and partial-states in the NOx SIP Call Program can be found at: http://www3.epa.gov/airmarkets/progress/reports/program_basics.html. We assigned only those counties in Alabama, Michigan and Missouri as NOx SIP call based on the map on page 8. The state NOx

RACT regulations summary (Pechan, 2001) is from a year 2001 analysis, so some states may have updated their rules since that time.

Table 4-41. Stationary gas turbines NSPS analysis and resulting emission rates used to compute controls

NOx Emission Limits for New Stationary Combustion Turbines				
Firing Natural Gas	**<50 MMBTU/hr**	**50-850 MMBTU/hr**	**>850 MMBTU/hr**	
Federal NSPS	100	25	15	ppm
State RACT Regulations	**5-100 MMBTU/hr**	**100-250 MMBTU/hr**	**>250 MMBTU/hr**	
Connecticut	225	75	75	ppm
Delaware	42	42	42	ppm
Massachusetts	65*	65	65	ppm
New Jersey	50*	50	50	ppm
New York	50	50	50	ppm
New Hampshire	55	55	55	ppm
* Only applies to 25-100 MMBTU/hr				
Notes: The above state RACT table is from a 2001 analysis. The current NY State regulations have the same emission limits.				
	New source emission rate (Fn)		**NOx ratio**	**Control (%)**
NOx SIP Call states plus CA	= 25 / 42 =		0.595	40.5%
Other states	= 25 / 105 =		0.238	76.2%

Regarding stationary gas turbine lifetimes, the IPM financial modeling documentation lists the book life of combustion turbines as 30 years, with a debt life of 15 years, and a U.S. MACRS Depreciation Schedule of 15 years (EPA, 2013). This same documentation lists the book life of nuclear units at 40 years. IPM uses a 60-year lifetime for nuclear units in its simulations of unit retirements. Using the same relationship between estimated lifetime and book life for nuclear units of 1.5, the estimated lifetime for a combustion turbine would be 45 years. This is the same as an annual retirement rate of 2.2 percent.

For projection factor development, the existing source emission ratio was set to 1.0 for combustion turbines. The new source emission ratio for the NOx SIP Call states and California is the ratio of state NOx emission limit to the Federal NSPS. A complicating factor in the above is the lack of size information in the stationary source SCCs. Plus, the size classifications in the NSPS do not match the size differentiation used in state air emission regulations. We accepted a simplifying assumption that most industrial applications of combustion turbines are in the 100-250 MMBtu/hr size range, and computed the new source emission rates as the NSPS emission limit for 50-850 MMBtu/hr units divided by the state emission limits. We used a conservative new source emission ratio by using the lowest state emission limit of 42 ppmv (Delaware). This yields a new source emission ratio of 25/42, or 0.595 (40.5 percent reduction) for states with existing combustion turbine emission limits. States without existing turbine NO_x limits would have a lower new source emission ratio -the uncontrolled emission rate (105 ppmv via AP-42) divided into 25 ppmv = 0.238 (76.2 percent reduction). This control was then plugged into *Equation 2* (see Section 4.2.4) as a function of the year-specific projection factor. Resulting controls greater than or equal to 1 percent were included in our projections. National Process Heaters

NSPS reductions from projected pre-NSPS 2023 inventory are shown in Table 4-42. This table reflects the impacts of both the MARAMA and non-MARAMA packets.

Table 4-42. National by-sector 2023en NO_X reductions from Stationary Natural Gas Turbine NSPS controls

Sector	Pre-NSPS Emissions	NSPS Reductions	NSPS % Reductions
Non-EGU Point (ptnonipm)	15,109	4,070	27%
Point Oil & Gas (pt_oilgas)	74,020	23,448	32%
Total	89,129	27,518	31%

4.2.4.7 Process heaters NO_X NSPS (ptnonipm, pt_oilgas)

Packet:
"CONTROL_2011v6.2_2025_NOX_Process_heaters_09dec2014_v0.txt"
"BETA_Controls_ProcessHeaters_NSPS_2023_30jul2016.csv" (MARAMA)

Process heaters are used throughout refineries and chemical plants to raise the temperature of feed materials to meet reaction or distillation requirements. Fuels are typically residual oil, distillate oil, refinery gas, or natural gas. In some sense, process heaters can be considered as emission control devices because they can be used to control process streams by recovering the fuel value while destroying the VOC. The criteria pollutants of most concern for process heaters are NOx and SO_2.

In 2011, process heaters have not been subject to regional control programs like the NOx SIP Call, so most of the emission controls put in-place at refineries and chemical plants have resulted from RACT regulations that were implemented as part of SIPs to achieve ozone NAAQS in specific areas, and refinery consent decrees. The boiler/process heater NSPS established NOx emission limits for new and modified process heaters. These emission limits are displayed in Table 4-43.

In order to develop a relationship between the typical process heater emission rates in 2011 compared with what the NSPS will require of new and modified sources, an analysis of the materials in the EPA docket (EPA-HQ-OAR-2007-0011) for the NSPS was performed. This docket contained an EPA memorandum that estimated the NOx emissions impacts for process heaters. Table 1 in that memo titled, "Summary of Representative Baseline NOx Concentrations for Affected Process Heaters," analysis can be used to establish an effective 2011 process heater NOx emission rate, although the information that EPA used in the revised NOx impact estimates probably uses data from a few years before 2011. It is likely that the data used are representative of 2011 emissions because the only wide-ranging program that has affected process heater emission rates recently have been consent decrees, and the emission reductions associated with these agreements should have been achieved before 2011. However, the compliance schedules are company-specific, and differ by company, so it is difficult to make overarching conclusions about when compliance occurred.

Table 4-43. Process Heaters NSPS analysis and 2011v6.2 new emission rates used to compute controls

NO_X emission rate Existing (Fe)	**Fraction at this rate**		
PPMV	**Natural Draft**	**Forced Draft**	**Average**
80	0.4	0	
100	0.4	0.5	
150	0.15	0.35	
200	0.05	0.1	
240	0	0.05	
Cumulative, weighted: Fe	104.5	134.5	**119.5**
NSPS Standard	40	60	
New Source NO_X ratio (Fn)	0.383	0.446	**0.414**
NSPS Control (%)	61.7	55.4	**58.6**

The EPA states that because it "does not have much data on the precise proportion of process heaters that are forced versus natural draft, so the nationwide impacts are expressed as a range bounded by these two scenarios." (Scenario 1 assumes all of the process heaters are natural draft process heaters and Scenario 2 assumes all of the process heaters are forced draft process heaters.)

For computations, the existing source emission ratio (Fe) was set to 1.0. The computed (average) NO_x emission factor ratio for new sources (Fn) is 0.41 (58.6 percent control). The retirement rate is the inverse of the expected unit lifetime. There is limited information in the literature about process heater lifetimes. This information was reviewed at the time that the Western Regional Air Partnership (WRAP) developed its initial regional haze program emission projections, and energy technology models used a 20-year lifetime for most refinery equipment. However, it was noted that in practice, heaters would probably have a lifetime that was on the order of 50 percent above that estimate. Therefore, a 30-year lifetime was used to estimate the effects of process heater growth and retirement. This yields a 3.3 percent retirement rate. This control was then plugged into *Equation 2* (see Section 4.2.4) as a function of the year-specific projection factor. Resulting controls greater than or equal to 1 percent were retained. National Process Heaters NSPS reductions from projected pre-NSPS 2023 inventory are shown in Table 4-44. This table reflects the impacts of both the MARAMA and non-MARAMA packets.

Table 4-44. National by-sector NO_X reductions from Process Heaters NSPS controls for 2023en

Sector	**Pre-NSPS Emissions**	**NSPS Reductions**	**NSPS % Reductions**
Non-EGU Point (ptnonipm)	72,798	20,151	28%
Point Oil & Gas (pt_oilgas)	7,352	1,828	25%
Total	80,149	21,979	27%

4.2.4.8 Arizona regional haze controls (ptnonipm)

Packet:

"CONTROL_2011v6.2_20xx_AZ_Regional_Haze_PT_24feb2015_v0.txt"

U.S. EPA Region 9 provided regional haze FIP controls for a few industrial facilities. Information on these controls are available in the *Federal Register* (EPA-R09-OAR-2013-0588; FRL-9912-97-OAR) at http://www.federalregister.com. These non-EGU controls have implementation dates between September 2017 and December 2018 and, therefore, do not reduce emissions in year 2017 projections. Year 2025 emissions are reduced at 5 smelter and cement units: NOx by 1,722 tons and SO_2 by 26,423 tons.

4.2.4.9 CISWI (ptnonipm)

Packet:

"CONTROL_CISWI_2011v6_22nov2013_v0.txt"

On March 21, 2011, the EPA promulgated the revised NSPS and emission guidelines for Commercial and Industrial Solid Waste Incineration (CISWI) units. This was a response to the voluntary remand that was granted in 2001 and the vacatur and remand of the CISWI definition rule in 2007. In addition, the standards re-development included the 5-year technology review of the new source performance standards and emission guidelines required under Section 129 of the Clean Air Act. The history of the CISWI implementation is documented here: https://www.epa.gov/stationary-sources-air-pollution/commercial-and-industrial-solid-waste-incineration-units-ciswi-new. Baseline and CISWI rule impacts associated with the CISWI rule are documented here: https://www.regulations.gov/document?D=EPA-HQ-OAR-2003-0119-2559. The EPA mapped the units from the CISWI baseline and controlled dataset to the 2011 NEI inventory and because the baseline CISWI emissions and the 2011 NEI emissions were not the same, the EPA computed percent reductions such that our future year emissions matched the CISWI controlled dataset values. CISWI controls are applied in Arkansas and Louisiana only, totaling 3,100 and 3,552 tons of SO_2 reductions in years 2017 and 2025 respectively. The reductions are greater in year 2025 because they are applied to year-specific projected (grown) emissions.

4.2.4.10 Petroleum Refineries: NSPS Subpart Ja (ptnonipm)

Packets:

"CONTROL_2011v6_3_2017_NSPS_Subpart_JA_07aug2017_v0"

On June 24, 2008, EPA issued final amendments to the Standards of Performance for Petroleum Refineries. This action also promulgated separate standards of performance for new, modified, or reconstructed process units after May 14, 2007 at petroleum refineries. The final standards for new process units included emissions limitations and work practice standards for fluid catalytic cracking units, fluid coking units, delayed coking units, fuel gas combustion devices, and sulfur recovery plants. In 2012, EPA finalized the rule after some amendments and technical corrections. See https://www.epa.gov/stationary-sources-air-pollution/petroleum-refineries-new-source-performance-standards-nsps-40-cfr for more details on NSPS – 40 CFR 60 Subpart Ja. These NSPS controls were implemented in the 2023en case in a CONTROL packet (CONTROL_2011v6_3_2017_NSPS_Subpart_JA_07aug2017_v0) that was applied to petroleum refineries in the ptnonipm sector. Table 4-39 below reflects the impacts of these NSPS controls on the ptnonipm sector.

Table 4-45. National emissions reductions from Petroleum Refineries NSPS controls for 2023en.

Year	Pollutant	Emissions Eligible for Control	Controlled (Final) Emissions	Reductions (tons)	% Reductions
NOX	2023	10,353	7,696	2,657	26%
SO2	2023	24,709	14,896	9,813	40%
VOC	2023	3,731	682	3,049	82%

4.2.4.11 Data from comments on previous platforms and recent comments (nonpt, ptnonipm, pt_oilgas)

Packets:

"CONTROL_2011v6.2_20xx_State_comments_2018docket_nonpt_15jan2015_v0.txt"
"CONTROL_2011v6_2_20xx_CD_St_com_2018docket_pt_15jan2015_fixed_01sep2015_v0.txt"
"BETA_Controls_STATE_RULES_AND_CONSENT_DECREES_2016_08_11.csv" (MARAMA)
"BETA_Controls_OTC_RULES_2016_08_13.csv" (MARAMA)

All remaining non-EGU point and nonpoint controls are discussed in this section. For the nonpoint sector, these controls are limited to comments/data-responses on the previous emissions modeling platforms, and the 2018 NODA process. For point sources, controls include data from the 2018 NODA process as well as a concatenation of all remaining controls not already discussed. These controls are split into separate packets for point and nonpoint sources.

Nonpoint packet: (CONTROL_2011v6.2_20xx_State_comments_2018docket_nonpt_15jan2015_v0.txt)
This packet contains all nonpoint controls not already discussed in previous sections (e.g., Fuel Sulfur rules, ICI boilers) provided in response to the 2018 NODA, and is restricted to VOC controls for Delaware, Massachusetts, Pennsylvania and Virginia, with the great majority of these controls restricted to Virginia. These VOC controls cover various state programs and rules such as auto refinishing, adhesives and surface coatings. Cumulatively, these VOC controls reduce nonpoint VOC by approximately 3,900 tons in 2017 and 4,100 tons in 2025.

Point packet: CONTROL_2011v6_2_20xx_CD_St_com_2018docket_pt_15jan2015_fixed.txt

This packet contains all point controls not already discussed in previous sections (e.g., Fuel Sulfur rules, ICI boilers). This packet includes new controls information provided in response to the 2018 NODA as well as "legacy" controls from the 2011v6.0 emissions modeling platform from numerous sources such as settlement and consent decree data gathering efforts, comments received during the CSAPR rulemaking process, regional haze modeling, and stack-specific control information provided by TCEQ.

New control information from the 2018 NODA responses is primarily limited to VOC controls from several states: Delaware, Massachusetts, New Jersey, Pennsylvania and Virginia. However, we also received comments with revised compliance dates, removal of existing control information, and updated controls from local settlements. The CONTROL packet comments field provides information on the source of new control information, where available.

The "old" control information includes information discussed in previous emissions modeling platforms; these CONTROL packet components are discussed in Section 4.2.9 in the 2011v6.1 emissions modeling platform TSD (EPA, 2014b).

Cumulative ptnonipm and pt_oilgas reductions to 2023 pre-controlled (projection factors already applied) from this CONTROL packet are shown in Table 4-46. This table reflects the impacts of both the MARAMA and non-MARAMA packets. In the August, 2016 data provided by MARAMA, impacts from the Pennsylvania RACT regulations were included. The estimated PA RACT NOx reduction for cement kilns, glass melting, and natural gas transmission was approximately 7700 tons. There were six MWC facilities in Pennsylvania be subject to RACT for a total of 19 units. However, these were not adjusted because all but one were found to alrady be emitting at rates under the applicable NOx RACT limit. The one unit that was found to be above the limit was not adjusted due to its small impact of approximately 6 tons. In addition, note that some of the natural gas transmission sources in Pennsylvania were affected by both RACT and the gas turbine NSPS.

Table 4-46. Summary of remaining nonpt, ptnonipm and pt_oilgas reductions for 2023en

Year	Pollutant	Emissions Eligible for Control	Controlled (Final) Emissions	Reductions	% Reductions
2023	CO	5,554	754	4,799	86%
2023	NH3	213	52	161	76%
2023	NOX	96,249	47,796	48,453	50%
2023	PM10	4,055	1,944	2,111	52%
2023	PM2.5	3,643	1,766	1,877	52%
2023	SO2	122,036	25,357	96,679	79%
2023	VOC	30,031	22,954	7,077	24%

For 2023en, additional reductions to ptnonipm sources were made to account for coal mine trucks in Wyoming getting cleaner in future years. The reductions were based on percent reductions to heavy duty offroad construction trucks and are shown in Table 4-47.

Table 4-47. Reductions in Wyoming coal mine trucks in 2023en

Year	Pollutant	Emissions Eligible for Control	Controlled (Final) Emissions	Reductions	% Reductions
2023	CO	17,238	3,475	13,763	78%
2023	NOX	15,808	8,332	7,477	47%
2023	PM10	1,051	240	811	77%
2023	PM2.5	1,024	234	790	77%
2023	SO2	343	208	134	39%
2023	VOC	190	158	31	17%

4.2.5 Stand-alone future year inventories (nonpt, ptnonipm)

This section discusses future year NEI non-EGU point and nonpoint emission inventories that were not created via CoST strategies/programs/packets. These inventories are either new to the future years because they did not exist in 2011 (e.g., new cement kilns, biodiesel and cellulosic plants), or are a complete replacement to the year 2011 NEI inventory in the case of portable fuel containers. New non-EGU facilities provided by South Carolina via the 2018 NODA on the 2011v6.0 platform were mistakenly omitted from both year 2017 and 2025 emissions modeling processing. Cumulatively, these new facilities would have added approximately 200 tons of NO_x, and under 100 tons of each of the remaining CAPs.

4.2.5.1 Portable fuel containers (nonpt)

Future year inventory: "pfc_2025_2011v6.2_ff10_28jan2015_13sep2016_v2.csv"

The EPA used future-year VOC emissions from Portable Fuel Containers (PFCs) from inventories developed and modeled for EPA's MSAT2 rule (EPA, 2007a). The six PFC SCCs are summarized below (note that the full SCC descriptions for these SCCs include "Storage and Transport; Petroleum and Petroleum Product Storage" as the beginning of the description).

- 2501011011 Residential Portable Fuel Containers: Permeation
- 2501011012 Residential Portable Fuel Containers: Evaporation
- 2501011014 Residential Portable Fuel Containers: Refilling at the Pump: Vapor Displacement
- 2501012011 Commercial Portable Fuel Containers: Permeation
- 2501012012 Commercial Portable Fuel Containers: Evaporation
- 2501012014 Commercial Portable Fuel Containers: Refilling at the Pump: Vapor Displacement

The future-year emissions reflect projected increases in fuel consumption, state programs to reduce PFC emissions, standards promulgated in the MSAT2 rule, and impacts of the RFS2 standards on gasoline volatility. The EPA developed year 2025 PFC emissions that include estimated Reid Vapor Pressure (RVP) and oxygenate impacts on VOC emissions, and more importantly, large increases in ethanol emissions from RFS2. These emission estimates also include gas can vapor displacement, tank permeation and diurnal emissions from evaporation. Because the future year PFC inventories contain ethanol in addition to benzene, the EPA developed a VOC E-profile that integrated ethanol and benzene (see Section 3.2.1.2 of the 2011v6.3 platform TSD for more details). Note that spillage emissions were not projected and were carried forward from 2011. We received projection and control packets from MARAMA in August 2016. We applied these packets to the PFC inventory to obtain year 2023 emissions for the MARAMA states. The names of these packets were the following:

- BETA_Projections_PFC_2023_10aug2016_emf.csv
- BETA_Controls_PFC_28jul2016.csv

A summary of the resulting PFC emissions for 2011 and 2025 (used for 2023) for MARAMA and non-MARAMA states are provided in Table 4-48. Note that for MARAMA states, PFCs were projected from 2011, with separate projections for 2023 and 2028. For non-MARAMA states, the EPA 2025 PFC inventory was used for 2023. Note that the EPA PFC inventory includes ethanol, but MARAMA inventories do not because they were projected from the 2011NEIv2.

Table 4-48. PFC emissions for 2011 and 2023 [tons]

	MARAMA Emissions		Difference	% Change
	2011	2023	2023	2023
VOC	38,152	12,595	-25,557	-67.0%
Benzene	463	474	10	2.3%

	non-MARAMA Emissions		Difference	% Change
	2011	2025	2025	2025
VOC	160,051	46,498	-113,553	-70.9%
Benzene	323	613	290	89.8%
Ethanol	0	3,294	n/a	

4.2.5.2 Biodiesel plants (ptnonipm)

New Future year inventory: "Biodiesel_Plants_2018_ff10"

The EPA's OTAQ developed an inventory of biodiesel plants for 2018. Plant location and production volume data came from the Tier 3 proposed rule[44,45]. The total volume of biodiesel came from the AEO 2013 early release, 1.3 BG for 2018. To reach the total volume of biodiesel, plants that had current production volumes were assumed to be at 100 percent production and the remaining volume was split among plants with planned production. Once facility-level production capacities were scaled, emission factors based on soybean oil feedstock were applied. These emission factors in Table 4-49 are in tons per million gallons (Mgal) and were obtained from the EPA's spreadsheet model for upstream EISA impacts developed for the RFS2 rule (EPA, 2010a). Inventories were modeled as point sources with *Google Earth* and web searching validating facility coordinates and correcting state-county FIPS.

Table 4-49. Emission Factors for Biodiesel Plants (Tons/Mgal)

Pollutant	Emission Factor
VOC	4.3981E-02
CO	5.0069E-01
NO_X	8.0790E-01
PM_{10}	6.8240E-02
$PM_{2.5}$	6.8240E-02
SO_2	5.9445E-03
NH_3	0
Acetaldehyde	2.4783E-07
Acrolein	2.1290E-07
Benzene	3.2458E-08
1,3-Butadiene	0
Formaldehyde	1.5354E-06

[44] U.S. EPA 2014.Regulatory Impact Analysis for Tier 3 Vehicle Emission and Fuel Standards Program. EPA-420-RD-143-0052.
[45] Cook, R. 2014. Development of Air Quality Reference Case Upstream and Portable Fuel Container Inventories for Tier 3 Final Rule. Memorandum to Docket EPA-HQ-OAR-2010-0162.

Table 4-50 provides the 2018 biodiesel plant emissions estimates. Since biofuels were not projected to change significantly between 2018 and 2023 the year 2018 inventory was used for year 2023. Emissions in 2011 are assumed to be near zero, and HAP emissions in 2023 are nearly zero. The emission factor for ethanol is 0.

Table 4-50. 2018 biodiesel plant emissions [tons]

Pollutant	2018
CO	649
NO_X	1048
PM_{10}	89
$PM_{2.5}$	89
SO_2	8
VOC	57

4.2.5.3 Cellulosic plants (nonpt)

New Future year inventories:
Primary inventory: "2018_cellulosic_inventory"
New Iowa inventory: "cellulosic_new_Iowa_plants_from2018docket_2011v6.2_ff10_28jan2015"

Development of primary inventory
Depending on available feedstock, cellulosic plants are likely to produce fuel through either a biochemical process or a thermochemical process. The EPA developed county-level inventories for biochemical and thermochemical cellulosic fuel production for 2018 to reflect AEO2013 energy renewable fuel volumes. Emissions factors for each cellulosic biofuel refinery reflect the fuel production technology used rather than the fuel produced. Emission rates in Table 4-51 and Table 4-52 were used to develop cellulosic plant inventories. Criteria pollutant emission rates are in tons per RIN gallon. Emission factors from the cellulosic diesel work in the Tier 3 NPRM were used as the emission factors for the thermochemical plants. Cellulosic ethanol VOC and related HAP emission factors from the Tier 3 NPRM were used as the biochemical VOC and related HAP emission factors. Because the future year cellulosic inventory contains ethanol, a VOC E-profile that integrated ethanol was used; see Section 3.2 of the 2011v6.3 platform TSD for more details.

Plants were treated as area sources spread across the entire area of whatever county they were considered to be located in. Cellulosic biofuel refinery siting was based on utilizing the lowest cost feedstock, accounting for the cost of the feedstock itself as well as feedstock storage and the transportation of the feedstock to the cellulosic biofuel refinery. The total number of cellulosic biofuel refineries was projected using volumes from AEO2013 (early release). The methodology used to determine most likely plant locations is described in Section 1.8.1.3 of the RFS2 RIA (EPA, 2010a). Table 4-53 provides the year 2018 cellulosic plant emissions estimates that were used in this year 2023 modeling platform.

Table 4-51. Criteria Pollutant Emission Factors for Cellulosic Plants (Tons/RIN gallon)

Cellulosic Plant Type	VOC	CO	NO_X	PM_{10}	$PM_{2.5}$	SO_2	NH_3
Thermochemical	5.92E-07	8.7E-06	1.31E-05	1.56E-06	7.81E-07	1.17E-06	1.44E-10
Biochemical	1.82E-06	1.29E-05	1.85E-05	3.08E-06	1.23E-06	6.89E-07	0

Table 4-52. Toxic Emission Factors for Cellulosic Plants (Tons/RIN gallon)

Plant Type	Acetaldehyde	Acrolein	Benzene	1,3-Butadiene	Formaldehyde	Ethanol
Thermochemical	2.95E-08	1.27E-09	9.61E-10	0	5.07E-09	2.09E-07
Biochemical	3.98E-07	1.11E-08	1.39E-08	0	2.28E-08	6.41E-07

Table 4-53. 2017 cellulosic plant emissions [tons]

Pollutant	Emissions
Acrolein	1
Formaldehyde	3
Benzene	0
Acetaldehyde	15
CO	4,435
Ethanol	106
NH_3	0
NO_X	6,702
PM_{10}	793
$PM_{2.5}$	398
SO_2	596
VOC	302

Development of new Iowa inventory

The Iowa DNR (Department of Natural Resources), via the 2018 NODA comments (see docket # EPA-HQ-OAR-2013-0809 under http://www.regulations.gov), provided information on new cellulosic ethanol capacity information for three facilities. Emissions for these facilities were computed using the emission factors previously discussed in Table 4-51 and Table 4-52. The resulting new facilities and NOx emissions, used for year 2023 are provided in Table 4-54. Note that these facilities are in a nonpoint inventory because latitude-longitude coordinates were not available.

Table 4-54. New cellulosic plants NOx emissions provided by Iowa DNR**.**

FIPS	County	Facility Name	Approximate Production Capacity (Mgal/yr)	NO_X Emissions
19093	Ida	Quad County Corn Processors' Adding Cellulosic Ethanol (ACE)	2	26
19147	Palo Alto	POET-DSM Project Liberty	25	329
19169	Story	DuPont Cellulosic Ethanol	30	394

4.2.5.4 New cement plants (nonpt)

Nonpoint Inventories: "cement_newkilns_year_2025_from_ISIS2013_NEI2011v1_NONPOINT_v0.csv"

As discussed in Section 4.2.3.7, the ISMP model, was used to project the cement manufacturing sector to future years. This section covers new ISMP-generated kilns that did not exist in the 2011 NEI. For kilns that were new in 2018, the EPA used two different approaches for modeling. The ISMP model created "generic" kilns in specific geographically strategic locations (counties) to cover the need for increased production/capacity in future years. Because these generic kilns are not permitted and the location in these counties is uncertain, these are modeled at the county-level to avoid placing new large modeled emissions sources into one grid cell. These nonpoint source kilns were then spatially allocated based on industrial land activity in the county.

For all ISMP future year emissions, PM_{10} is assigned as 0.85 of total PM provided by ISMP, and $PM_{2.5}$ is assigned as 0.15 of total PM. New ISMP-generated kilns are assigned as Precalciner kilns (SCC=30500623). While ISMP provides emissions for mercury, the EPA did not retain these in our modeling. Table 4-55 shows the magnitude of the new ISMP-based cement kilns. ISMP-generated kilns as nonpoint sources only.

Table 4-55. ISMP-generated nonpoint cement kiln emissions

Pollutant	Nonpoint Emissions
NO_X	10,255
$PM_{2.5}$	23
SO_2	5,311
VOC	250

4.2.5.5 New units from states (ptnonipm)

The State of Wisconsin Department of Natural Resources and MARAMA provided comments on the NODA for the 2011v6.3 platform that included the suggestion of new units for the ptnonipm sector that will be running by the year 2023 for the states of Wisconsin, Delaware, and West Virginia. The units listed in Table 4-56 have been incorporated into this platform.

File: "2023en_ptnonipm_new_units_state_comments_DE_WV_WI_09aug2017_v0.csv"

Table 4-56. New Non-EGU Point Units for 2023

Facility name	**EIS Facility ID**	**EIS Unit IDs**
Ameresco Delaware Energy-Central	16812111	113545813
Ameresco Delaware Energy-Southern	16810211	108718913
CRODA INC.	588911	108721913
PPG Industries, INC., Natrium Plant	4878711	71796413
Union Carbide Corporation	6884411	UCCI_B016, UCCI_B017, UCCI_B018, UCCI_B019, UCCI_B020

Facility name	EIS Facility ID	EIS Unit IDs
Williams Ohio Valley Midstream - Fort Beeler Gas Processing Plant	16886211	110325313, 110325513, 110325613, 110325713, 110325813, 110325913, 110326113, 110326213, 110326413, 110326513, 110326613, 110326713, 110326813, 110326913, 110327013, 110327113, 110327213, 110327313, 110327413
Armstrong World Industries - Millwood Facility	16886111	110321113, 110321313, 110321413, 110321513, 110321613, 110321713, 110321813, 110321913, 110322013, 110322113, 110322213
Williams Ohio Valley Midstream - Moundsville Fractionation Plant	16886311	110327513, 110327813, 110327913, 110328013
Marathon Petroleum - Neal Propane Cavern	16886611	110333413, 110333513, 110333613
Williams Ohio Valley Midstream - Moundsville Fractionation Plant	16886311	110327613, 110327713
Marathon Petroleum - Butane Cavern	16886511	110333113, 110333213, 110333313
Georgia-Pacific Consumer Products LP	4944011	113709613
Proctor & Gamble Paper Products CO	4943711	125438213
Packaging Corporation of America-Tomahawk	4985811	113802813
Expera Specialty Solutions INC	4943911	122251813

4.3 Mobile source projections

Mobile source monthly inventories of onroad and nonroad mobile emissions were created for 2023 using a combination of the MOVES2014a and the NMIM models. The 2023 onroad emissions account for changes in activity data and the impact of on-the-books rules including some of the recent regulations such as the Light Duty Vehicle GHG Rule for Model-Year 2017-2025, and the Tier 3 Motor Vehicle Emission and Fuel Standards Rule (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3). Local inspection and maintenance (I/M) and other onroad mobile programs are included such as California LEVIII, the National Low Emissions Vehicle (LEV) and Ozone Transport Commission (OTC) LEV regulations (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-new-motor-vehicles-and-2), local fuel programs, and Stage II refueling control programs. Table 4-1 provides references to many of these programs.

Nonroad mobile emissions reductions for these years include reductions to various nonroad engines such as diesel engines and recreational marine engine types (pleasure craft), fuel sulfur content, and evaporative emissions standards.

Onroad mobile sources are comprised of several components and are discussed in Section 4.3.1. Monthly nonroad equipment mobile emission projections are discussed in Section 4.3.2. Locomotives and CMV projections were discussed in Section 4.2.3.3.

4.3.1 Onroad mobile (onroad)

The onroad emissions for 2023 use the same SMOKE-MOVES system as for the base year (see Section 2.1). Meteorology, speed, spatial surrogates and temporal profiles, representative counties, and fuel months were the same as for 2011. For the 2011v6.3 platform, the EPA developed activity data and emissions factors directly for 2023.

4.3.1.1 Future activity data

Estimates of total national VMT in 2023 came from AEO 2016 (https://www.eia.gov/outlooks/aeo/) transportation projections. Trends were developed by calculating ratios between 2017 AEO and 2023 AEO[46] estimates and applying the trends to the 2017 VMT from the 2011v6.3 emissions platform. In states for which we received 2018 VMT for use in the 2011v6.2 and 2011v6.3 emissions platforms, 2018 state-submitted VMT was projected using AEO trends from 2018 to 2023, rather than from 2017 to 2023. These ratios were developed for light versus heavy duty and for four fuel types: gasoline, diesel, E-85, and CNG. The projection factors, the national 2017 VMT from the 2011v6.3 platform ("VMT 2017") by broad vehicle and fuel type, and the default future VMT ("VMT 2023") are shown in Table 4-57. Note that where states provided 2018 VMT, the 2023 VMT does not exactly equal the 2017 VMT times the ratio.

Table 4-57. Projection factors for 2023 (in millions of miles)[47]

Classification	MOVES source types	VMT 2017	Ratio 2023	VMT 2023
LD gas	11,21,31,32	2,894,984	1.02357	2,958,777
HD gas	42,43,51,52,53,54	22,600	1.10173	25,018
HHD gas	61	835	1.83151	1,528
LD diesel	21,31,32	93,339	2.33508	212,725
HD diesel	41,42,43,51,52,53,54	73,374	1.10235	80,857
HHD diesel	61,62	151,984	1.05092	159,783
Bus CNG	42	480	1.00496	487
LD E-85	21,31,32	14,784	1.16852	17,245
Total	N/A	3,252,378	N/A	3,456,420

In the above table, light duty (LD) includes passenger cars, light trucks, and sometimes motorcycles, heavy duty (HD) includes buses and single unit trucks, and heavy-heavy duty (HHD) includes combination trucks. The specific MOVES source type codes are listed above. These national SCC6 ratios were applied to the 2017ek VMT to create an EPA estimate of 2023 VMT at the county, SCC level.

Two additional steps were incorporated into the VMT projections. First, a set of states provided 2018 VMT projections for use in the 2011v6.2 and 2011v6.3 emissions platforms: Alabama, Connecticut, Georgia, Maine, Maryland, Massachusetts, Michigan, Missouri, Nevada, New York, New Jersey, North Carolina, Utah,

[46] By "2017 AEO" and "2023 AEO," this refers to the AEO2016's estimates of national VMT in those specific calendar years.
[47] Note: The LD ratios were further adjusted to take into account of high vs low growth of human population (discussed below). On average, the LD ratios match those in this table. For the actual VMT, see the inventory packaged with the cases. In addition, areas for which we incorporated state-submitted VMT for 2018 into the 2011v6.3 emissions platform were projected from 2018 to 2023, rather than from 2017.

Vermont, Virginia, and Wyoming[48]. For these states, 2018 VMT was projected to 2023 using AEO2016-based trends from 2018 to 2023, similarly to how the rest of the country was projected using AEO2016-based trends from 2017 to 2023. This was done so that the 2018-to-2017 backcasting performed in the 2011v6.3 emissions platform, which is based on older AEO estimates (AEO2014), would not affect these new 2023 projections. Second, the EPA adjusted the national LD ratios so that it would reflect regional differences in growth rate. The EPA analyzed LD VMT and corroborated that it had a high correlation with human population. Therefore, if a region has strong human population growth in the future, it will likely have larger VMT growth than the national average. To take account of this spatial difference in growth, the EPA used human population to adjust the national LD VMT growth rate so that on average the growth rate matched the national average, but any specific county growth rate was adjusted by the human population growth for that county:

$$VMTprojFactor_{sc} = AEOprojFactor_{s} * (1 + D((\frac{humanProjFactor_{c}}{natlhumanProjFactor}) - 1))$$

where

- s = source type/fuel
- c = county
- VMTprojFactor = county VMT projection factor (by source/fuel)
- AEOprojFactor = national VMT projection factor from AEO (by source/fuel)
- humanProjFactor = human projection factor for the county (year specific)
- natlhumanProjFactor = national human projection factor (year specific)
- D = damping factor, 0 = no county adjustment, 1 = full county variation

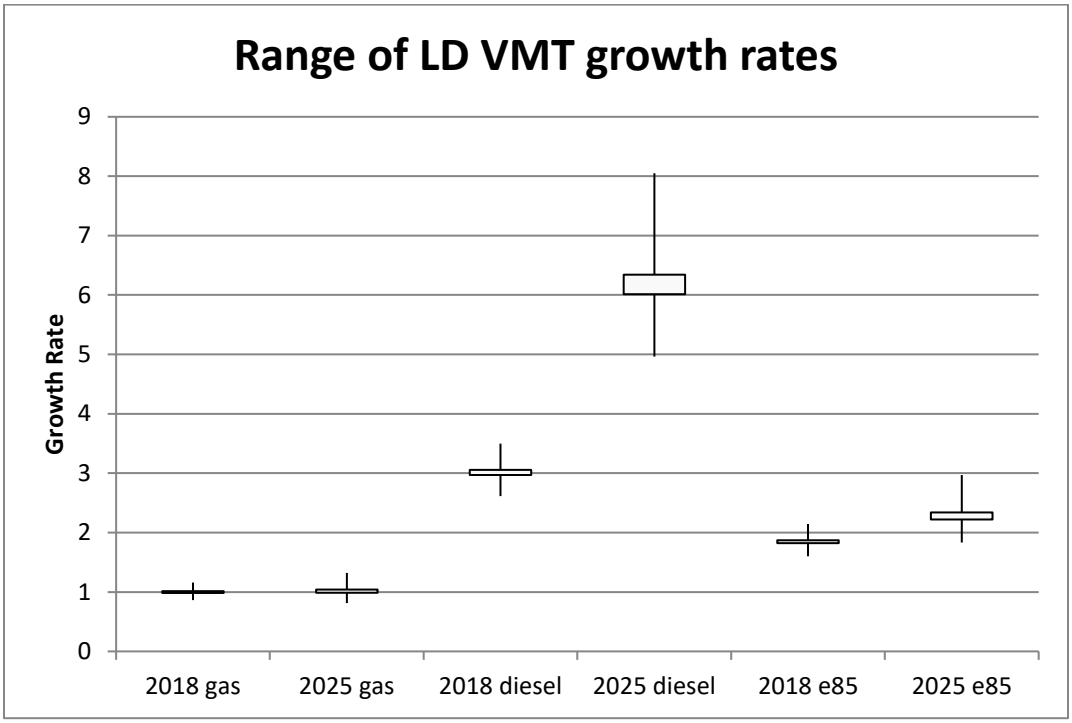
The specific value of D used for EPA projections was 0.5. This was based on an analysis of the growth of LD vehicles over time as compared to human population, which was found to be about 0.5 vehicles per person. The LD growth rates will vary by county, fuel, and year. The range of these growth rates are shown in Figure 4-3.

Vehicle population (VPOP) was developed by creating VMT/VPOP ratios from the 2011NEIv2 VMT and 2011NEIv2 VPOP at the county, fuel and vehicle type (SCC6) level. These ratios were applied to the 2023 VMT to create a 2023 VPOP.

Hoteling (HOTELING) was developed by creating VMT/HOTELING ratios from the 2011 NEIv2 VMT and 2011 NEIv2 HOTELING at the county level. For these ratios, the VMT was limited to combination long-haul trucks (SCC6 220262) on restricted access roads. The HOTELING was the total of auxiliary power units (APU) and extended idle (EXT). These ratios were applied to the 2023 VMT to create a 2023 HOTELING. To get the APU split, 22.62 percent of HOTELING was assumed to be APU in all counties. This is consistent with MOVES2014a default splits for APU for calendar years 2017 and 2025, interpolated to 2023.

[48] For many of these states, we used the county total from the state data and distributed those totals to EPA's SCCs based on default projected VMT. For Michigan, SEMCOG provided the Detroit projections and the rest of the counties came from the state. For Missouri, the state provided the 5 counties around St Louis. For Nevada, the EPA received projections only for Clark County. For Georgia, the state agreed with our default projection method but they wanted to use Georgia-provided human population projections for distributing the LD VMT growth rates to counties. They provided the human population for the 21 Atlanta counties. For the remaining counties, Georgia asked to use EPA defaults.

Figure 4-3. Light Duty VMT growth rates based on AEO2014



4.3.1.2 Set up and run MOVES to create emission factors

Emission factor tables were created by running SMOKE-MOVES using the same procedures and models as described for 2011 (see the 2011NEIv2 TSD and Section 2.1). The same meteorology and the same representative counties were used. Changes between 2011 and future years (2023) are predominantly due to activity data, fuels, national and local rules, and age distributions. Age (i.e., model year) distributions were projected forward using the methodology described in the MOVES activity report (EPA, 2016c), although some states supplied age distributions in their CDBs. Fleet turnover resulted in a greater fraction of newer vehicles meeting stricter emission standards. The similarities and differences between the two runs are described in Table 4-58.

Table 4-58. Inputs for MOVES runs for 2023

Element	**2023 MOVES Inputs**
Code	MOVES20151201 (MOVES2014a)
Rep. county database	285RepCos2023_M2014_20160520
Default database	movesdb20151028
VMT and VPOP	2023el
Hydrocarbon speciation	CB6v2 done inside MOVES
Fuels	M2014a_fuelsupply AND regioncountytrnoda_20151203
CA LEVIII	ca_standards_SS_20140903 (16 states)

The following states were modeled as having adopted the California LEV III program (see Table 4-59):

Table 4-59. CA LEVIII program states

FIPS	State Name
06	California
09	Connecticut
10	Delaware
23	Maine
24	Maryland
25	Massachusetts
34	New Jersey
36	New York
41	Oregon
42	Pennsylvania
44	Rhode Island
50	Vermont
53	Washington

Fuels were projected into the future using estimates from the AEO2014 (http://www.eia.gov/forecasts/aeo/), release date May 7th 2014, as well as fuel properties changing as part of the Tier 3 Emissions and Fuel Standards Program (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3). The AEO2014 projection includes market shares of E10, E15, and E85 in 2018, as well as biodiesel market shares up to B5 (note that these values do not assume full implementation of the RFS2 program). The regional fuel properties and renewable volumes in 2011 were projected to 2018 in order to preserve the regional variation present in these fuel supplies, with total fuel volumes aligned to those in the AEO2014.

4.3.1.3 California and Texas adjustments

A set of adjustments were done in SMOKE-MOVES to create 2023 emissions: 1) refueling, and 2) California and Texas emissions.

The first set of adjustment factors was for refueling. This uses the same approach as was used in 2011 (see the Section 2.1 for details) to account for the few counties in Colorado that provided point source gas refueling emissions. These adjustments essentially zero out the MOVES-based gasoline refueling emissions (SCC 2201*62) in these counties so that the point estimates will be used instead and, thus, refueling emissions will not be double-counted.

The second set of adjustment factors was used to incorporate future year emissions provided by California. The same approach as was used in 2011 was used to match the emissions totals provided by CARB. The only differences between the 2011 approach and that applied for 2023 are that the latter uses the 2023 emissions provided by CARB and the 2023 EPA SMOKE-MOVES output to apportion and temporalize the emissions.

The third set of adjustment factors was meant to incorporate emissions provided by Texas. Conceptually, the EPA used the trend of 2017 to 2023 based on the EPA's estimates to project Texas' submitted emissions for 2017. Mathematically, this is equivalent to taking the Texas adjustment factors derived for 2017 and applying them directly to EPA's 2023 run.

4.3.2 Nonroad Mobile Source Projections (nonroad)

The projection of locomotive and CMV emissions to 2023 is described in Section 4.2.3.3. Most of the remaining sources in the nonroad sector are projected by running the NMIM model with fuels and vehicle populations appropriate to 2023; this section describes the projection of these sources.

The nonroad sector includes monthly exhaust, evaporative and refueling emissions from nonroad engines (not including commercial marine, aircraft, and locomotives) derived from NMIM for all states except California and Texas. NMIM provides nonroad emissions for VOC by three emission modes: exhaust, evaporative and refueling.

With the exception of California and Texas, U.S. emissions for the nonroad sector (defined as the equipment types covered by the NONROAD model) were created using a consistent NMIM-based approach as was used for 2011. Specifically, NMIM version 20090504 utilized NONROAD2008a including future-year equipment population estimates, control programs to the year 2023, and inputs were either state-supplied as part of the 2011NEIv1 and 2011NEIv2 process or national level inputs. Fuels for 2023 were assumed to be E10 everywhere for nonroad equipment. The databases used in the 2023 run were NMIM county database "NCD20160627_nei2023v1" and fuels for the year 2023. The 2023 emissions account for changes in activity data (based on NONROAD model default growth estimates of future-year equipment population) and changes in fuels and engines that reflect implementation of national regulations and local control programs that impact each year differently due to engine turnover.

The version of NONROAD used was the current public release, NR08a, which models all in-force nonroad controls. The represented rules include:

- "Clean Air Nonroad Diesel Final Rule - Tier 4", published June, 2004: https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-nonroad-diesel.
- Control of Emissions from Nonroad Large Spark-Ignition Engines, and Recreational Engines (Marine and Land-Based), November 8, 2002 ("Pentathalon Rule").
- Small Engine Spark Ignition ("Bond") Rule, October, 2008: https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-small-equipment-tools.

Not included are voluntary local programs such as encouraging either no refueling or evening refueling on Ozone Action Days.

California and Texas nonroad emissions

Similar to the 2011 base year nonroad mobile, NMIM was not used to generate future-year nonroad emissions for California. The CARB-supplied 2023 nonroad annual inventories, which included all CAPs including NH_3, were distributed to monthly emissions values by using monthly temporal profiles assigned by SCC. This is a change from future year California nonroad inventories in prior emissions platforms, in which NMIM monthly inventories were used to compute monthly ratios by county, SCC7, mode and pollutant. See Section 3.2 of the 201v6.3 TSD for details on speciation of California nonroad data. The CARB nonroad emissions include nonroad rules reflected in the December 2010 Rulemaking Inventory (http://www.arb.ca.gov/regact/2010/offroadlsi10/offroadisor.pdf) and those in the March 2011 Rule Inventory, the Off-Road Construction Rule Inventory for "In-Use Diesel."

For Texas, the EPA combined Texas' submitted estimates for 2011 with EPA projections of nonroad emissions into 2023. The EPA used the trend of 2011 to 2023 based on EPA's estimates to project Texas' submitted

emissions for 2011. The projections were based on state-wide SCC7, mode, poll ratios[49] of 2023 NMIM to 2011 NMIM. These ratios were then applied to Texas' submitted 2011 nonroad emissions, which had already been distributed to a monthly inventory to create 2023 monthly nonroad inventories. Please refer to the 2011v6.3 TSD (EPA, 2016) for more information on the year 2011 data obtained from Texas.

4.4 Projections of "Other Emissions": Offshore Category 3 Commercial Marine Vessels and Drilling Platforms, Canada and Mexico (othpt, othar, and othon)

As described in Section 2.5, emissions from Canada, Mexico, and drilling platforms are included as part of three emissions modeling sectors: othpt, othar, and othon. For oil drilling platforms, the EPA used emissions from the 2011NEIv2 point source inventory for 2011 and both future years. The Canadian onroad (othon) and nonroad emissions in othar sector for the 2023en case consisted of year 2025 inventory dataset acquired from Environment Canada (see Tables 5-11 and 5-12). The Canadian point sources in for the othpt sector consisted of year 2025 inventory dataset acquired from Environment Canada (see Table 5-13). Area, nonroad, and point emissions for Mexico are based on the Inventario Nacional de Emisiones de Mexico, 2008 projected to years 2018 and 2025, then interpolated to 2023 (ERG, 2014a). Onroad emissions for Mexico are based on run of MOVES-Mexico for 2023 (ERG, 2016).

[49] These ratios were initially attempted by county/SCC7/mode/pollutant, but due to significantly different distributions of certain source types between the EPA and TCEQ's emissions, this created unreasonable growth in certain areas. The above approach was used except in the following, relatively limited conditions. If a state/SCC7/mode/pollutant was in the EPA's 2023 emissions but not in the EPA's 2011 emissions; 2023 EPA emissions were used in the final inventory. If a state/SCC7/mode/pollutant was in TCEQ's 2011 emissions but was not in EPA's 2023 emissions, then state/SCC3/mode/pollutant ratios were used to project to 2023.

5 Emission Summaries

The following tables summarize emissions differences between the 2011 evaluation case and the 2023 base case. These summaries are provided at the national level by sector for the contiguous U.S. and for the portions of Canada and Mexico inside the smaller 12km domain (12US2) discussed in Section 0. The afdust sector emissions represent the summaries *after* application of both the land use (transport fraction) and meteorological adjustments; therefore, this sector is called "afdust_adj" in these summaries. The onroad sector totals are post-SMOKE-MOVES totals, representing air quality model-ready emission totals, and include CARB emissions for California and TCEQ emissions for Texas. The cmv sector includes U.S. emissions within state waters only; these extend to roughly 3-5 nautical miles offshore and includes CMV emissions at U.S. ports. "Offshore to EEZ" represents CMV emissions that are within the (up to) 200 nautical mile EEZ boundary but are outside of U.S. state waters along with the offshore oil platform emissions from the NEI. Finally, the "Non-US SECA C3" represents all non-U.S. and non-Canada emissions outside of the (up to) 200nm offshore boundary, including all Mexican CMV emissions. Canadian CMV emissions are included in the othar sector.

National emission totals by air quality model-ready sector are provided for all CAP emissions for the 2011 evaluation case in Table 5-1. The total of all sectors in the 2011 evaluation case are listed as "Con U.S. Total." Table 5-2 provides national emissions totals by sector for CAPs in the 2023 base case.

Table 5-3 provides national-by sector emission summaries for CO for the 2011 evaluation case and 2023 base case, along with percent change from 2011 to 2023. Table 5-4 through Table 5-9 provide the same summaries for NH_3, NOx, $PM_{2.5}$, PM_{10}, SO_2 and VOC, respectively. Note that the same fire emissions are used in all cases. Tables 5-10 through Table 5-12 provide summaries of the Canadian emissions for the entire country used in the 2011 and 2023 base cases for onroad, area, and point source emissions. Tables 5-13 through Table 5-15 provide summaries of the Mexican emissions for the entire country used in the 2011 and 2023 base cases for onroad, area, and point source emissions

Table 5-1. National by-sector CAP emissions summaries for the 2011 evaluation case

Sector	CO	NH_3	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC
afdust_adj				6,732,941	923,590		
ag		3,515,198					
agfire	1,030,817	3,321	46,035	152,837	101,379	17,755	80,540
cmv_c1c2	58,543	167	288,726	9,712	9,294	6,217	7,696
cmv_c3	11,955	65	125,374	9,946	8,829	84,992	4,888
nonpt	1,645,989	94,242	720,454	491,825	404,258	276,332	3,671,322
np_oilgas	635,942	0	667,068	17,784	16,333	17,232	2,482,590
nonroad	13,951,020	2,627	1,630,301	162,417	154,657	4,031	2,024,419
onroad	25,981,557	120,859	5,708,150	326,900	188,925	28,195	2,713,181
ptfire	20,562,697	329,330	333,398	2,171,987	1,844,263	165,773	4,688,094
ptegu	792,414	25,066	2,096,058	283,066	208,122	4,670,713	38,060
ptnonipm	2,297,549	66,048	1,212,616	477,328	320,816	1,049,374	800,815
pt_oilgas	235,162	5,947	509,856	14,585	13,935	66,577	164,098
rail	122,703	347	791,381	25,898	23,963	7,936	40,851
rwc	2,517,844	19,693	34,436	381,476	381,252	8,954	442,541
Con U.S. Total	**69,844,194**	**4,182,911**	**14,163,853**	**11,258,702**	**4,599,616**	**6,404,080**	**17,159,096**
Offshore to EEZ	176,338	188	904,453	26,401	24,692	139,270	81,713
Non-US SECA C3	16,191	0	191,001	16,228	14,930	120,316	6,878
Canada othafdust				1,192,039	242,374		
Canada othar	2,038,390	338,056	376,758	288,021	157,205	33,464	776,733
Canada othon	1,507,754	6,326	332,349	15,107	5,014	1,270	138,319
Canada othpt	512,629	11,390	231,609	51,137	25,784	522,537	166,284
Canada ptfire_mxca	798,710	13,037	14,048	87,398	73,401	6,481	194,844
Mexico othar	186,575	168,840	183,383	90,691	42,623	10,184	420,637
Mexico othon	1,476,625	2,154	363,342	8,788	3,254	4,432	136,891
Mexico othpt	153,387	3,945	333,368	59,325	45,963	471,847	57,090
Mexico ptfire_mxca	736,810	13,583	31,403	104,125	87,025	6,394	172,196
Non-US Total	**7,603,409**	**557,519**	**2,961,713**	**1,939,261**	**722,265**	**1,316,195**	**2,151,585**

* “Offshore to EEZ” includes both the offshore point emissions, and the “Offshore to EEZ” c3marine emissions.

Table 5-2. National by-sector CAP emissions summaries for the 2023 base case

Sector	CO	NH_3	NO_X	PM_{10}	$PM_{2.5}$	SO_2	VOC
afdust_adj				7,498,365	1,009,616		
ag		3,602,039					
agfire	1,030,817	3,321	46,035	152,837	101,379	17,755	80,540
cmv_c1c2	57,696	170	175,059	5,387	5,155	1,987	5,241
cmv_c3	18,569	65	105,567	2,126	1,884	4,824	7,639
nonpt	1,682,696	94,695	733,016	509,892	427,719	96,043	3,452,177
np_oilgas	690,025	0	670,895	24,780	21,786	49,707	2,966,396
nonroad	12,627,798	3,228	856,831	84,153	78,858	2,380	1,177,147
onroad	11,300,137	82,106	1,786,856	232,752	79,527	12,114	987,796
ptfire	20,562,697	329,330	333,398	2,171,987	1,844,263	165,773	4,688,094
ptegu	598,510	29,691	1,051,725	173,057	138,932	1,335,974	32,702
ptnonipm	2,271,136	64,691	1,156,792	473,720	320,641	731,219	782,504
pt_oilgas	231,798	5,917	424,595	15,508	14,847	64,990	177,353
rail	145,627	376	563,382	14,236	13,165	340	21,384
rwc	2,368,934	18,499	34,918	362,897	362,651	7,908	415,748
Con U.S. Total	**53,586,440**	**4,234,128**	**7,939,069**	**11,721,698**	**4,420,423**	**2,491,013**	**14,794,722**
Offshore to EEZ	205,146	188	716,768	9,630	9,125	11,615	92,462
Non-US SECA C3	27,845	0	266,129	10,232	9,371	69,507	11,821
Canada othafdust				1,353,416	270,071		
Canada othar	2,192,418	338,711	238,830	284,898	151,849	22,783	800,300
Canada othon	877,268	5,098	141,282	5,520	5,025	549	47,883
Canada othpt	636,056	15,412	221,980	57,514	31,196	409,282	186,100
Canada ptfire_mxca	798,710	13,037	14,048	87,398	73,401	6,481	194,844
Mexico othar	217,518	167,660	212,147	95,486	46,311	12,159	505,017
Mexico othon	1,543,506	2,853	376,485	9,581	4,586	6,370	143,725
Mexico othpt	199,007	5,669	376,422	71,542	54,940	361,230	80,922
Mexico ptfire_mxca	736,810	13,583	31,403	104,125	87,025	6,394	172,196
Non-US Total	**7,434,284**	**562,210**	**2,595,494**	**2,089,342**	**742,899**	**906,371**	**2,235,269**

Table 5-3. National by-sector CO emissions (tons/yr) summaries and percent change

Sector	2011 CO	2023 CO	% change 2011 to 2023
afdust_adj	0	0	0%
ag	0	0	0%
agfire	1,030,817	1,030,817	0%
cmv_c1c2	58,543	57,696	-1%
cmv_c3	11,955	18,569	55%
nonpt	1,645,989	1,682,696	2%
np_oilgas	635,942	690,025	9%
nonroad	13,951,020	12,627,798	-9%
onroad	25,981,557	11,300,137	-57%
ptfire	20,562,697	20,562,697	0%
ptegu	792,414	598,510	-24%
ptnonipm	2,297,549	2,271,136	-1%
pt_oilgas	235,162	231,798	-1%
rail	122,703	145,627	19%
rwc	2,517,844	2,368,934	-6%
Con U.S. Total	**69,844,194**	**53,586,440**	**-23%**
Offshore to EEZ	176,338	205,146	16%
Non-US SECA C3	16,191	27,845	72%
Canada othafdust	0	0	0%
Canada othar	2,038,390	2,192,418	8%
Canada othon	1,507,754	877,268	-42%
Canada othpt	512,629	636,056	24%
Canada ptfire_mxca	798,710	798,710	0%
Mexico othar	186,575	217,518	17%
Mexico othon	1,476,625	1,543,506	5%
Mexico othpt	153,387	199,007	30%
Mexico ptfire_mxca	736,810	736,810	0%
Non-US Total	**7,603,409**	**7,434,284**	**-2%**

Table 5-4. National by-sector NH_3 emissions (tons/yr) summaries and percent change

Sector	2011 NH_3	2023 NH_3	% change 2011 to 2023
afdust_adj	0	0	0%
ag	3,515,198	3,602,039	2%
agfire	3,321	3,321	0%
cmv_c1c2	167	170	2%
cmv_c3	65	65	0%
nonpt	94,242	94,695	0%
np_oilgas	0	0	0%
nonroad	2,627	3,228	23%
onroad	120,859	82,106	-32%
ptfire	329,330	329,330	0%
ptegu	25,066	29,691	18%
ptnonipm	66,048	64,691	-2%
pt_oilgas	5,947	5,917	-1%
rail	347	376	8%
rwc	19,693	18,499	-6%
Con U.S. Total	**4,182,911**	**4,234,128**	**1%**
Offshore to EEZ	188	188	0%
Non-US SECA C3	0	0	0%
Canada othafdust	0	0	0%
Canada othar	338,056	338,711	0%
Canada othon	6,326	5,098	-19%
Canada othpt	11,390	15,412	35%
Canada ptfire_mxca	13,037	13,037	0%
Mexico othar	168,840	167,660	-1%
Mexico othon	2,154	2,853	32%
Mexico othpt	3,945	5,669	44%
Mexico ptfire_mxca	13,583	13,583	0%
Non-US Total	**557,519**	**562,210**	**1%**

Table 5-5. National by-sector NO_x emissions (tons/yr) summaries and percent change

Sector	2011 NO_x	2023 NO_x	% change 2011 to 2023
afdust_adj	0	0	0%
ag	0	0	0%
agfire	46,035	46,035	0%
cmv_c1c2	288,726	175,059	-39%
cmv_c3	125,374	105,567	-16%
nonpt	720,454	733,016	2%
np_oilgas	667,068	670,895	1%
nonroad	1,630,301	856,831	-47%
onroad	5,708,150	1,786,856	-69%
ptfire	333,398	333,398	0%
ptegu	2,096,058	1,051,725	-50%
ptnonipm	1,212,616	1,156,792	-5%
pt_oilgas	509,856	424,595	-17%
rail	791,381	563,382	-29%
rwc	34,436	34,918	1%
Con U.S. Total	**14,163,853**	**7,939,069**	**-44%**
Offshore to EEZ	904,453	716,768	-21%
Non-US SECA C3	191,001	266,129	39%
Canada othafdust	0	0	0%
Canada othar	376,758	238,830	-37%
Canada othon	332,349	141,282	-57%
Canada othpt	231,609	221,980	-4%
Canada ptfire_mxca	14,048	14,048	0%
Mexico othar	183,383	212,147	16%
Mexico othon	363,342	376,485	4%
Mexico othpt	333,368	376,422	13%
Mexico ptfire_mxca	31,403	31,403	0%
Non-US Total	**2,961,713**	**2,595,494**	**-12%**

Table 5-6. National by-sector $PM_{2.5}$ emissions (tons/yr) summaries and percent change

Sector	2011 $PM_{2.5}$	2023 $PM_{2.5}$	% change 2011 to 2023
afdust_adj	923,590	1,009,616	9%
ag	0	0	0%
agfire	101,379	101,379	0%
cmv_c1c2	9,294	5,155	-45%
cmv_c3	8,829	1,884	-79%
nonpt	404,258	427,719	6%
np_oilgas	16,333	21,786	33%
nonroad	154,657	78,858	-49%
onroad	188,925	79,527	-58%
ptfire	1,844,263	1,844,263	0%
ptegu	208,122	138,932	-33%
ptnonipm	320,816	320,641	0%
pt_oilgas	13,935	14,847	7%
rail	23,963	13,165	-45%
rwc	381,252	362,651	-5%
Con U.S. Total	**4,599,616**	**4,420,423**	**-4%**
Offshore to EEZ	24,692	9,125	-63%
Non-US SECA C3	14,930	9,371	-37%
Canada othafdust	242,374	270,071	11%
Canada othar	157,205	151,849	-3%
Canada othon	5,014	5,025	0%
Canada othpt	25,784	31,196	21%
Canada ptfire_mxca	73,401	73,401	0%
Mexico othar	42,623	46,311	9%
Mexico othon	3,254	4,586	41%
Mexico othpt	45,963	54,940	20%
Mexico ptfire_mxca	87,025	87,025	0%
Non-US Total	**722,265**	**742,899**	**3%**

Table 5-7. National by-sector PM_{10} emissions (tons/yr) summaries and percent change

Sector	2011 PM_{10}	2023 PM_{10}	% change 2011 to 2023
afdust_adj	6,732,941	7,498,365	11%
ag	0	0	0%
agfire	152,837	152,837	0%
cmv_c1c2	9,712	5,387	-45%
cmv_c3	9,946	2,126	-79%
nonpt	491,825	509,892	4%
np_oilgas	17,784	24,780	39%
nonroad	162,417	84,153	-48%
onroad	326,900	232,752	-29%
ptfire	2,171,987	2,171,987	0%
ptegu	283,066	173,057	-39%
ptnonipm	477,328	473,720	-1%
pt_oilgas	14,585	15,508	6%
rail	25,898	14,236	-45%
rwc	381,476	362,897	-5%
Con U.S. Total	**11,258,702**	**11,721,698**	**4%**
Offshore to EEZ	26,401	9,630	-64%
Non-US SECA C3	16,228	10,232	-37%
Canada othafdust	1,192,039	1,353,416	14%
Canada othar	288,021	284,898	-1%
Canada othon	15,107	5,520	-63%
Canada othpt	51,137	57,514	12%
Canada ptfire_mxca	87,398	87,398	0%
Mexico othar	90,691	95,486	5%
Mexico othon	8,788	9,581	9%
Mexico othpt	59,325	71,542	21%
Mexico ptfire_mxca	104,125	104,125	0%
Non-US Total	**1,939,261**	**2,089,342**	**8%**

Table 5-8. National by-sector SO_2 emissions (tons/yr) summaries and percent change

Sector	2011 SO_2	2023 SO_2	% change 2011 to 2023
afdust_adj	0	0	0%
ag	0	0	0%
agfire	17,755	17,755	0%
cmv_c1c2	6,217	1,987	-68%
cmv_c3	84,992	4,824	-94%
nonpt	276,332	96,043	-65%
np_oilgas	17,232	49,707	188%
nonroad	4,031	2,380	-41%
onroad	28,195	12,114	-57%
ptfire	165,773	165,773	0%
ptegu	4,670,713	1,335,974	-71%
ptnonipm	1,049,374	731,219	-30%
pt_oilgas	66,577	64,990	-2%
rail	7,936	340	-96%
rwc	8,954	7,908	-12%
Con U.S. Total	**6,404,080**	**2,491,013**	**-61%**
Offshore to EEZ	139,270	11,615	-92%
Non-US SECA C3	120,316	69,507	-42%
Canada othafdust	0	0	0%
Canada othar	33,464	22,783	-32%
Canada othon	1,270	549	-57%
Canada othpt	522,537	409,282	-22%
Canada ptfire_mxca	6,481	6,481	0%
Mexico othar	10,184	12,159	19%
Mexico othon	4,432	6,370	44%
Mexico othpt	471,847	361,230	-23%
Mexico ptfire_mxca	6,394	6,394	0%
Non-US Total	**1,316,195**	**906,371**	**-31%**

Table 5-9. National by-sector VOC emissions (tons/yr) summaries and percent change

Sector	2011 VOC	2023 VOC	% change 2011 to 2023
afdust_adj	0	0	0%
ag	0	0	0%
agfire	80,540	80,540	0%
cmv_c1c2	7,696	5,241	-32%
cmv_c3	4,888	7,639	56%
nonpt	3,671,322	3,452,177	-6%
np_oilgas	2,482,590	2,966,396	19%
nonroad	2,024,419	1,177,147	-42%
onroad	2,713,181	987,796	-64%
ptfire	4,688,094	4,688,094	0%
ptegu	38,060	32,702	-14%
ptnonipm	800,815	782,504	-2%
pt_oilgas	164,098	177,353	8%
rail	40,851	21,384	-48%
rwc	442,541	415,748	-6%
Con U.S. Total	**17,159,096**	**14,794,722**	**-14%**
Offshore to EEZ	81,713	92,462	13%
Non-US SECA C3	6,878	11,821	72%
Canada othafdust	0	0	0%
Canada othar	776,733	800,300	3%
Canada othon	138,319	47,883	-65%
Canada othpt	166,284	186,100	12%
Canada ptfire_mxca	194,844	194,844	0%
Mexico othar	420,637	505,017	20%
Mexico othon	136,891	143,725	5%
Mexico othpt	57,090	80,922	42%
Mexico ptfire_mxca	172,196	172,196	0%
Non-US Total	**2,151,585**	**2,235,269**	**4%**

Table 5-10. Canadian province emissions changes from 2011 to 2023 for othon sector

2023 othon emissions (tons)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)
Province	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Newfoundland	38,454	18,791	-51.1%	6,054	2,611	-56.9%	2,439	818	-66.4%
Prince Edward Island	12,516	6,398	-48.9%	2,985	1,100	-63.1%	980	300	-69.4%
Nova Scotia	66,500	30,624	-53.9%	10,626	4,183	-60.6%	4,560	1,385	-69.6%
New Brunswick	62,881	30,018	-52.3%	12,978	4,945	-61.9%	4,956	1,576	-68.2%
Quebec	450,802	238,728	-47.0%	94,288	33,176	-64.8%	33,137	10,911	-67.1%
Ontario	583,811	387,770	-33.6%	133,818	49,835	-62.8%	58,001	19,480	-66.4%
Manitoba	147,307	72,096	-51.1%	28,630	15,482	-45.9%	16,257	5,558	-65.8%
Saskatchewan	160,734	88,473	-45.0%	39,296	26,347	-33.0%	16,126	6,618	-59.0%
Alberta	428,529	249,051	-41.9%	108,703	69,301	-36.2%	38,108	15,453	-59.5%
British Columbia	296,378	158,262	-46.6%	64,498	30,926	-52.1%	29,932	10,786	-64.0%
Yukon	5,977	1,993	-66.7%	1,969	1,004	-49.0%	585	161	-72.4%
N W Territories	5,301	2,015	-62.0%	1,215	632	-48.0%	454	142	-68.7%
Nunavut	0	0	0.0%	0	0	0.0%	0	0	0.0%
Canada Total	2,259,190	1,284,220	-43.2%	505,059	239,542	-52.6%	205,535	73,190	-64.4%

Table 5-11. Canadian province emissions changes from 2011 to 2023 for othar sector

2023 othar emissions (tons)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)
Province	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Newfoundland	240,084	266,592	11.0%	44,914	31,834	-29.1%	66,538	73,243	10.1%
Prince Edward Island	25,798	26,965	4.5%	3,179	1,661	-47.8%	8,447	8,584	1.6%
Nova Scotia	116,388	104,911	-9.9%	46,345	20,535	-55.7%	37,795	34,034	-10.0%
New Brunswick	78,228	84,324	7.8%	12,980	8,326	-35.9%	28,181	30,887	9.6%
Quebec	970,074	995,472	2.6%	124,163	72,342	-41.7%	278,853	280,783	0.7%
Ontario	977,428	1,043,706	6.8%	138,510	95,720	-30.9%	326,896	333,517	2.0%
Manitoba	100,965	121,472	20.3%	35,123	19,465	-44.6%	63,740	69,277	8.7%
Saskatchewan	120,537	133,515	10.8%	73,713	40,146	-45.5%	97,252	98,004	0.8%
Alberta	312,576	377,812	20.9%	150,466	106,892	-29.0%	219,727	241,602	10.0%
British Columbia	282,114	314,793	11.6%	133,298	77,738	-41.7%	104,627	113,422	8.4%
Yukon	7,418	7,822	5.4%	419	6,441	1435.6%	2,439	2,566	5.2%
N W Territories	4,094	3,239	-20.9%	2,536	1,864	-26.5%	1,536	1,187	-22.7%
Nunavut	30,279	41,032	35.5%	3,228	12,542	288.5%	7,776	11,101	42.8%
Canada Total	3,265,982	3,521,654	7.8%	768,873	495,504	-35.6%	1,243,806	1,298,207	4.4%

Table 5-12. Canadian province emissions changes from 2011 to 2023 for othpt sector

2023 othpt emissions (tons)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)	2011	2023	% diff (2023-2011)
Province	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Newfoundland	9,951	11,245	13.0%	15,449	17,288	11.9%	4,707	4,984	5.9%
Prince Edward Island	167	153	-8.4%	269	234	-13.0%	210	236	12.7%
Nova Scotia	16,033	3,616	-77.4%	23,948	17,174	-28.3%	5,853	4,841	-17.3%
New Brunswick	20,861	24,210	16.1%	15,790	17,138	8.5%	6,465	7,275	12.5%
Quebec	470,224	641,119	36.3%	39,911	42,254	5.9%	37,770	39,339	4.2%
Ontario	92,784	103,009	11.0%	76,441	77,106	0.9%	64,127	64,552	0.7%
Manitoba	4,777	5,583	16.9%	3,590	4,250	18.4%	23,880	20,134	-15.7%
Saskatchewan	47,251	47,839	1.2%	69,971	57,526	-17.8%	188,075	223,364	18.8%
Alberta	556,850	574,346	3.1%	489,584	421,837	-13.8%	556,009	554,800	-0.2%
British Columbia	181,571	280,949	54.7%	86,375	140,438	62.6%	74,301	104,369	40.5%
Yukon	288	216	-25.1%	18	27	50.7%	24	32	33.2%
N W Territories	4,217	4,847	14.9%	9,497	15,040	58.4%	2,036	2,155	5.9%
Nunavut	843	686	-18.6%	3,154	1,110	-64.8%	49	37	-23.3%
Canada Total	1,405,817	1,697,818	20.8%	833,998	811,424	-2.7%	963,504	1,026,119	6.5%

Table 5-13. Mexican state emissions changes from 2011 to 2023 for othon sector

2023 othon emissions (tons)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)
State	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Aguascalientes	74,458	72,499	-2.6%	18,716	19,700	5.3%	7,126	7,314	2.6%
Baja Calif Norte	292,747	316,731	8.2%	74,570	77,577	4.0%	25,233	26,025	3.1%
Baja Calif Sur	83,274	91,452	9.8%	19,961	20,750	4.0%	6,999	7,340	4.9%
Campeche	52,849	58,506	10.7%	9,367	9,834	5.0%	3,948	4,122	4.4%
Coahuila	170,357	165,632	-2.8%	38,217	40,294	5.4%	15,532	16,135	3.9%
Colima	59,533	65,737	10.4%	11,485	12,026	4.7%	4,735	5,004	5.7%
Chiapas	114,015	125,700	10.2%	23,295	24,325	4.4%	9,109	9,519	4.5%
Chihuahua	280,049	271,634	-3.0%	76,676	80,295	4.7%	26,460	27,193	2.8%
Distrito Federal	602,306	602,050	0.0%	143,350	138,120	-3.6%	60,134	60,474	0.6%
Durango	98,318	107,195	9.0%	24,238	25,168	3.8%	8,817	9,370	6.3%
Guanajuato	230,777	224,860	-2.6%	57,800	60,848	5.3%	22,563	23,431	3.8%
Guerrero	156,199	172,474	10.4%	28,815	30,232	4.9%	12,770	13,669	7.0%
Hidalgo	131,136	127,736	-2.6%	34,009	35,730	5.1%	12,794	13,110	2.5%
Jalisco	456,462	433,740	-5.0%	122,360	125,191	2.3%	45,893	47,241	2.9%
Mexico	413,998	448,551	8.3%	102,556	103,470	0.9%	38,111	38,793	1.8%
Michoacan	301,589	330,111	9.5%	68,641	71,574	4.3%	27,435	29,395	7.1%
Morelos	83,388	81,392	-2.4%	19,926	20,997	5.4%	7,929	8,274	4.3%
Nayarit	71,260	78,690	10.4%	13,702	14,352	4.7%	5,947	6,409	7.8%
Nuevo Leon	340,264	353,709	4.0%	86,518	86,734	0.3%	34,033	35,793	5.2%
Oaxaca	98,480	95,690	-2.8%	26,792	27,781	3.7%	8,496	8,625	1.5%
Puebla	196,606	212,743	8.2%	49,244	51,425	4.4%	18,745	19,950	6.4%
Queretaro	71,514	69,650	-2.6%	20,361	21,327	4.7%	6,963	7,164	2.9%
Quintana Roo	67,166	65,537	-2.4%	13,672	14,466	5.8%	5,594	5,739	2.6%
San Luis Potosi	144,504	140,708	-2.6%	32,362	34,138	5.5%	13,518	14,187	4.9%
Sinaloa	203,180	223,769	10.1%	46,984	48,875	4.0%	17,555	18,869	7.5%
Sonora	195,052	214,002	9.7%	46,289	48,130	4.0%	17,094	18,303	7.1%
Tabasco	93,227	103,029	10.5%	17,304	18,148	4.9%	7,343	7,754	5.6%
Tamaulipas	296,180	325,932	10.0%	58,506	61,170	4.6%	24,360	25,872	6.2%
Tlaxcala	33,247	32,217	-3.1%	8,901	9,355	5.1%	3,266	3,321	1.7%
Veracruz	265,631	259,302	-2.4%	68,186	71,617	5.0%	24,046	24,651	2.5%
Yucatan	97,722	95,382	-2.4%	20,606	21,783	5.7%	8,431	8,745	3.7%
Zacatecas	112,450	122,582	9.0%	28,420	29,527	3.9%	10,411	11,130	6.9%
Mexico Total	5,887,937	6,088,942	3.4%	1,411,830	1,454,958	3.1%	541,390	562,919	4.0%

Table 5-14. Mexican state emissions changes from 2011 to 2023 for othar sector

2023 othar emissions (tons)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)
State	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Aguascalientes	4,018	4,901	22.0%	6,605	7,492	13.4%	19,358	23,699	22.4%
Baja Calif Norte	13,589	19,079	40.4%	21,841	28,254	29.4%	61,514	77,009	25.2%
Baja Calif Sur	3,110	4,372	40.6%	4,996	6,085	21.8%	10,889	14,748	35.4%
Campeche	51,137	55,561	8.7%	35,074	34,844	-0.7%	35,129	41,592	18.4%
Coahuila	12,444	14,769	18.7%	15,089	19,367	28.4%	48,687	58,739	20.6%
Colima	8,562	10,303	20.3%	3,883	4,601	18.5%	16,571	20,176	21.8%
Chiapas	305,524	354,916	16.2%	22,097	23,492	6.3%	312,206	365,483	17.1%
Chihuahua	61,301	67,860	10.7%	55,606	59,045	6.2%	99,006	116,057	17.2%
Distrito Federal	10,780	14,230	32.0%	7,966	10,765	35.1%	108,040	112,654	4.3%
Durango	39,499	43,328	9.7%	27,428	28,670	4.5%	51,830	59,027	13.9%
Guanajuato	71,662	83,363	16.3%	41,641	49,568	19.0%	122,993	141,500	15.0%
Guerrero	156,577	167,856	7.2%	5,770	6,172	7.0%	176,647	192,150	8.8%
Hidalgo	98,080	110,966	13.1%	17,781	21,582	21.4%	113,582	128,929	13.5%
Jalisco	61,762	70,602	14.3%	47,329	50,076	5.8%	147,659	174,141	17.9%
Mexico	178,322	219,642	23.2%	32,009	37,849	18.2%	344,893	416,931	20.9%
Michoacan	115,037	132,429	15.1%	21,496	37,382	73.9%	152,964	171,488	12.1%
Morelos	26,857	27,190	1.2%	13,692	5,457	-60.1%	45,963	52,672	14.6%
Nayarit	23,142	26,534	14.7%	13,483	13,091	-2.9%	30,199	36,612	21.2%
Nuevo Leon	31,440	38,770	23.3%	24,518	30,517	24.5%	88,474	108,061	22.1%
Oaxaca	238,829	255,390	6.9%	13,735	14,059	2.4%	250,320	270,763	8.2%
Puebla	202,340	227,306	12.3%	17,744	21,075	18.8%	250,507	283,412	13.1%
Queretaro	26,941	34,278	27.2%	8,463	12,791	51.1%	50,165	61,365	22.3%
Quintana Roo	26,335	35,351	34.2%	5,137	5,773	12.4%	38,633	53,296	38.0%
San Luis Potosi	88,201	98,880	12.1%	22,207	27,521	23.9%	106,283	118,702	11.7%
Sinaloa	54,362	59,869	10.1%	35,373	38,123	7.8%	76,165	85,204	11.9%
Sonora	26,007	30,706	18.1%	23,917	27,984	17.0%	60,018	72,372	20.6%
Tabasco	91,388	102,556	12.2%	14,024	16,009	14.1%	103,490	117,803	13.8%
Tamaulipas	44,743	51,876	15.9%	46,959	54,576	16.2%	70,902	83,656	18.0%
Tlaxcala	21,451	25,104	17.0%	6,672	7,438	11.5%	32,549	38,656	18.8%
Veracruz	357,503	389,550	9.0%	48,159	50,987	5.9%	390,957	432,607	10.7%
Yucatan	97,808	113,125	15.7%	7,176	7,935	10.6%	111,556	131,043	17.5%
Zacatecas	30,865	32,736	6.1%	38,745	40,253	3.9%	36,798	40,838	11.0%
Mexico Total	2,579,614	2,923,397	13.3%	706,612	798,834	13.1%	3,564,949	4,101,385	15.0%

Table 5-15. Mexican state emissions changes from 2011 to 2023 for othpt sector

2023 othpt emissions (tons)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)	2011el	2023el	% diff (2023el-2011el)
State	CO	CO	CO	NOX	NOX	NOX	VOC	VOC	VOC
Aguascalientes	275	391	42.3%	987	1,407	42.6%	2,151	3,069	42.7%
Baja Calif Norte	8,083	17,500	116.5%	14,498	32,455	123.9%	13,603	19,505	43.4%
Baja Calif Sur	644	173	-73.1%	8,899	2,582	-71.0%	610	771	26.4%
Campeche	9,342	11,361	21.6%	35,616	41,077	15.3%	3,637	4,324	18.9%
Coahuila	31,659	35,549	12.3%	217,689	218,533	0.4%	7,328	10,306	40.6%
Colima	1,496	1,052	-29.7%	15,921	7,294	-54.2%	1,514	2,152	42.1%
Chiapas	2,861	3,919	37.0%	5,503	7,500	36.3%	3,926	5,439	38.5%
Chihuahua	11,318	15,659	38.4%	11,989	13,663	14.0%	5,540	7,803	40.8%
Distrito Federal	887	1,321	49.0%	2,582	3,853	49.2%	25,747	36,748	42.7%
Durango	3,552	4,737	33.4%	6,988	7,371	5.5%	3,727	5,261	41.1%
Guanajuato	78,844	95,712	21.4%	9,566	12,567	31.4%	11,245	14,846	32.0%
Guerrero	3,200	3,184	-0.5%	14,706	14,270	-3.0%	785	952	21.2%
Hidalgo	123,941	218,498	76.3%	35,641	50,270	41.0%	8,325	14,004	68.2%
Jalisco	3,766	5,367	42.5%	7,403	10,547	42.5%	18,313	26,129	42.7%
Mexico	7,294	14,501	98.8%	17,656	35,567	101.4%	56,433	81,136	43.8%
Michoacan	3,341	4,753	42.3%	4,966	6,938	39.7%	6,306	8,997	42.7%
Morelos	1,553	2,216	42.7%	4,249	6,064	42.7%	3,381	4,825	42.7%
Nayarit	553	789	42.8%	375	538	43.2%	1,673	2,387	42.7%
Nuevo Leon	86,971	107,975	24.1%	41,887	57,573	37.4%	15,730	22,180	41.0%
Oaxaca	113,001	135,442	19.9%	10,928	13,944	27.6%	8,267	10,729	29.8%
Puebla	2,994	4,748	58.6%	7,360	11,104	50.9%	4,317	6,168	42.9%
Queretaro	3,184	6,613	107.7%	9,793	22,762	132.4%	7,013	10,332	47.3%
Quintana Roo	410	550	34.1%	616	388	-37.0%	1,016	1,441	41.8%
San Luis Potosi	6,764	14,529	114.8%	22,263	33,743	51.6%	7,563	11,590	53.2%
Sinaloa	1,315	1,098	-16.5%	10,982	2,049	-81.3%	3,641	5,076	39.4%
Sonora	4,299	8,350	94.2%	14,581	18,526	27.1%	4,786	7,018	46.6%
Tabasco	7,682	10,102	31.5%	23,255	29,986	28.9%	6,767	8,468	25.1%
Tamaulipas	71,893	89,752	24.8%	34,020	42,968	26.3%	34,256	46,543	35.9%
Tlaxcala	286	435	52.1%	962	1,531	59.1%	1,425	2,033	42.7%
Veracruz	88,864	108,452	22.0%	48,607	56,892	17.0%	30,199	40,973	35.7%
Yucatan	3,210	3,679	14.6%	11,020	11,529	4.6%	4,454	6,206	39.3%
Zacatecas	3	4	42.0%	11	15	42.4%	226	322	42.7%
Mexico Total	683,482	928,414	35.8%	651,521	775,506	19.0%	303,905	427,730	40.7%

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STATE OF NEW MEXICO
ENVIRONMENTAL IMPROVEMENT BOARD

IN THE MATTER OF THE APPEALS OF THE AIR QUALITY PERMIT NO. 7482-M1 ISSUED TO 3 BEAR DELAWARE OPERATING – NM LLC — EIB No. 20-21(A)

AND

REGISTRATION NOS. 8729, 8730, AND 8733 UNDER GENERAL CONSTRUCTION PERMIT FOR OIL AND GAS FACILITIES — EIB No. 20-33(A)

WildEarth Guardians,
Petitioner

THE NEW MEXICO ENVIRONMENT DEPARTMENT'S
STATEMENT OF INTENT TO PRESENT DIRECT TECHNICAL TESTIMONY

Pursuant to 20.1.2.206 NMAC, the Air Quality Bureau ("Bureau") of the Environmental Protection Division ("Division") of the New Mexico Environment Department ("Department") submits this Statement of Intent to Present Direct Technical Testimony in support of its approval of Air Quality Permit No. 7482-M1, issued to 3-Bear Delaware Operating – NM LLC ("3-Bear Permit") for the Libby Gas Plant in Lea County, New Mexico, and General Construction Permit for Oil and Gas Facilities ("GCP O&G") Registration Nos. 8729, 8730, and 8733 (collectively, the "Registrations") for XTO Energy Co.'s Corral Canyon 23 and Big Eddy Unit DI 38 (Nos. 8729 and 8730, respectively), and Spur Energy Partners LLC's Dorami 2H, 4H and 9H Federal Oil Tank Battery (No. 8733), all located in Eddy County, at the public hearing beginning September 23, 2020 on the consolidated appeal petitions filed by WildEarth Guardians.

1. Name of Person Filing the Statement

The Air Quality Bureau of the Environmental Protection Division of the Department.

2. The Division's Position on the Petition

The Bureau, on behalf of the Division, opposes the Petitions.

3. Technical Witness Information

The Bureau will call the following witnesses at the hearing to present technical testimony:

Sufi Mustafa: Mr. Mustafa is Manager of the Modeling and Emissions Inventory Unit in the Bureau's Planning Section. He has been employed by the Department for nineteen years. Mr. Mustafa's educational and professional backgrounds are described in his resume, attached as NMED Exhibit 2. His business address is 525 Camino de los Marquez, Suite #1, Santa Fe, New Mexico 87505. Mr. Mustafa is expected to provide testimony regarding ozone and how it is formed; the nature of ozone as an air pollutant and how it is modeled; and how the modeling informs the regulatory regime for controlling ozone pollution under the federal Clean Air Act and the New Mexico Air Quality Control Act.. Mr. Mustafa's written testimony is provided as NMED Exhibit 1.

Elizabeth Bisbey-Kuehn: Ms. Bisbey-Kuehn is Chief of the Department's Air Quality Bureau. She has held this position since 2017. She has been employed by the Department over fifteen years. Her business address is 525 Camino de los Marquez, Suite #1, Santa Fe, New Mexico 87505. Ms. Bisbey-Kuehn's educational and professional background is described in her resume, attached as NMED Exhibit 4. Ms. Bisbey-Kuehn is expected to provide testimony on the following topics: the regulatory regime for ozone set forth under the CAA and the State of New Mexico's role in that regime; the New Mexico statutory and regulatory framework for regulating ozone pollution; the Department's Ozone Attainment Initiative and the steps that the Department is currently taking to address areas of the State where monitors are registering exceedances of the ozone NAAQS; the path forward for the State in addressing ozone pollution. Ms. Bisbey-Kuehn's written direct testimony is provided as NMED Exhibit 3.

Kerwin Singleton: Mr. Singleton is the Chief of the Bureau's Planning Section. He has

held this position since 2018. He has been employed by the Department for sixteen years. Mr. Singleton's educational and professional backgrounds are described in his resume, attached as NMED Exhibit 8. His business address is 525 Camino de los Marquez, Suite #1, Santa Fe, New Mexico 87505. Mr. Singleton will not be providing direct technical testimony in this proceeding, but he will be available for rebuttal and cross-examination as needed.

Ted Schooley: Mr. Schooley is the Chief of the Bureau's Permitting Section. He has held this position since 2014. He has been employed by the Department for nineteen years. Mr. Schooley's educational and professional backgrounds are described in his resume, attached as NMED Exhibit 9. His business address is 525 Camino de los Marquez, Suite #1, Santa Fe, New Mexico 87505. Mr. Schooley will not be providing direct technical testimony in this proceeding, but he will be available for rebuttal and cross-examination as needed.

Angela Raso: Ms. Raso is a Dispersion Modeler for the Bureau. She has held this position since 2018. Ms. Raso's educational and professional backgrounds are described in her resume, attached as NMED Exhibit 10. Her business address is 525 Camino de los Marquez, Suite #1, Santa Fe, New Mexico 87505. Ms. Raso will not be providing direct technical testimony in this proceeding, but she will be available for rebuttal and cross-examination as needed.

The Bureau hereby reserves the right to call any other person to present rebuttal testimony and to support the admission of any exhibit.

4. Estimated Length of Witness Direct Testimony at the Hearing

Mr. Mustafa	1 hour
Ms. Bisbey-Kuehn	1 hour
Mr. Singleton	No direct testimony
Mr. Schooley	No direct testimony
Ms. Raso	No direct testimony

5. Exhibit List

The Department intends to offer the following exhibits into evidence at the hearing:

EXHIBIT NUMBER	TITLE OF EXHIBIT
NMED Exhibit 1	Testimony of Sufi Mustafa
NMED Exhibit 2	Resume of Sufi Mustafa
NMED Exhibit 3	NMED Air Quality Bureau's Air Dispersion Modeling Guidelines (June 6, 2019)
NMED Exhibit 4	US EPA's Draft Guidance for Ozone and Fine Particulate Matter Permit Modeling (February 10, 2020)
NMED Exhibit 5	Testimony of Elizabeth Bisbey-Kuehn
NMED Exhibit 6	Resume of Elizabeth Bisbey Kuehn
NMED Exhibit 7	Southern New Mexico Ozone Study Technical Support Document (October 19, 2016)
NMED Exhibit 8	Resume of Kerwin Singleton
NMED Exhibit 9	Resume of Ted Schooley
NMED Exhibit 10	Resume of Angela Raso

The Bureau hereby reserves the right to introduce and to move for admission of any other exhibit in support of rebuttal testimony at the hearing.

Respectfully submitted,

NEW MEXICO ENVIRONMENT DEPARTMENT

/s/ *Lara Katz*

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CERTIFICATE OF SERVICE

I hereby certify that a copy of the foregoing Statement of Intent to Present Technical Testimony was served via electronic mail on the following parties of record on August 3, 2020:

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NMED
EXHIBIT 1

STATE OF NEW MEXICO
ENVIRONMENTAL IMPROVEMENT BOARD

IN THE MATTER OF THE APPEALS OF THE AIR QUALITY PERMIT NO. 7482-M1 ISSUED TO 3 BEAR DELAWARE OPERATING – NM LLC **EIB No. 20-21(A)**

AND

REGISTRATION NOS. 8729, 8730, AND 8733 UNDER GENERAL CONSTRUCTION PERMIT FOR OIL AND GAS FACILITIES **EIB No. 20-33(A)**

WildEarth Guardians,
Petitioner

DIRECT TECHNICAL TESTIMONY OF SUFI MUSTAFA

I. INTRODUCTION

My name is Sufi Mustafa. I am Manager of the Modeling and Emissions Inventory Unit of the Planning Section of the Air Quality Bureau ("AQB" or "Bureau") of the New Mexico Environment Department ("NMED" or "Department"). I present this written testimony on behalf of the Department for the consolidated public hearings on the appeal petitions filed by WildEarth Guardians ("WEG") in EIB 20-21(A) and EIB 20-33(A). In EIB 20-21(A), WEG challenges the Department's approval of Air Quality Permit No. 7482-M1, issued to 3-Bear Delaware Operating – NM LLC ("3-Bear Permit") for the Libby Gas Plant in Lea County, New Mexico. WEG contends that the Department failed to perform air quality modeling or other technical analyses to evaluate the impacts of the permitted activities on ambient ozone levels in the area. WEG further objects that air quality monitors in Hobbs and Carlsbad are registering ozone levels in excess of the U.S. Environmental Protection Agency's ("EPA") National Ambient Air Quality Standard ("NAAQS"), and therefore the Department's decision to approve the Permit was arbitrary and

NMED Exhibit 1

capricious because it authorized additional ozone precursors that would necessarily "cause or contribute to air contaminant levels in excess of any [NAAQS]."

In EIB 20-33(A), WEG challenges the Department's approval of General Construction Permit for Oil and Gas Facilities ("GCP O&G") Registration Nos. 8729, 8730, and 8733 (collectively, the "Registrations") for XTO Energy Co.'s Corral Canyon 23 and Big Eddy Unit DI 38 (Nos. 8729 and 8730, respectively), and Spur Energy Partners LLC's Dorami 2H, 4H and 9H Federal Oil Tank Battery (No. 8733), all located in Eddy County, New Mexico. WEG points to Table 103 in the GCP O&G, which lists all applicable regulations that a registrant must comply with and includes ambient air quality standards. WEG contends that because monitors in the area are registering exceedances of the ozone NAAQS, it is impossible for the facilities to demonstrate compliance with the requirements of the GCP O&G, and therefore the Department's approval of the Registrations was unlawful, arbitrary and capricious.

As the Modeling Unit Manager, I am charged with reviewing and assigning air dispersion modeling analyses that are provided in support of air quality permitting actions. My staff and I ensure that the modeling analyses submitted by permit applicants conform to the most current US EPA modeling guidelines and predict concentrations below applicable ambient air quality standards. My testimony will address the following topics: what ozone is and how it is formed; the nature of ozone as an air pollutant and how it is modeled; and how the modeling informs the regulatory regime for controlling ozone pollution under the federal Clean Air Act and the New Mexico Air Quality Control Act.

II. QUALIFICATIONS

I have a doctorate in Chemistry from the New Mexico School of Mining and Technology. I started my career twenty-five years ago as an analytical chemist at the New Mexico State Health

Department's Scientific Lab Division. I joined AQB nineteen years ago as a Modeler, and later the Staff Manager for the Air Dispersion Modeling and Emission Inventory Section. In my current position with the Air Quality Bureau, I supervise three full time modelers who perform and review air dispersion modeling analyses. These analyses predict air quality in an area, and are used in the air quality permitting process to ensure facilities that obtain air quality permits will be in compliance with applicable air quality standards. My staff and I have extensive experience in the use of the EPA regulatory model known as the American Meteorological Society/Environmental Protection Agency Regulatory Model ("AERMOD"), which is used for short range air quality analyses under state and federal air quality regulations.

My full background and qualifications are set forth in my resume, which is marked as NMED Exhibit 2.

III. AMBIENT AIR QUALITY STANDARDS

The Clean Air Act requires EPA to set ambient air quality standards for pollutants it determines are harmful to human health and the environment. These standards are in the form of maximum allowable concentrations in the ambient air during a specified time period and are designed to protect the most sensitive individuals from harm from airborne pollutants. EPA has established ambient air quality standards for six "criteria" pollutants in outdoor air. These pollutants are carbon monoxide ("CO"); nitrogen dioxide ("NO2"); sulfur dioxide ("SO2"); particulate matter ("PM") at 10 microns or less, referred to as coarse particulate matter, and at 2.5 microns or less, referred to as fine particulate matter; ground level ozone; and lead.

To prevent relatively clean areas from degrading to levels just barely in compliance with the air quality standards, limits on the allowable change in air quality have been established by EPA in the form of Prevention of Significant Deterioration ("PSD") increments. Compliance

demonstrations for PSD increments demonstrate that the deterioration is less than the allowable increment for a pollutant.

Along with the PSD increments and NAAQS concentrations of criteria pollutants, EPA also set up Significant Impact Level ("SIL") concentrations, which are thresholds below which the source is not considered to contribute to any predicted exceedance of air quality standards or PSD increments.

V. DEMONSTRATION OF COMPLIANCE WITH NAAQS FOR PERMITTED SOURCES

Demonstrating compliance with NAAQS for a new facility or a modification to an existing facility typically involves the use of air dispersion models to simulate the impacts of the proposed project. NMED and EPA both have guidance that prescribes the methodology and the types of modeling analyses to be used by applicants and NMED to demonstrate compliance with the NAAQS. The Bureau's Air Dispersion Modeling Guidelines (June 6, 2019) ("NMED Modeling Guidelines"), are attached hereto as NMED Exhibit 3; EPA's most recent guidance - Draft Guidance for Ozone and Fine Particulate Matter Permit Modeling (February 10, 2020) ("EPA Modeling Guidance") – is attached hereto as NMED Exhibit 4. Note that there are different types of models and modeling assessments used for different types of air pollutants, which is explained in detail the following section. Regulatory models such as AERMOD are used to determine short distance impacts up to approximately a few hundred square miles.

The Board's requirements for air dispersion modeling are detailed at 20.2.70.300.D.10 NMAC (Operating Permits), 20.2.72.203.A.4 NMAC (Construction Permits), and 20.2.74.305 NMAC (Permits - Prevention of Significant Deterioration), and 20.2.79 NMAC (Nonattainment). For a construction permit application, an air dispersion modeling analysis is typically required to demonstrate compliance with applicable ambient air quality standards.

When a construction permit application involving air dispersion modeling is received, modeling staff initially verify that the application contains the required application forms and modeling reports, and determine whether the modeling files provided by the applicant are readable. Once the application has been ruled complete, Bureau staff will perform a complete review of the modeling files. This analysis includes a review to make sure that the data in the modeling files are consistent with the information in the permit application, and may involve the emission rate of each emission point; the elevation of sources, receptors, and buildings; and other aspects of the modeling inputs. If the dispersion modeling analysis submitted with the permit application and reviewed by the Department adequately demonstrates that ambient air concentrations will be below air quality standards and/or PSD increments, the modeler will summarize the findings and include the report summary the permit file. If dispersion modeling predicts that the construction or modification causes or significantly contributes to an exceedance of a New Mexico standard, a NAAQS, or a PSD increment, the permit cannot be issued by the Department.

IV. OZONE BASICS

The ozone molecule is composed of three oxygen atoms. Ground level ozone is formed when nitrogen oxides and volatile organic compounds react in the presence of sunlight. As the amount of these compounds increase in the air during warm days and intense sunlight, the essential chemical reactions take place to form ozone. Therefore, we tend to see spikes in ozone concentrations during the summer months.

Man-made, or anthropogenic sources of nitrogen oxides ("NOx") include products of fuel combustion. Volatile organic compounds ("VOCs") are emitted from various anthropogenic sources and processes such as motor vehicles; chemical manufacturing facilities; evaporative losses from crude oil holding tanks; and consumer and commercial products. Natural sources of

nitrogen oxides include lightning NO_X, microbial processes that occur in soils, and wildland fires. Vegetation is the major natural source of VOCs; other natural sources include animals and microbes.

Ozone is a reactive molecule that causes irritation and inflammation to the respiratory system and tissue damage to vegetation. While ozone is beneficial when it is present in the stratosphere to block harmful light radiation from reaching us, it is harmful when it is present in the lower troposphere, where we live and breathe. EPA has determined that ground level ozone is a criteria pollutant requiring a NAAQS for protection of public health. In 2015, EPA revised the ozone NAAQS downward from 75 ppb to 70 ppb.

VI. OZONE MODELING

Ozone is different from the other criteria pollutants in that it is not directly emitted from sources, but instead is primarily formed in the ambient air through chemical interactions between other precursor pollutants. Pollutants that are emitted directly by a source are known as "primary pollutants," and are generally NOx, SO2, PM10, PM2.5, and lead. Pollutants that are formed through chemical interactions in the ambient air, such as ozone, are known as "secondary pollutants." Dispersion modeling for primary pollutants simulates dispersion of that pollutant in the air after it is emitted from the source. By contrast, modeling for a secondary pollutant such as ozone must be capable of simulating chemistry in addition to dispersion. This is commonly done using photochemical models that simulate atmospheric chemistry as well as atmospheric mixing.

The addition of chemistry adds substantial complexity to the model. The impacts of a facility's emissions on primary pollutant concentrations are typically evaluated for a facility alone and is done with modeling that covers an area of a few hundred square miles. The impact of a facility's emissions on secondary pollutant concentrations must be evaluated in relation to

emissions from other sources, since the precursors reacting to create secondary pollutants are often emitted from multiple sources and sectors. In addition to regulated facilities, ozone precursors are emitted from numerous other anthropogenic and natural sources, as well as being transported from surrounding states and countries. Precursors can travel hundreds of miles in the atmosphere before reacting to form ozone. This makes it necessary to have not only a detailed understanding of the emissions from regulated facilities in an area, but also emissions from sources hundreds of miles away.

The potential complexity of photochemical modeling has led several organizations, including EPA and the Western Regional Air Partnership ("WRAP"), to develop modeling platforms that contain most of the information necessary for photochemical grid modeling exercises. Despite the development of these platforms, photochemical modeling exercises are still highly complex, and are mostly conducted by private specialists under contract with state and local air quality agencies. These specialized studies are far more costly then dispersion modeling; for instance, the photochemical modeling associated with the Department's Ozone Attainment Initiative is being performed by highly specialized contractors at a cost of over three-hundred thousand dollars. The NMED Modeling Guidelines recognize the cost and difficulty of ozone modeling, stating as follows:

> In accordance with [EPA's MERPs Guidance], NMED performs ozone modeling on a regional scale as the need arises, rather than requiring permit applicants to quantify their contribution to a regional ozone concentration. Comprehensive ozone modeling is too resource intensive to attach this expense to a typical permit application, and screening modeling on an affordable scale currently cannot quantify a source's impacts to ambient ozone concentrations.

NMED Modeling Guidance, at p. 24.

Due to the cost and complexity of ozone modeling, NMED performs a different type of analysis to determine ozone impacts from facilities that are designated as "minor PSD sources", as explained below.

VII. NEW SOURCE REVIEW PERMITTING AND OZONE

According to the New Mexico air quality regulations, facilities that require a New Source Review ("NSR") air quality permit must demonstrate compliance with applicable air quality standards. For this purpose, applicants use air dispersion modeling analyses to predict what the concentrations of most criteria pollutants will be after the project construction. In general, a US EPA approved regulatory model, AERMOD, is used. The model requires various inputs, including the post-construction project emissions of various criteria air pollutants such as carbon monoxide, nitrogen oxides, sulfur dioxide, and particulate matter. The model's output are the predicted pollutant concentrations, which are compared against the national and New Mexico air quality standards to demonstrate compliance after construction.

As noted above, because ozone is not directly emitted from a facility, but its formation is the result of precursor pollutants such as NOx and VOC emissions in a region undergoing complex chemical reactions, predicting an individual facility's contribution to the ozone levels in a region is extremely difficult compared to the directly emitted pollutants. For this reason, the Board's rules do not require the Department to evaluate ozone impacts for individual NSR minor source permit applications. *See* 20.2.72.500 NMAC (Table I – Significant Ambient Concentrations) (note the absence of ozone).

The Bureau follows the EPA Modeling Guidance, which uses a two-tiered demonstration approach to address single-source impacts on ambient ozone concentrations from major sources (those that emit more than 250 tons per year of any regulated pollutant). This type of demonstration

is included in the NMED Modeling Guidelines and is the basis for NMED's modeling requirements. Tier I is a screening tool under the PSD permitting program that uses Modeled Emission Rates for Precursors ("MERPs"), and Tier II requires the application of photochemical grid models to determine whether the source makes a significant impact on ozone and secondary $PM_{2.5}$. MERPs provide a scaling factor for emissions at a subject facility based on photochemical modeling done for a 'representative facility'. These scaling factors allow precursor emissions to be converted to an estimated ozone concentration based on the atmospheric conditions in the area surrounding the representative facility. The closest representative facilities to Carlsbad and the Permian Basin are located 90 miles to the northwest in Otero County, New Mexico, and 150 miles to the northeast in Terry County, Texas. The scaling factors from both representative facilities indicate that an individual facility would have to emit more than 250 tons per year of both NO_X and VOCs to cause ozone concentrations to increase more than a significant amount (the SIL) of ozone.

Because the allowable emissions from minor sources such as 3-Bear Libby Gas Plant do not, by definition, have the potential to emit NOx or VOCs in quantities exceeding 250 tons per year, there is no basis for the Department to require further analyses of ozone impacts from such sources. This determination and methodology is in accordance with the EPA Modeling Guidance and the NMED Modeling Guidelines, which does not require source specific ozone modeling for minor sources.

VIII. GENERAL CONSTRUCTION PERMITS AND OZONE

General Construction Permits are issued for minor emission sources in a specific industry sector. The Department issues general permits in order to register groups of sources that have similar operations, processes, and emissions and that are subject to the same or substantially

similar requirements. *See* 20.2.72.220.A(1) NMAC. General permits provide an additional permitting option for specific source types that can meet the predetermined permit requirements *See* 20.2.72.220.C(1) NMAC. The GCP O&G authorizes an owner or operator to construct, modify, and operate an oil and gas facility in New Mexico (excluding Bernalillo County, tribal lands, and designated nonattainment areas) under the conditions set forth in the permit.

In the permit hearing before the Board on the GCP O&G, the Department presented testimony regarding the air dispersion modeling analyses that were performed for hypothetical oil and gas facilities to determine conditions under which a permitted facility would be in compliance with applicable ambient air quality standards. Because only minor sources can register under the GCP O&G, the MERP analyses show that the impact of such facilities will be below the ozone SIL, and therefore are not considered to significantly contribute to ozone formation. This determination and methodology is in accordance with the EPA Modeling Guidance and the NMED Modeling Guidelines, which does not require source specific ozone modeling for minor sources.

IX. CONCLUSION

The Department evaluated the 3-Bear NSR Permit and the GCP Registrations as directed under the Act and the Board's regulations. It is my opinion that the both the NSR Permit and the GCP Registrations comply with the AQCA and the air quality rules. It is also my opinion that there is no scientific or technical evidence on which the Department could determine that the activities authorized by the NSR Permit or any of the Registrations would cause or contribute to violations of the ozone NAAQS. Therefore, the Board should uphold the Department's decision to approve the Permit and the Registrations.

NMED
EXHIBIT 2

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EDUCATION & TRAINING:

Ph.D. in Chemistry, August 2000
New Mexico Institute of Mining and Technology, Socorro, New Mexico, USA.

MS in Organic Chemistry, January 1988
University of the Punjab - Institute of Chemistry, Lahore, Pakistan.

BS in Chemistry, Minors in Statistics and Zoology, January 1985
University of the Punjab, Lahore, Pakistan.

PROFESSIONAL WORK EXPERIENCE:

New Mexico State Environment Department, Air Quality Bureau:
Manager - Air Dispersion Modeling Section: March 2004 to present

- Manage staff, assign tasks to complete the section workload, conduct employee performance appraisals.
- Strategic planning and coordination with other Bureau managers and supervisors.
- Support the development of new air quality regulations.
- Extensive experience working with the regulated industry and consultants.

New Mexico State Environment Department, Air Quality Bureau:
Environmental Scientist: June 2001 to March 2004

- Performed *Air Dispersion Modeling* for air quality permits using regulatory air dispersion models to ensure compliance with national and state air quality standards.
- Familiar with State and US Environmental Protection Agency (EPA) air quality regulations including New Source Review (NSR) and Prevention of Significant Deterioration (PSD).
- Developed a good understanding of Atmospheric Science and Air Pollution Dispersion.
- Employed Fourier Transform IR Spectrometer for real-time air toxics monitoring.
- Attended comprehensive training related to air quality regulations, emission sources, public outreach, etc. Following is alisting of few training classes:
  - Basic New Source Review
  - Principles and Practice of Air Pollution Control
  - Air Dispersion Modeling and Risk Assessment
  - Air Quality Compliance and Enforcement
  - Air Dispersion Modeling using AERMOD
  - Consent Building

New Mexico State Health Department, Scientific Laboratory Division:
Laboratory Scientist III: December 1993 to October 1998

- Analyzed water, soil and air samples for organic contaminants using gas chromatography/mass spectrometer and various other detectors.
- Wrote Quality Control Procedures and analytical reports using MS Office software.
- Worked with clients regarding environmental sampling and regulatory issues.
- Responsible for troubleshooting and maintenance of analytical equipment.
- Used comprehensive database of organic compounds and sample analyses, devised analytical data quality control checks.

Petroleum Recovery Research Center, NMIMT, Socorro, NM.
Research Assistant: January 1990-August 1993

- Dissertation Project: *"Direct Thickeners for Dense CO2"*
- Synthesized new organic initiators.
- Investigated electron donors for the electron donor-mediated living carbocationic polymerization of isobutylene.
- Synthesized and characterized living sulfonated polyisobutylene telechelic ionomers and their association in various solvents.
- Investigated one-pot synthesis of narrow molecular weight distribution living sulfonated telechelic Polyisobutylenes.
- Wrote grant requests, project progress reports and research papers.

Chemistry Department, NMIMT, Socorro, NM:
Teaching Assistant in Chemistry: August 1989-May 1990

- Taught General Chemistry, Quantitative Analytical Chemistry and laboratory courses.

Imperial Chemical Industries (ICI) Paints Business Area, Lahore, Pakistan
Management Trainee Chemist: January 1988-August 1989

- Developed and tested automotive and industrial paints according to the need of the clients.
- Performed quality control and assurance checks on the production line.
- Tested raw material.
- Supervised technical staff in the development laboratory.

NMED
EXHIBIT 3

New Mexico Air Quality Bureau

Air Dispersion Modeling Guidelines

Revised June 6, 2019

Recent changes to the Modeling Guidelines are described in Appendix A at the end of this document.

Notes:
EPA in-stack ratio database:
https://www.epa.gov/scram/nitrogen-dioxidenitrogen-oxide-stack-ratio-isr-database

Significance levels for PM2.5 and ozone:
https://www.epa.gov/sites/production/files/2016-08/documents/pm2_5_sils_and_ozone_draft_guidance.pdf
2017 Appendix W:
https://www3.epa.gov/ttn/scram/appendix_w/2016/AppendixW_2017.pdf

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1.0 INTRODUCTION

1.1 Introductory Comments

Air pollution has been proven to have serious adverse impacts on human health and the environment. In response, governments have developed air quality standards designed to protect health and secondary impacts. The only way to predict compliance with these standards by a facility or modification that does not yet exist is to use models to simulate the impacts of the project. Regulatory models strike a balance between cost-effectiveness and accuracy, though the field of air quality prediction is not necessarily an inexpensive or a highly accurate field. The regulatory model design is an attempt to apply requirements in a standard way such that all sources are treated equally and equitably.

It is the duty of the NMED/Air Quality Bureau (the Bureau) to review modeling protocols and the resulting modeling analyses to ensure that air quality standards are protected and to ensure that regulations are applied consistently. This document is an attempt to document clear and consistent modeling procedures in order to achieve these goals. Occasionally, a situation will arise when it makes sense to deviate from the guidelines because of special site-specific conditions. Suggested deviations from the guidelines should be documented in a modeling protocol and submitted to the Bureau for approval prior to submission of modeling.

In general, the procedures in the EPA document, Guideline On Air Quality Models[1] (EPA publication number EPA-450/2-78-027R (revised)) as modified by Supplements A, B, and C should be followed when conducting the modeling analysis. This EPA document provides complete guidance on appropriate model applications. The purpose of this document is to provide clarification, additional guidance, and to highlight differences between the EPA document and New Mexico State modeling requirements.

Please do not hesitate to call the Bureau modeling staff with any questions you have before you begin the analysis. We are here to help; however, we will not conduct modeling courses. There are many courses offered which teach the principles of dispersion modeling. These courses provide a much better forum for learning about modeling than the Bureau modeling staff can provide.

1.2 The Modeling Review Process

1.2.1 Modeling Protocol Review

A modeling protocol should be submitted and approved before submitting a permit application. The Bureau will make every attempt to approve, conditionally approve, or reject the protocol within two weeks. Details regarding the protocol are described in section 6.0, Modeling Protocols. Protocols will be archived in the modeling archives in the protocol section until they can be stored with the files for the application.

1.2.2 Permit Modeling Evaluation

When a permit application involving air dispersion modeling is received, modeling staff has 30 days to determine whether the modeling analysis is administratively complete. The modeling section staff will make a quick determination to see if the modeling analysis appears complete. This involves checking to see if

[1] Environmental Protection Agency, 40 CFR Part 51, Revision to the Guideline on Air Quality Models http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

modeling files are attached and readable and verifying that application forms and modeling report are present. If the analysis is incomplete, the staff will inform the applicant of the deficiencies as quickly as possible. This will halt the permitting process until sufficient information is submitted. Deficiencies not resolved prior to the completeness determination deadline may result in ruling the application incomplete.

After the application has been ruled complete, Bureau staff will perform a complete review of the modeling files. This analysis includes a review to make sure that information in the modeling files are consistent with the information in the permit application and may involve the emission rate of each emission point, the elevation of sources, receptors, and buildings, evaluation and modification of DEM data, property fence line, or other aspects of the modeling inputs. If the dispersion modeling analysis submitted with the permit application adequately demonstrates that ambient air concentrations will be below air quality standards and/or Prevention of Significant Deterioration (PSD) increments, the Bureau modeler will summarize the findings and provide the information to the permit writer. If dispersion modeling predicts that the construction or modification causes or significantly contributes to an exceedance of a New Mexico or National Ambient Air Quality Standard (NMAAQS or NAAQS) or PSD increment, the permit cannot be issued under the normal permit process. For nonattainment modeling, refer to 20.2.72.216 NMAC, 20.2.79 NMAC, or contact the Bureau for further information.

The application (including modeling) is expected to be complete and in good order at the time it is received. However, the Bureau will accept general modifications or revisions to the modeling before the modeling is reviewed provided that the changes do not conflict with good modeling practices. Once the modeling review begins, only changes to correct problems or deficiencies uncovered during the review of the modeling will normally be accepted, and the Bureau will provide a deadline by which changes need to be submitted to allow for them to be reviewed and for the permit to be issued. No changes to modeling will be allowed after the review has been completed.

2.0 MODELING REQUIREMENTS AND STANDARDS

2.1 Regulatory Requirement for Modeling

The requirements to perform air dispersion modeling are detailed in New Mexico Administrative Code (NMAC) **20.2.70.300.D.10 NMAC** (Operating Permits), **20.2.72.203.A.4 NMAC** (Construction Permits), and **20.2.74.305 NMAC** (Permits - Prevention of Significant Deterioration), and 20.2.79 NMAC (Nonattainment). The language from these sections is listed below for easy reference.

Basically, with a construction permit application, an analysis of air quality standards is required, which normally requires air dispersion modeling. In some cases, previous modeling may satisfy this requirement. In these cases, the applicant may seek a modeling waiver from the Bureau. In any case, it is the responsibility of the applicant to provide the modeling, or the justification for the modeling waiver, or the air quality analysis for nonattainment areas. Title V sources that have not demonstrated compliance with a standard or increment are required to come into compliance with this applicable requirement. This may be accomplished by modeling to show the area is in attainment with this standard or increment. If they are not able to model compliance, then a compliance plan will be needed.

2.1.1 Title V Operating Permits

Federal air quality standards are applicable requirements for sources required to have an operating permit. Modeling is usually not required to issue a Title V operating permit. If a facility is not required to have a construction permit (e.g., some landfills and "Grandfathered" facilities) then it will need to model any new emissions or changes that could increase ambient pollutant concentrations.

Selected Title V regulatory language applying to modeling is copied below for easy reference.

> **20.2.70.7 NMAC DEFINITIONS:** In addition to the terms defined in 20.2.2 NMAC (definitions), as used in this part the following definitions shall apply.
>
> E. "Applicable requirement" means all of the following, as they apply to a Part 70 source or to an emissions unit at a Part 70 source (including requirements that have been promulgated or approved by the board or US EPA through rulemaking at the time of permit issuance but have future-effective compliance dates).
>
> (11) Any national ambient air quality standard.
>
> (12) Any increment or visibility requirement under Part C of Title I of the federal act, but only as it would apply to temporary sources permitted pursuant to Section 504(e) of the federal act.
>
> **20.2.70.201 NMAC REQUIREMENT FOR A PERMIT:**
>
> D, Requirement for permit under 20.2.72 NMAC.
>
> (1) Part 70 sources that have an operating permit and do not have a permit issued under 20.2.72 NMAC or 20.2.74 NMAC shall submit a complete application for a permit under 20.2.72 NMAC within 180 days of September 6, 2006. The department shall consider and may grant reasonable requests for extension of this deadline on a case-by-case basis.
>
> (2) Part 70 sources that do not have an operating permit or a permit under 20.2.72 NMAC upon the effective date of this subsection shall submit an application for a permit under 20.2.72 NMAC within 60 days after submittal of an application for an operating permit.
>
> (3) Paragraphs 1 and 2 of this subsection shall not apply to sources that have demonstrated compliance with both the national and state ambient air quality standards through dispersion modeling or other method approved by the department and that have requested incorporation of conditions in their operating permit to ensure compliance with these standards.

20.2.70.300.D.10 NMAC

(10) Provide certification of compliance, including all of the following.

(a) A certification, by a responsible official consistent with Subsection E of 20.2.70.300 NMAC, of the source's compliance status for each applicable requirement. For national ambient air quality standards, certifications shall be based on the following.

(i) For first time applications, this certification shall be based on modeling submitted with the application for a permit under 20.2.72 NMAC.

(ii) For permit renewal applications, this certification shall be based on compliance with the relevant terms and conditions of the current operating permit.

2.1.2 New Source Review (NSR) Permitting for Minor Sources

For new permits, a demonstration of compliance with air quality standards, PSD increments, and toxic air pollutants subject to 20.2.72.403.A(2) is required for all pollutants emitted by the facility. For significant revisions, a demonstration of compliance with air quality standards, PSD increments, and toxic air pollutants subject to 20.2.72.403.A(2) is required for all pollutants affected by the modification or permit revision. For technical revisions involving like kind replacement, as specified in 20.2.72.219B(1)(d), a demonstration that the replacement unit has stack parameters which are at least as effective in the dispersion of air pollutants is required (provided previous modeling determined the area to be in compliance with air quality standards). Permits for sources not in attainment with standards should refer to 20.2.72.216 NMAC, NONATTAINMENT AREA REQUIREMENTS.

If previous modeling has demonstrated compliance for each averaging period of each pollutant with a state or federal ambient air quality standard or toxic air pollutant, and that modeling used current modeling practices and is up-to-date for that area, then a modeling waiver may be used as the discussion demonstrating compliance. Otherwise, new modeling is required. For other minor source permitting actions, modeling is not part of the permitting process. Modeling waivers do not apply to nonattainment areas.

Selected NSR regulatory language applying to modeling is copied below for easy reference.
Definition of modification:

20.2.72.7 DEFINITIONS: In addition to the terms defined in 20.2.2 NMAC (Definitions) as used in this Part:

P. "Modification" means any physical change in, or change in the method of operation of, a stationary source which results in an increase in the potential emission rate of any regulated air contaminant emitted by the source or which results in the emission of any regulated air contaminant not previously emitted, but does not include:

(1) a change in ownership of the source;

(2) routine maintenance, repair or replacement;

(3) installation of air pollution control equipment, and all related process equipment and materials necessary for its operation, undertaken for the purpose of complying with regulations adopted by the board or pursuant to the Federal Act; or

(4) unless previously limited by enforceable permit conditions:

(a) an increase in the production rate, if such increase does not exceed the operating design capacity of the source;

(b) an increase in the hours of operation; or

(c) use of an alternative fuel or raw material if, prior to January 6, 1975, the source was capable of accommodating such fuel or raw material, or if use of an alternate fuel or raw material is caused by any natural gas curtailment or emergency allocation or any other lack of supply of natural gas.

Requirements for permit:

20.2.72.200 APPLICATION FOR CONSTRUCTION, MODIFICATION, NSPS, AND NESHAP - PERMITS AND REVISIONS:

A. Permits must be obtained from the Department by:

(1) Any person constructing a stationary source which has a potential emission rate greater than 10 pounds per hour or 25 tons per year of any regulated air contaminant for which there is a National or New Mexico Ambient Air Quality Standard. If the specified threshold in this subsection is exceeded for any one regulated air contaminant, all regulated air contaminants with National or New Mexico Ambient Air Quality Standards emitted are subject to permit review. Within this subsection, the potential emission rate for nitrogen dioxide shall be based on total oxides of nitrogen;

(2) Any person modifying a stationary source when all of the pollutant emitting activities at the entire facility, either prior to or following the modification, emit a regulated air contaminant for which there is a National or New Mexico Ambient Air Quality Standard with a potential emission rate greater than 10 pounds per hour or 25 tons per year and the regulated air contaminant is emitted as a result of the modification. If the specified threshold in this subsection is exceeded for any one regulated air contaminant, all regulated air contaminants with National or New Mexico Ambient Air Quality Standards emitted by the modification are subject to permit review. Within this subsection, the potential emission rate for nitrogen dioxide shall be based on total oxides of nitrogen;

Like-kind-replacement required modeling:

20.2.72.219 PERMIT REVISIONS:

B. Technical Permit Revisions:

(1) Technical permit revision procedures may be used only for:

(d) Modifications that replace an emissions unit for which the allowable emissions limits have been established in the permit, provided that the new emissions unit:

(i) Is equivalent to the replaced emissions unit, and serves the same function within the facility and process;

(ii) Has the same or lower capacity and potential emission rates;

(iii) Has the same or higher control efficiency, and stack parameters which are at least as effective in the dispersion of air pollutants;

(vi) Would not, when operated under applicable permit conditions, cause or contribute to a violation of any National or New Mexico Ambient Air Quality Standard; and

Modeling requirements for new permits or significant revisions:

20.2.72.203.A.4 NMAC

Contain a regulatory compliance discussion demonstrating compliance with each applicable air quality regulation, ambient air quality standard, prevention of significant deterioration increment, and provision of 20.2.72.400 NMAC - 20.2.72.499 NMAC. The discussion must include an analysis, which may require use of US EPA-approved air dispersion model(s), to (1) demonstrate that emissions from routine operations will not violate any New Mexico or National Ambient Air Quality Standard or prevention of significant deterioration increment, and (2) if required by 20.2.72.400 NMAC - 20.2.72.499 NMAC, estimate ambient concentrations of toxic air pollutants.

2.1.3 NSR Permitting for PSD Major Sources

PSD major sources and major modifications have additional modeling requirements beyond those of minor sources. PSD major source modeling authority is contained here:

20.2.74.305 NMAC AMBIENT AIR QUALITY MODELING: All estimates of ambient concentrations required by this Part shall be based on applicable air quality models, data bases, and other requirements as specified in EPA's Guideline on Air Quality Models (EPA-450/2-78-027R, July, 1986), its revisions, or any superseding EPA document, and approved by the Department. Where an air quality impact model specified in the Guideline on Air Quality Models is inappropriate, the model may be modified or another model substituted. Any substitution or modification of a model must be approved by the Department. Notification shall be given by the Department of such a substitution or modification and the opportunity for public comment provided for in fulfilling the public notice requirements in subsection B of 20.2.74.400 NMAC. The Department will seek EPA approval of such substitutions or modifications.

2.2 Air pollutants

Emissions of Sulfur Dioxide (SO_2), Particulate matter with an aerodynamic diameter of less than or equal to 10 micrometers (PM_{10}), Particulate matter with an aerodynamic diameter of less than or equal to 2.5 micrometers ($PM_{2.5}$), Carbon Monoxide (CO), Nitrogen Dioxide (NO_2), Lead (Pb), Hydrogen sulfide (H_2S), and air toxics as listed in 20.2.72 NMAC are pollutants that may require modeling. Ozone and Volatile Organic Compound (VOC) emissions do not currently require a modeling analysis for a PSD minor source. If NO_X or VOCs are subject to PSD review, you should contact NMED and the EPA Regional Office to determine current ozone modeling requirements.

2.3 Modeling Exemptions and Reductions

2.3.1 Modeling waivers

In some cases, the demonstration that ambient air quality standards and PSD increments will not be violated can be satisfied with a discussion of previous modeling. If emissions have been modeled using current modeling procedures and air quality standards, and this modeling is still valid for the current standards, then the modeling waiver form may be submitted to request approval of a modeling waiver. The Bureau will determine on a case-by-case basis if the modeling waiver can be granted. The waiver discussion and written waiver approval should be included in the modeling section of the application.

The Bureau has performed generic modeling to demonstrate that the following small sources do not need modeling. The application must include a modeling waiver form to document the basis of the waiver. Permitting staff must approve the total emission rates during the permitting process for any waiver to be valid.

Table 1. Very small emission rate modeling waiver requirements

Pollutant	If all emissions come from stacks 20 feet or greater in height and there are no horizontal stacks or raincaps (lb/hr)	If not all emissions come from stacks 20 feet or greater in height, or there are horizontal stacks, raincaps, volume, or area sources (lb/hr)
CO	50	2
H_2S (Pecos-Permian Basin)	0.1	0.02
H_2S (Not in Pecos-Permian Basin)	0.01	0.002
Lead	Waiver not available.	Waiver not available.
NO_2	2	0.025
PM2.5	0.3	0.015
PM10	1.0	0.05
SO_2	2	0.025
Reduced sulfur (Pecos-Permian Basin)	0.033	Waiver not available.
Reduced sulfur (Not in Pecos-Permian Basin)	Waiver not available.	Waiver not available.

2.3.2 General Construction Permits (GCPs)

General Construction Permits do not require modeling. General modeling was performed in the development of these permits.

2.3.3 Streamlined Compressor Station Modeling Requirements

Compressor stations may be eligible for streamlined permits under the authority of **20.2.72.300-399 NMAC**. Streamlined permits have reduced modeling analysis requirements.

Streamlined Compressor Station Location Requirements

Restrictions preventing use of streamlined permits in certain locations are listed in **20.2.72.301 NMAC**. Those restrictions dealing with location are described below.

According to **20.2.72.301.B.4 NMAC**, the facility cannot co-locate with petroleum refineries, chemical manufacturing plants, bulk gasoline terminals, natural gas processing plants, or at any facility containing sources in addition to IC engines and/or turbines for which an air quality permit is required through state or federal air quality regulations.

20.2.72.301.B.5 NMAC restricts the location of streamlined permit in areas predicted by air quality monitoring or modeling to have more than 80% of state or federal ambient air quality standards or PSD increments consumed. Table 2, below, is a list of these areas. This restriction means that any streamlined permit applicant wishing to locate in a nonattainment area or those areas listed in Table 2 must demonstrate, using air dispersion modeling, that the entire facility will not produce any concentrations above significance levels.

Table 2. Areas Where Streamlined Permits Are Restricted

County	Latitude	Longitude	Radius (m)
San Juan	36.73120	-107.9608189	3000
San Juan	36.48296	-108.1200487	1000

* Locations within 150 meters of a facility that emits 25 tons per year of NO_X are restricted areas for streamlined compressor station permits unless modeling is performed.

20.2.72.301.B.6 NMAC prohibits the location of streamline permit from use in areas if the nearest property boundary will be located less than:
(a) 1 kilometer (km) from a school, residence, office building, or occupied structure. Buildings and structures within the immediate industrial complex of the source are not included.
(b) 3 km from the property boundary of any state park, Class II wilderness area, Class II national wildlife refuge, national historic park, state recreation area, or community with a population of more than twenty thousand people.

Table 3. List of state parks, Class I areas, Class II wilderness areas, Class II national wildlife refuges, national historic parks, and state recreation areas

County	Name	Type	Min. Distance (km)
Bernalillo	Sandia Mountain Wilderness	State Wilderness	3
Catron	Gila Wilderness	Class I Area	30
Catron	Gila Cliff Dwelling	National Monuments	3
Catron	Datil Well	Recreation Sites	3
Chaves	Bottomless Lake	Class II State Parks	3
Chaves	Salt Creek Wilderness Area	Class I Area	30
Chaves	Bitter Lake National W.R.	Class II Wildlife Refuge	3
Cibola	Bluewater Lake	Class II State Parks	3
Cibola	El Malpais	National Monuments	3
Cibola	El Morro	National Monuments	3
Colfax	Cimarron Canyon	Class II State Parks	3
Colfax	Maxwell National W.R.	Class II Wildlife Refuge	3
Colfax	Capulin	National Monuments	3
DeBaca	Sumner Lake	Class II State Parks	3
DeBaca	Ft. Sumner	State Monuments	3
Dona Ana	Leesburg Dam	Class II State Parks	3
Dona Ana	Aguirre Springs	Recreation Sites	3
Dona Ana	Ft. Seldon	State Monuments	3
Eddy	Carlsbad Caverns National Park	Class I Area	30
Eddy	Living Desert	Class II State Parks	3
Grant	Gila Wilderness	Class I Area	30
Grant	City of Rocks	Class II State Parks	3
Guadalupe	Santa Rosa Lake	Class II State Parks	3
Harding	Chicosa Lakes	Class II State Parks	3
Harding	Kiowa National Grasslands	National Grasslands	3
Lea	Harry McAdams	Class II State Parks	3
Lincoln	White Mountain Wilderness	Class I Area	30
Lincoln	Valley of Fires	Class II State Parks	3
Lincoln	Lincoln	State Monuments	3

County	Name	Type	Min. Distance (km)
Luna	Pancho Villa	Class II State Parks	3
Luna	Rock Hound	Class II State Parks	3
McKinley	Red Rock	Class II State Parks	3
Mora	Coyote Creek	Class II State Parks	3
Mora	Ft. Union	National Monuments	3
Otero	Oliver Lee	Class II State Parks	3
Otero	White Sands	National Monuments	3
Otero	Three Rivers Petro	Recreation Sites	3
Quay	Ute Lake	Class II State Parks	3
Rio Arriba	San Pedro Parks Wilderness	Class I Area	30
Rio Arriba	El Vado Lake	Class II State Parks	3
Rio Arriba	Heron Lake	Class II State Parks	3
Rio Arriba	Navajo Lake (Sims)	Class II State Parks	3
Rio Arriba	Chama River Canyon Wilderness	State Wilderness	3
Roosevelt	Oasis	Class II State Parks	3
Roosevelt	Grulla National W. R.	Class II Wildlife Refuge	3
San Juan	Navajo (Pine)	Class II State Parks	3
San Juan	Chaco Canyon	National Historic Park	3
San Juan	Aztec Ruins	National Monuments	3
San Juan	Angel Peak (National)	Recreation Area	3
San Miguel	Conchas Lake	Class II State Parks	3
San Miguel	Storey Lake	Class II State Parks	3
San Miguel	Villanueva	Class II State Parks	3
San Miguel	Las Vegas National W. R.	Class II Wildlife Refuge	3
San Miguel	Pecos	National Monuments	3
Sandoval	Bandelier Wilderness	Class I Area	30
Sandoval	Coronado	Class II State Parks	3
Sandoval	Rio Grande Gorge/Fenton Lake	Class II State Parks	3
Sandoval	Bandelier	National Monuments	3
Sandoval	Sandia Crest (State)	Recreation Area	3
Sandoval	Coronado	State Monuments	3
Sandoval	Jemez	State Monuments	3
Sandoval	Sandia Mountain Wilderness	State Wilderness	3
Santa Fe	Hyde Memorial	Class II State Parks	3
Sierra	Caballo Lake	Class II State Parks	3
Sierra	Elephant Butte Lake	Class II State Parks	3
Sierra	Percha Dam	Class II State Parks	3
Socorro	Bosque del Apache Wilderness	Class I Area	30
Socorro	Sevillita National W.R.	Class II Wildlife Refuge	3
Taos	Pecos Wilderness	Class I Area	30
Taos	Wheeler Park Wilderness	Class I Area	30
Taos	Kit Carson	Class II State Parks	3
Taos	Rio Grande Gorge	Recreation Sites	3
Taos	Latir Peak Wilderness	State Wilderness	3
Torrance	Manzano Mountain	Class II State Parks	3
Torrance	Grand Guivira	National Monuments	3

County	Name	Type	Min. Distance (km)
Torrance	Quarai at Salinas	National Monuments	3
Torrance	Abo at Salinas	State Monuments	3
Torrance	Manzano Mountain Wilderness	State Wilderness	3
Union	Clayton Lake	Class II State Parks	3
Valencia	Sen. Willie Chavez	Class II State Parks	3
Valencia	Manzano Mountain Wilderness	State Wilderness	3

(c) 10 km from the boundary of any community with a population of more than forty-thousand people, or
(d) 30 km from the boundary of any Class I area;

20.2.72.301.B.7 NMAC prohibits the location of streamline permit in Bernalillo County or within 15 km of the Bernalillo County line.

Streamlined Compressor Station Modeling and Public Notice Requirements

Modeling and public notice requirements for streamlined compressor station permits depend on the amount of emissions from the facility. Refer to the table below, using the maximum of the Potential to Emit (PTE) of each regulated contaminant from all sources at the facility to determine applicability. The potential to emit for nitrogen dioxide shall be based on total oxides of nitrogen. The effects of building downwash shall be included in modeling if there are buildings at the site.

Table 4. Streamlined Permit Applicability Requirements for facilities with less than 200 tons/year PTE

Applicable Regulation	PTE (TPY)	Modeling Requirements (from 20.2.72.301 D NMAC)
20.2.72.301 D (1)	<40	• None
20.2.72.301 D (2)	<100	• The impact on ambient air from all sources at the facility shall be less than the ambient significance levels.
20.2.72.301 D (3)	<200	• Air quality impacts must be less than 50% of all applicable NAAQS, NMAAQS and PSD increments. • There shall be no adjacent sources emitting the same air contaminant(s) as the source within 2.5 km of the modeled NO_2 impact area. • The sum of all potential emissions for NO_X from all adjacent sources within 15 km of the NO_X ROI must be less than 740 tons/year. • The sum of all potential emissions for NO_X from all adjacent sources within 25 km of the NO_X ROI must be less than 1540 tons/year.

There are other criteria that must be met for streamlined permits for compressor stations. Please refer to **20.2.72.300-399 NMAC** for more information.

2.3.4 Minor NSR Exempt Equipment

Exempt equipment under 20.7.72.202 NMAC do not need to be included in modeling for 20.2.72 NMAC permits. The exemption does not exclude them from modeling requirements under other types of permits, such as 20.2.70 NMAC or 20.2.74 NMAC.

2.4 Levels of Protection

2.4.1 Significance Levels

Modeling significance levels are thresholds below which the source is not considered to contribute to any predicted exceedance of air quality standards or PSD increments. The definition of 'source' can apply to the whole facility or to the modifications at the facility. For a new facility or an unpermitted facility, NMED considers the entire facility to be the 'source'. For other cases, 'source' includes only the new equipment or new emissions increases described in the current application. Equipment that replaces other equipment is part of the new equipment.

Example of source to model for permitting:
The entire facility was modeled for annual NO_2 and 1-hour and 8-hour CO in 1999 but was never modeled for 1-hour NO_2. The facility applies to replace a widget. If this widget emits only NO_2 and CO, then modeling review is applicable for these pollutants. For CO and for NO_2, the applicant may model only the replacement widget. If the impacts from the widget alone are below significance levels, then modeling is done for that pollutant/averaging period. If the impacts from the widget alone are above significance levels, then the entire facility plus nearby sources must be modeled for comparison with air quality standards and PSD increments.

Significance levels are listed in **20.2.72.500 NMAC** and are repeated in the sections below. Always use the maximum predicted concentration from the source for radius of impact/significance level determination. Even if the form of the standard allows it to be exceeded several times per period, that fraction is based on cumulative concentration and cannot be related to partial concentrations. If multiple years of meteorological data are used, then the average of those concentrations is compared with the significance level, except for $PM_{2.5}$ and 1-hour SO_2, for which the maximum across multiple years is compared with the significance level.

Use of the $PM_{2.5}$ significant ambient concentration level or significant monitoring concentration for PSD major modifications or new PSD major sources is not allowed. This significant ambient concentration level may still be used for minor source permitting.

2.4.2 Air Quality Standards

Air quality standards are maximum allowable concentrations that are designed to protect the most sensitive individuals from harm from airborne pollutants. National Ambient Air Quality Standards (NAAQS) and New Mexico Ambient Air Quality Standards (NMAAQS) are explained below. Unless otherwise noted, standards are not to be exceeded.

2.4.3 Prevention of Significant Deterioration (PSD) Increments

To prevent relatively clean areas from degrading to levels just barely in compliance with the air quality standards, limits on the change have been established in the form of PSD increments. Compliance demonstrations for PSD increments demonstrate that the deterioration is less than the allowable increment.

List of State air quality standards:
http://www.nmcpr.state.nm.us/nmac/parts/title20/20.002.0003.htm

2.5 Concentration Conversions

Many of the air quality standards are written in the form of parts per million (ppm) or parts per billion (ppb), but the models generally give output in units of micrograms per cubic meter (μg/m^3). EPA has verbally communicated to NMED that AERMOD output is expressed at Standard Temperature and Pressure (STP) conditions. Therefore, most air quality standards can be compared to modeled concentration without corrections for elevation (and associated low pressure). If a need for elevation correction arises, a method to adjust for elevation is listed below.

2.5.1 Gaseous Conversion Factor for Elevation and Temperature Correction

The following equation calculates the conversion from μg/m^3 to ppm, with corrections for temperature and pressure (elevation):

$$ppm = 4.553 \times 10^{-5} \times \frac{C \times T}{M_w} \times 10^{Z \times 1.598 \times 10^{-5}}$$

or, rearranged to calculate μg/m^3:

$$C = ppm \times M_W / (T \times (4.553\ E\text{-}5) \times (10^{Z \times 1.598\ E\text{-}5}))$$

where:

C = component concentration in μg/m^3.
T = average summer morning temperature in Rankin at site (typically 530 R).
M_w = molecular weight of component.
Z = site elevation, in feet.

2.5.2 Gaseous Conversion Factor at Standard Temperature and Pressure (STP) Conditions

Federal standards are expressed as mass per unit volume or ppm or ppb under standard temperature and pressure.

> "40 CFR 50.3 Reference conditions.
> All measurements of air quality that are expressed as mass per unit volume (e.g., micrograms per cubic meter) other than for particulate matter (PM2.5) standards contained in §§ 50.7 and 50.13 and lead standards contained in § 50.16 shall be corrected to a reference temperature of 25 (deg) C and a reference pressure of 760 millimeters of mercury (1,013.2 millibars)."

If a monitored or modeled concentration has been adjusted to STP, then the following equation calculates the conversion from ppm to μg/m^3 for NAAQS:

$$C = ppm \times M_w \times 40.8727$$

or, rearranged to calculate ppm:

$$ppm = C / (M_w \times 40.8727)$$

where:

C = component concentration in μg/m^3.
M_w = molecular weight of component.

$$p = p_0 \cdot \left(1 - \frac{L \cdot h}{T_0}\right)^{\frac{g \cdot M}{R \cdot L}} \approx p_0 \cdot \exp\left(-\frac{g \cdot M \cdot h}{R \cdot T_0}\right),$$

Parameter	Description	Value
p_0	sea level standard atmospheric pressure	101325 Pa
L	temperature lapse rate	0.0065 K/m
T_0	sea level standard temperature	288.15 K
g	Earth-surface gravitational acceleration	9.80665 m/s^2
M	molar mass of dry air	0.0289644 kg/mol
R	universal gas constant	8.31447 J/(mol•K)

$[PM10]_{STP} = [PM10]_{modeled}\ (P_{standard})(T_{measured})/((P_{calculated\ by\ elevation})(T_{standard}))$

2.6 Modeling the Standards and Increments

Unless otherwise specified, the discussion of the standards assumes one year of representative meteorological data is used. For multiple years of data, some pollutants use the average of the values predicted for each year as the design value. Others (including PM2.5, CO, and Pb) use the maximum value from the multiple years of data. Verify the form of the standard in regulations and EPA memos if multiple years of meteorological data are being used. Background concentrations are averaged over three years unless otherwise specified.

In cases where all the emissions of the pollutant in question are emitted from permitted sources, the nearby sources may be modeled instead of adding the background concentration. CO, NO_2, and SO_2 may use this substitution if they are over 10 km from the center of Albuquerque and El Paso. To use this substitution, include all nearby sources.

2.6.1 Carbon Monoxide (CO) Standards

Table 5A: Carbon Monoxide Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS (ppm)	NAAQS ($\mu g/m^3$)	NMAAQS (ppm)	NMAAQS ($\mu g/m^3$)
8-hour	500	9	10,303.6	8.7	9,960.1
1-hour	2,000	35	40,069.6	13.1	14,997.5

2.6.1.1 Design value of CO standard.

CO NAAQS are not to be exceeded more than once per year. NMAAQS are not to be exceeded. Demonstration of compliance with CO NMAAQS automatically demonstrates compliance with NAAQS.

2.6.1.2 Modeling for the CO design value.

Tier 1, 1-hour NMAAQS: Model the entire facility to determine the high 1-hour concentration. Add the high 1-hour background concentration to the high 1-hour predicted concentration to determine the total design concentration for comparison to the 1-hour NMAAQS.

Tier 1, 8-hour NMAAQS: Model the entire facility to determine the high 8-hour concentration. Add the high 8-hour background concentration to the high 8-hour predicted concentration to determine the total design concentration for comparison to the 8-hour NMAAQS.

Optionally, all nearby sources may be modeled instead of adding a background concentration, if the facility is over 10 km from the center of Albuquerque and El Paso.

Tier 2: Hourly background concentrations may be added instead of the maximum concentrations for each averaging period.

2.6.2 Hydrogen sulfide (H_2S) Standards

Table 5B: Hydrogen Sulfide Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NMAAQS (ppm)	NMAAQS ($\mu g/m^3$)	Notes
1-hour	1.0	0.010	13.9	For the state, except for the Pecos-Permian Basin Intrastate AQCR. Not to be exceeded more than once per year.
1/2-hour	5.0	0.10	139.3	For the Pecos-Permian Basin Intrastate AQCR
1/2-hour	5.0	0.030	41.8	for within 5-miles of the corporate limits of municipalities within the Pecos-Permian Basin AQCR

Design value of standard: For modeling ½-hour H_2S NMAAQS, use the 1-hour averaging time because the models cannot resolve less than one-hour increments.

Model the entire facility and any nearby sources and compare the high 1-hour concentration to the standard for that region. No background concentration is added.

2.6.3 Lead (Pb) Standards

Table 5C: Lead Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
Quarterly	0.03	0.15

Design value of standard: For modeling quarterly lead averages, use the monthly averaging period as a conservative approach, unless the model being used has a quarterly averaging period or post-processing is desired to calculate quarterly values. Model the entire facility without surrounding sources and compare the high month concentration to the standard. No background concentration is added.

2.6.4 Nitrogen Dioxide (NO_2) Standards

Table 5D: NO_2 Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS (ppb)	NAAQS ($\mu g/m^3$)	NMAAQS (ppb)	NMAAQS ($\mu g/m^3$)	Class II PSD Increment ($\mu g/m^3$)	Class I PSD Significance Level ($\mu g/m^3$)	Class I PSD Increment ($\mu g/m^3$)
annual	1.0	53	99.66	50	94.02	25	0.1[8]	2.5
24-hour	5.0			100	188.03			
1-hour	7.52[1]	100	188.03					

[1] EPA proposed significance level of 4 ppb corrected to a reference temperature of 25°C and a reference pressure of 760 millimeters of mercury.

2.6.4.1 Design value of NO_2 standard

Demonstration of compliance with 1-hour standard is automatically a demonstration of compliance with the 24-hour NMAAQS. Otherwise, the 24-hour NO_2 standard is compared with the highest 24-hour average calculated by the model.

The annual NMAAQS design value is determined by modeling the entire facility and adding the annual background concentration. The total is compared to the standard. Optionally, to determine the total design value, the facility and all nearby sources may be modeled instead of adding a background concentration if the facility is over 10 km from the center of Albuquerque and El Paso.

The annual NO_2 PSD increment is compared with the annual average calculated by the model.

The 1-hour NO_2 standard is compared with the 3-year average of the 98th-percentile of the annual distribution of daily maximum 1-hour concentrations. If one year of on-site meteorological data is used, the 98th-percentile value associated with the 1-year period of meteorological data modeled is the design value. Each day of modeling, the maximum 1-hour concentration is determined for each receptor. The high-eighth-high value at each receptor is calculated, and the maximum of these is compared with the standard. If multiple years are modeled, the maximum value is averaged over the span of years before comparing with standards.

2.6.4.2 NO_2 Reactivity

Combustion processes emit nitrogen oxides in the forms of nitrogen oxide (NO) and nitrogen dioxide (NO_2). Only the concentration of NO_2 is regulated by air quality standards; however, emissions of nitrogen oxides ($NO_X = NO + NO_2$) must be modeled to estimate total NO_2 concentrations because nitrogen oxides change form in the atmosphere.

Two key reactions are most important in determining the equilibrium (or quasi-equilibrium) ratio of NO_2 to NO.

$NO + O_3 \rightarrow NO_2 + O_2$

$NO_2 + h\nu$ (energy) $\rightarrow NO + O$

Many other reactions participate in the determination of the atmospheric concentration of NO_2. As the plume travels away from the stack, more and more ozone diffuses into the plume, enabling the relatively quick reaction to form NO_2.

2.6.4.3 Estimating NO_2 concentrations

The Bureau has approved techniques, described below, for estimating NO_2 concentrations from NO_X point sources. Note that NO_2 emissions reported by the emissions inventory are actually NO_X emissions.

Tier 1, Total Conversion Technique: 100% conversion

This technique assumes all the NO_X is converted to NO_2. This simple technique is suitable for small facilities where compliance with standards is not a problem.

Tier 2, Ambient Ratio Method 2 (ARM2) Technique

ARM2 method is included as an option in AERMOD. This method is approved without the need for EPA approval. 0.5 is the national default for minimum ambient ratio. A minimum ambient ratio as low as 0.2 may be used by providing evidence that the in-stack ratio of the modeled emission units is equal to or lower than the minimum ambient ratio used. The default maximum ratio is 0.9.

Tier 3, Ozone Reaction Techniques

Two methods account for the ozone that mixes into the plumes and encourages NO_2 formation: Ozone Limiting Method (OLM) and Plume Volume Molar Ratio Method (PVMRM). Both these techniques are accepted and are built into AERMOD.

OLM assumes an NO_2 plume and an NO plume are each dispersing. The in-stack ratio of NO_2/NO_X is used to determine the amount of nitrogen dioxide initially in each plume. The concentration of NO at each receptor is assumed to react stoichiometrically with the background ozone concentration at that time to form NO_2. Contributions from both plumes are added to get the NO_2 concentration at that time.

PVMRM works similarly to OLM but uses the total volume of the plume by the time it reaches the receptor to calculate how much ozone is available for reaction. Both methods result in greater conversion with greater distance from the source but use different approximations for determining how much ozone has dispersed into the plume.

Both methods require additional information.

For the equilibrium NO_2/NO_X ratio, the value of 0.9 is approved.

For the in-stack NO_2/NO_X ratio, values lower than 0.5 must be justified with data. Combustion involving excess oxygen results in higher in-stack NO_2/NO_X ratios than do stoichiometric reactions. The facility may use an in-stack ratio of 0.5 without justification. Surrounding sources, if required, may be modeled with an in-stack ratio of 0.3 without justification.

Recent ozone data representative of the area should be used. See the section on background concentrations for more information.

Special techniques are required to model PSD increment with OLM or PVMRM if increment-expanding sources are being modeled. No negative emission rates can be used. See *ADDENDUM, USER'S GUIDE FOR THE AMS/EPA REGULATORY MODEL – AERMOD (EPA-454/B-03-001, September 2004)*, Pg. 25, for more details on the PSDCREDIT option**.** **(http://www.rflee.com/RFL_Pages/AERMOD_USERGUIDE_ADDENDUM_06341.pdf)**

Combined-Plume Option vs. Individual-Plume Option

AERMOD provides two options for calculating ozone-limited NO_2 concentrations, the "plume-by-plume" (INDVDL) calculation, and the combined plume (SRCGRP) calculation. The Bureau has accepted a general demonstration that if two plumes are impacting the same receptor at the same time, then the two plumes have merged. If the plumes do not impact the same receptor at the same time, then the plumes have not merged, but both options will calculate the same concentration for that hour. Therefore, the Bureau will accept either INDVL or SRCGP option without additional demonstrations.

2.6.4.4 Modeling for the 1-hour NO_2 design value

Model the entire facility and add the 98th percentile 1-hour background concentration to compare to the design value. Optionally, all nearby sources may be modeled instead of adding a background concentration if the facility is over 10 km from the center of Albuquerque and El Paso, Texas. Refined hourly background concentrations may be used instead of the maximum 1-hour concentration as described in the section on background concentrations.

Before attempting to calculate the design value, first locate the areas with highest overall concentrations. Place a few receptors in these areas and re-run the model in these areas. The maximums will occur in nearly the same places.

Maximum modeled concentration may also be used as a conservative approximation of the design value.

"The highest of the average 8th-highest (98th-percentile) concentrations across all receptors, based on the length of the meteorological data period, represents the modeled 1-hour NO_2 design value based on the form of the standard."

2.6.4.5 Modeling for the annual NO_2 NMAAQS design value

Model the entire facility and add the annual background concentration to compare to the design value. Optionally, all nearby sources may be modeled instead of adding a background concentration if the facility is over 10 km from the center of Albuquerque and El Paso, Texas. (Use of hourly background concentrations does not affect the result for an annual average).

2.6.4.6 Modeling for the annual NO_2 PSD increment design value

Model all increment-consuming parts of the facility and increment-consuming nearby sources of the facility (or nearby sources of the Class I area for Class I analysis). Compare the result to the design value. All sources (not just increment affecting sources) will need to be modeled in order to take credit for increment expanding sources using OLM or PVMRM. See the AERMOD User's Guide Addendum for more details.

2.6.5 Ozone (O_3) Standards

Ozone is normally only modeled for regional compliance demonstrations and does not need to be modeled for air quality permits. However, permit applicants for PSD applications that apply to NO_X or VOCs should contact NMED and the EPA Regional Office to determine how to complete the ozone ambient impact analysis.

Table 5E: O_3 Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS (ppm)	NAAQS ($\mu g/m^3$)
8-hour	1.96 [2]	0.07[1]	137.3

[1] To attain this standard, the 3-year average of the fourth-highest daily maximum 8-hour average ozone concentrations measured at each monitor within an area over each year must not exceed 0.07 ppm.
[2] 1.0 ppb, Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program, EPA, April 17, 2018

Ozone concentrations may be estimated using the following method derived from the MERP guidance[2].

[O3] = ((NO_X emission rate (tons/year) /184) + (VOC emission rate (tons/year) /1049)) x 1.96 $\mu g/m^3$

> "Simulation of ozone formation and transport is a highly complex and resource intensive exercise. Control agencies with jurisdiction over areas with ozone problems are encouraged to use photochemical grid models, such as the Models-3/Community Multi-scale Air Quality (CMAQ) modeling system, to evaluate the relationship between precursor species and ozone." --68234 Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005 / Rules and Regulations

In accordance with this guidance, NMED performs ozone modeling on a regional scale as need arises, rather than requiring permit applicants to quantify their contribution to a regional ozone concentration. Comprehensive ozone modeling is too resource intensive to attach this expense to a typical permit application, and screening modeling on an affordable scale currently cannot quantify a source's impacts to ambient ozone concentrations.

Regional ozone modeling for the Four Corners area was done in 2009 (see http://www.nmenv.state.nm.us/aqb/4C/Modeling.html) and the Air Quality Bureau is continuing to analyze ozone in the region.

2.6.6 Particulate matter less than 2.5 micrometers in aerodynamic diameter ($PM_{2.5}$) Standards

[2] Guidance on the Development of Modeled Emission Rates for Precursors (MERPS) as a Tier 1 Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program, Richard A. Wayland, EPA, December 2, 2016.

Table 5F: $PM_{2.5}$ Air Quality Standards[3]

Averaging Period	Significance Level [4] ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	Class II PSD Increment[3] ($\mu g/m^3$)	Class I PSD Significance Level ($\mu g/m^3$)	Class I PSD Increment[3] ($\mu g/m^3$)
annual	0.2	12 [1]	4	0.05	1
24-hour	1.2	35 [2]	9	0.27	2

[1] To attain this standard, the 3-year average of the annual arithmetic mean $PM_{2.5}$ concentrations from single or multiple community-oriented monitors must not exceed 12.0 ug/m^3.
[2] To attain this standard, the 3-year average of the 98th percentile of 24-hour concentrations at each population-oriented monitor within an area must not exceed 35 ug/m^3.
[3] For any period other than an annual period, the applicable maximum allowable increase may be exceeded during one such period per year at any one location.
[4] Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program, EPA, April 17, 2018.

$PM_{2.5}$ secondary formation concentrations may be estimated using the following method derived from the MERP guidance[4].

$[PM_{2.5}]_{annual}$ =
((NO_X emission rate (tons/year) /3184) + (SO_2 emission rate (tons/year) /2289)) x 0.2 $\mu g/m^3$

$[PM_{2.5}]_{24\text{-hour}}$ =
((NO_X emission rate (tons/year) /1155) + (SO_2 emission rate (tons/year) /225)) x 1.2 $\mu g/m^3$

Secondary formation from the project should be added to the modeled value. Refined factors for certain geographic areas may be developed using the MERP guidance.

2.6.6.1 $PM_{2.5}$ design value

The 24-hour design value is the 98th percentile of the combined concentrations from all sources. The annual design value is the annual average.

2.6.6.2 Modeling for the 24-hour $PM_{2.5}$ design value

AERMOD and current emissions inventories currently do not account for secondary formation of $PM_{2.5}$ in the atmosphere. Sources that emit at least 40 tons per year of NO_X or at least 40 tons per year of SO_2 are

[3] Prevention of Significant Deterioration (PSD) for Particulate Matter Less Than 2.5 Micrometers ($PM_{2.5}$) – Increments, Significant Impact Levels (SILs) and Significant Monitoring Concentration (SMC), ENVIRONMENTAL PROTECTION AGENCY
40 CFR Parts 51 and 52, RIN 2060-AO24 http://www.epa.gov/nsr/documents/20100929finalrule.pdf
[4] Guidance on the Development of Modeled Emission Rates for Precursors (MERPS) as a Tier 1 Demonstration Tool for Ozone and PM2.5 under the PSD Permitting Program, Richard A. Wayland, EPA, December 2, 2016.

considered to emit significant amounts of precursors. Sources with significant increases of $PM_{2.5}$ precursors must qualitatively and/or quantitatively account for secondary formation of $PM_{2.5}$.[5]

Two tiers of modeling are available for $PM_{2.5}$ modeling. Both tiers include modeling the facility and nearby sources and adding secondary formation and a background concentration to that. Particulate sources typically have impacts in the immediate vicinity of the source that are not represented in background monitors, so double-counting of background concentrations is expected to be limited.

Add the design value of the modeled direct $PM_{2.5}$ to the design value of the secondary $PM_{2.5}$ and the design value of the background $PM_{2.5}$.

Tier 1: To the modeled concentration(s), add the secondary $PM_{2.5}$ and the 98th percentile 24-hour monitored background concentration.
Tier 2: Add the secondary $PM_{2.5}$ and the monthly or quarterly maximum background concentrations to daily modeled concentrations. Compare the high-eighth-high combined concentration with the 24-hour standard. If multiple years of meteorological data are used, then the high-eighth-high combined concentration is compared with the standard.

2.6.6.3 Modeling for the 24-hour $PM_{2.5}$ PSD increment design value

Model the high-second-high concentration of all increment-consuming sources at the facility and at nearby sources. Calculate secondary formation from NO_X and SO_2 increases after the appropriate baseline date and add that to the modeled concentration. Compare the total with the 24-hour PSD increment.

2.6.6.4 Modeling for the annual $PM_{2.5}$ PSD increment design value

Model all increment-consuming sources at the facility and at nearby sources. Calculate secondary formation from NO_X and SO_2 increases after the appropriate baseline date and add that to the modeled concentration. Compare the total predicted annual average concentration with the allowable increment.

2.6.7 Particulate matter less than 10 micrometers in aerodynamic diameter (PM_{10}) Standards

Table 5G: PM_{10} Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	PSD Increment[2] Class II ($\mu g/m^3$)	PSD Class I Significance Level ($\mu g/m^3$)	PSD Class I Increment[2] ($\mu g/m^3$)
annual	1.0		17	0.2[1]	4
24-hour	5.0	150	30	0.3[1]	8

[1] EPA proposed significance level
[2] For any period other than an annual period, the applicable maximum allowable increase may be exceeded during one such period per year at any one location.

2.6.7.1 Modeling for the 24-hour PM_{10} NAAQS design value

[5] Guidance for PM2.5 Permit Modeling, Stephen D. Page, May 20, 2014.
http://www.epa.gov/ttn/scram/guidance/guide/Guidance_for_PM25_Permit_Modeling.pdf

If PM2.5 emission rates are modeled as equal to PM10 emission rates, then the PM2.5 NAAQS demonstration will satisfy the requirement for demonstration of compliance with PM10 NAAQS. However, PM10 PSD increment demonstration is not necessarily satisfied by any PM2.5 modeling.

The 24-hour NAAQS is not to be exceeded more than once per year.
Use high second high and a single year of representative meteorological data. This is approximately equivalent to the high fourth high specified in the multi-year analysis.
"…[W]hen n years are modeled, the (n+1)th highest concentration over the n-year period is the design value, since this represents an average or expected exceedance rate of one per year."
http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

Two tiers of modeling are available for PM_{10} NAAQS modeling. Both tiers include modeling the facility and nearby sources and adding a background concentration to that. Particulate sources typically have impacts in the immediate vicinity of the source that are not represented in background monitors, so double-counting of background concentrations is expected to be limited.

Tier 1, option 1: Use highest predicted concentration (instead of the high second high) and a single year of representative meteorological data. To the modeled concentration, add the high second high 24-hour monitored background concentration.

Tier 1, option 2: Use high second high predicted concentration and a single year of representative meteorological data. To the modeled concentration, add the highest 24-hour monitored background concentration.

Tier 2: Add monthly maximum background concentrations to daily modeled concentrations. The high-second-high combined concentration may be compared with the 24-hour standard.

2.6.7.2 Modeling for the 24-hour PM_{10} PSD increment design value

Model all increment-consuming sources at the facility and at nearby sources. Compare the high-second-high predicted concentration with the allowable increment.

2.6.7.3 Modeling for the annual PM_{10} PSD increment design value

Model all increment-consuming sources at the facility and at nearby sources. Compare the predicted annual average concentration with the allowable increment.

2.6.8 Sulfur Dioxide (SO_2) Standards

Table 5I: SO_2 Air Quality Standards

Averaging Period	Significance Level ($\mu g/m^3$)	NAAQS (ppb)	NAAQS ($\mu g/m^3$)	NMAAQS (ppb)	NMAAQS ($\mu g/m^3$)	PSD Class II Increment[3] ($\mu g/m^3$)	PSD Class I Significance Level ($\mu g/m^3$)	PSD Class I Increment[3] ($\mu g/m^3$)
annual	1.0			20	52.4	20	0.1[2]	2
24-hour	5.0			100	261.9	91	0.2[2]	5
3-hour	25.0	500	1309.3			512	1.0[2]	25
1-hour	7.8[1]	75	196.4					

[1] EPA proposed 1-hour significance level of 3 ppb corrected to a reference temperature of 25°C and a reference pressure of 760 millimeters of mercury.

[2] EPA proposed significance level.
[3] For any period other than an annual period, the applicable maximum allowable increase may be exceeded during one such period per year at any one location.

2.6.8.1 SO_2 design value

In NMAC, the SO_2 standards for the area within 3.5 miles of the Chino Mines Company smelter furnace stack at Hurley are set equal to the federal standards. However, since this stack no longer exists, the distance is irrelevant. The NMAAQS listed in table 5I apply for the entire state.
Demonstration of compliance with 1-hour standard will also demonstrate compliance with the other standards, but not necessarily the PSD increments.

The form is the 3-year average of the 99th percentile of the annual distribution of daily maximum 1-hour average concentrations.

2.6.8.2 Modeling for the 1-hour SO_2 NAAQS

The standard is calculated similarly to the NO_2 1-hour standard instructions in section 2.6.4.4, but the fourth highest is used in place of the eighth highest (and 99th percentile is substituted for 98th percentile). All sulfur oxides are assumed to be in the form of SO_2. If multiple years are modeled, the resulting high-fourth-high values at each receptor are averaged over the years modeled and the maximum average value is compared with the standard.

Tier 1: Add the 99th percentile 1-hour background concentration to 99th percentile modeling for the entire facility (without neighboring sources) and compare the total with the 1-hour NAAQS. Optionally, to determine the total design value, the facility and all nearby sources may be modeled instead of adding a background concentration if the facility is over 10 km from the center of Albuquerque and El Paso.

Tier 2: Add the hourly 1-hour background concentrations (as described in the background concentration section) to each hour of the modeling results and compare the 99th percentile of the totals with the 1-hour NAAQS. Optionally, to determine the total design value, the facility and all nearby sources may be modeled instead of adding a background concentration if the facility is over 10 km from the center of Albuquerque and El Paso.

2.6.8.3 Modeling for the 3-hour SO_2 PSD increment

Model the increment consuming emissions at the facility and at nearby sources and compare the high-second-high 3-hour average with the allowable PSD increment.

2.6.8.4 Modeling for the 24-hour SO_2 PSD increment

Model the increment consuming emissions at the facility and at nearby sources and compare the high-second-high 24-hour average with the allowable PSD increment.

2.6.8.5 Modeling for the annual SO_2 PSD increment

Model the increment consuming emissions at the facility and at nearby sources and compare the predicted annual average with the allowable PSD increment.

2.6.9 Total Reduced Sulfur Except For Hydrogen Sulfide Standards

Table 5J: Total Reduced Sulfur except for H_2S Air Quality Standards

Averaging Period	NMAAQS (ppm)	Notes
1/2-hour	0.003	for the state, except for the Pecos-Permian Basin Intrastate AQCR
1/2-hour	0.010	for the Pecos-Permian Basin Intrastate AQCR
1/2-hour	0.003	For within corporate limits of municipalities within the Pecos-Permian Basin Intrastate Air Quality Control Region.
1/2-hour	0.003	For within five miles of the corporate limits of municipalities having a population of greater than twenty thousand and within the Pecos-Permian Basin Intrastate Air Quality Control Region

2.6.9.1 Total Reduced Sulfur design value

EPA test methods suggest that reduced sulfur compounds in some cases consist primarily of carbon disulfide (CS_2), carbonyl sulfide (COS), and hydrogen sulfide (H_2S). To calculate the parts per million of reduced sulfur, use the average molecular weight in the sample. For example, 1-heptanethiol ($CH_3[CH_2]6SH$) has a molecular weight of 132.3.

For modeling ½-hour total reduced sulfur NMAAQS, use the 1-hour averaging time because the models cannot resolve less than one hour increments.

2.6.9.2 Modeling the Total Reduced Sulfur ½-hour NMAAQS

Model the entire facility and compare the 1-hour predicted concentration with the ½-hour NMAAQS. Surrounding sources and background concentrations are not added.

Table 6A. Air Quality Standard Summary (Without Notes).

Pollutant	Avg. Period	Sig. Lev. ($\mu g/m^3$)	Class I Sig. Lev. ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)	NMAAQS ($\mu g/m^3$ unless noted)	PSD Increment Class I ($\mu g/m^3$)	PSD Increment Class II ($\mu g/m^3$)
CO	8-hour	500		10,303.6	9,960.1		
	1-hour	2,000		40,069.6	14,997.5		
H_2S	1-hour	1.0			13.9		
	1/2-hour	5.0			139.3		
	1/2-hour	5.0			41.8		
Pb	Quarterly	0.03		0.15			
NO_2	annual	1.0	0.1	99.66	94.02	2.5	25
	24-hour	5.0			188.03		
	1-hour	7.52		188.03			
O_3	8-hour	1.96		137.3			
$PM_{2.5}$	annual	0.2	0.05	12		1	4
	24-hour	1.2	0.27	35		2	9
PM_{10}	annual	1.0	0.2			4	17
	24-hour	5.0	0.3	150		8	30
SO_2	annual	1.0	0.1		52.4	2	20
	24-hour	5.0	0.2		261.9	5	91
	3-hour	25.0	1.0	1309.3		25	512
	1-hour	7.8		196.4			
Reduced S	1/2-hour				3 ppb		
	1/2-hour				10 ppb		

Table 6B. Standards for which Modeling is not Required.

Standard not Modeled	Surrogate that Demonstrates Compliance
CO 8-hour NAAQS	CO 8-hour NMAAQS
CO 1-hour NAAQS	CO 1-hour NMAAQS
NO_2 annual NAAQS	NO_2 annual NMAAQS
NO_2 24-hour NMAAQS	NO_2 1-hour NAAQS
O_3 8-hour	Regional modeling
SO_2 annual NMAAQS	SO_2 1-hour NAAQS
SO_2 24-hour NMAAQS	SO_2 1-hour NAAQS
SO_2 3-hour NAAQS	SO_2 1-hour NAAQS

Table 6C. Modeling the Design Value Summary (Default Modeling).

Averaging Period	Add Nearby Sources?	Add Background Concentration?	Modeled Concentration
CO 8-hour NMAAQS	No* (Yes)	Yes* (high 8 hour) (No)	high 8 hour
CO 1-hour NMAAQS	No* (Yes)	Yes* (high 1 hour) (No)	high 1 hour
H_2S 1-hour or ½-hour NMAAQS	Yes	No	high 1 hour
Pb Quarterly NMAAQS	No	No	high month
NO_2 annual NMAAQS	No* (Yes)	Yes* (annual average) (No)	annual average
NO_2 annual PSD increment	Yes	No	annual average
NO_2 1-hour NAAQS	No* (Yes)	Yes* (1-hr 98th percentile) (No)	98th-percentile 1 hour
$PM_{2.5}$ annual NAAQS	Yes	Yes (annual average)	annual average
$PM_{2.5}$ annual PSD increment	Yes	No	annual average
$PM_{2.5}$ 24-hour NAAQS	Yes	Yes (24-hr 98th percentile)	98th-percentile 24 hour
$PM_{2.5}$ 24-hour PSD increment	Yes	No	high 24 hour
PM_{10} annual PSD increment	Yes	No	annual average
PM_{10} 24-hour NAAQS	Yes	Yes (high 24 hour)	high second high 24 hour
PM_{10} 24-hour PSD increment	Yes	No	high second high 24 hour
SO_2 annual PSD increment	Yes	No	annual average
SO_2 24-hour PSD increment	Yes	No	high second high 24 hour
SO_2 3-hour PSD increment	Yes	No	high second high 3 hour
SO_2 1-hour NAAQS	No* (Yes)	Yes* (high 1 hour) (No)	99th-percentile 1 hour
Reduced S ½-hour NMAAQS	No	No	high 1 hour

* Standards marked with an asterisk normally offer the choice to either model nearby sources or add a representative background concentration.

2.7 PSD Increment Modeling

2.7.1 Air Quality Control Regions and PSD Baseline Dates

Any facility that is required to provide an air dispersion modeling analysis with its construction permit application is required to submit a PSD increment consumption analysis unless none of its sources consume PSD increment. Table 7 serves as a tool to determine which sources to include in PSD increment modeling.

Table 7: PSD Increment Consumption and Expansion

Sources that do not consume PSD increment	• Temporary emissions (sources involved in a project that will be completed in a year or less). • Any facility or modification to a facility constructed before the PSD major source baseline date. • Any minor source constructed before the PSD minor source baseline date.
Sources that consume PSD increment	• Any new emissions or increase in emissions after the PSD Minor Source Baseline date (for that AQCR and pollutant). • Any new emissions or increase in emissions at a PSD Major source that occurs after the Major Source Baseline Date.
Sources that expand PSD increment	• A permanent reduction in actual emissions from a baseline source.

Notes:

- EPA memos written before the publication of the Draft NSR Workshop Manual indicate that PSD regulations were not intended to apply to temporary pilot projects. The memo clearly indicated that the pilot project did not need a PSD permit.
- If a minor source facility once existed but shut down before the minor source baseline date, then it would not be considered to be part of the baseline.
- Haul road emissions are treated the same way other sources of emissions are treated.
- An increase in emissions due to increased utilization of a facility, such as de-bottlenecking, are treated as any other increase in emissions.
- The Bureau interprets temporary emissions to mean emissions at the location that will occur for less than one year or emissions of standby or emergency equipment that operates less than 500 hours per year. For example, if a series of three gravel crushers operate at a mine for more than one year, PSD increment modeling should be performed because the mining operations at the location are not temporary in nature, even though none of the of individual crushers remained on-site for an entire year.

Table 8: Minor Source Baseline Dates by Air Quality Control Region

AQCR	NO_2 Date	SO_2 Date	PM_{10} Date	$PM_{2.5}$ Date
12	8/10/1995	8/10/1995	8/10/1995	Not established
14	6/6/1989	8/7/1978	8/7/1978	Not established
152	3/26/1997	5/14/1981	3/26/1997	2/11/2013
153	8/2/1995	Not established	6/16/2000	Not established
154	Not established	Not established	Not established	Not established
155	3/16/1988	7/28/1978	2/20/1979	11/13/2013
156	Not established	8/4/1978	8/4/1978	Not established
157	Not established	Not established	Not established	Not established

Table 9: Major Source Baseline Dates and Trigger Dates

Pollutant	Major Source Baseline Date	Trigger Date
PM	January 6, 1975	August 7, 1977
SO_2	January 6, 1975	August 7, 1977
NO_2	February 8, 1988	February 8, 1988
$PM_{2.5}$	October 20, 2010	October 20, 2011

2.7.2 PSD Class I Areas

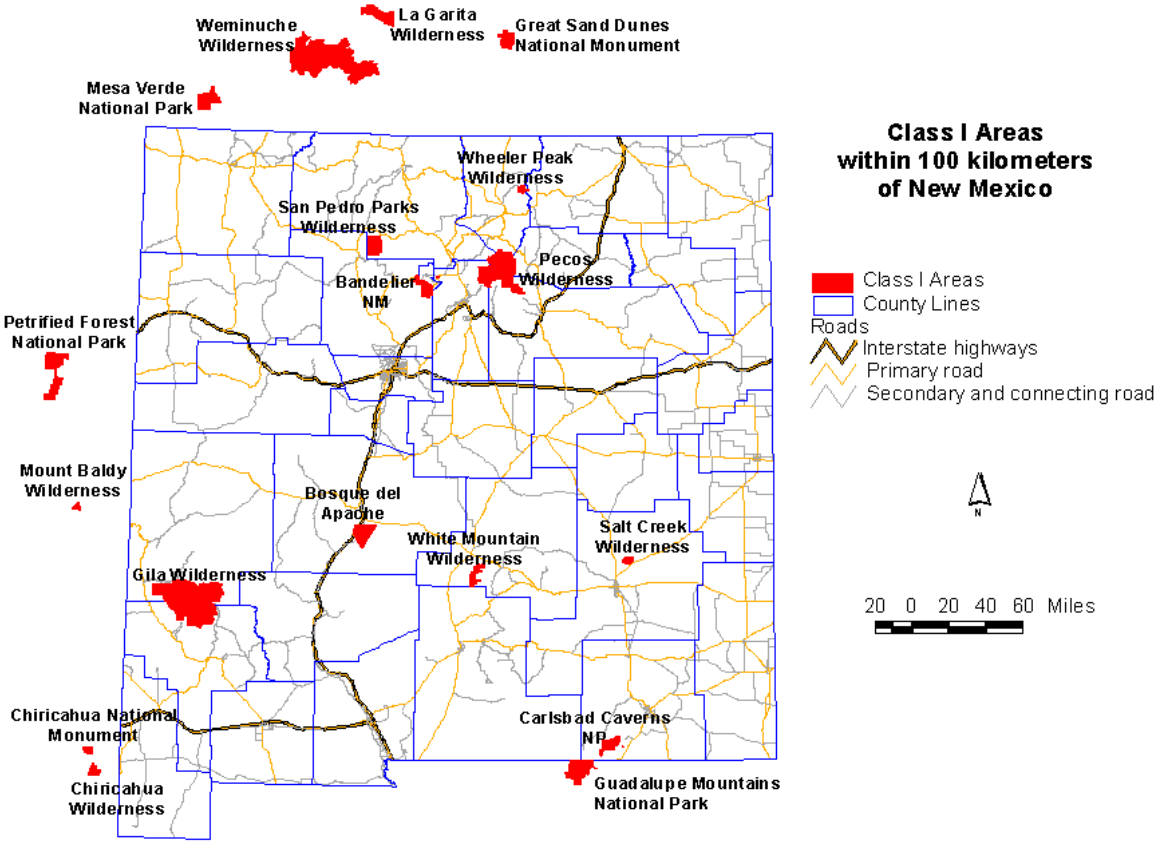


Figure 1: Class I areas

2.7.3 PSD Class I Area Proposed Significance Levels

The Environmental Protection Agency (EPA) has proposed significance levels for PSD Class I areas. No significance levels have been promulgated, but the Federal land managers (FLMs) are currently accepting the use of this value.

Table 10. Class I Prevention of Significant Deterioration Significance Levels

Pollutant	Averaging Period	Significance Level ($\mu g/m^3$)	PSD Class I Increment ($\mu g/m^3$)
Sulfur Dioxide (SO_2)	annual [a] 24-hour 3-hour	0.1 [b] 0.2 [b] 1.0 [b]	2 5 25
PM_{10}	annual [a] 24-hour	0.2 [b] 0.3 [b]	4 8
Nitrogen Dioxide (NO_2)	annual [a]	0.1 [b]	2.5
$PM_{2.5}$	annual 24-hour	0.06 0.07	1 2

[a] annual arithmetic mean
[b] EPA proposed significance level

2.8 New Mexico State Air Toxics Modeling

Modeling must be provided for any toxic air pollutant sources that may emit any toxic pollutant in excess of the emission levels specified in **20.2.72.502 NMAC** - Permits for Toxic Air Pollutants. Sources may use a correction factor based on release height for the purpose of determining whether modeling is required. Divide the emission rate for each release point by the correction factor for that release height on Table 11 and add the total values together to determine the total adjusted emission rate. If the total adjusted emission rate is higher than the emission rate in pounds per hour listed in **20.2.72.502 NMAC**, then modeling is required. The controlled emission rate (not the adjusted emission rate) of the toxic pollutant should be used for the dispersion modeling analysis.

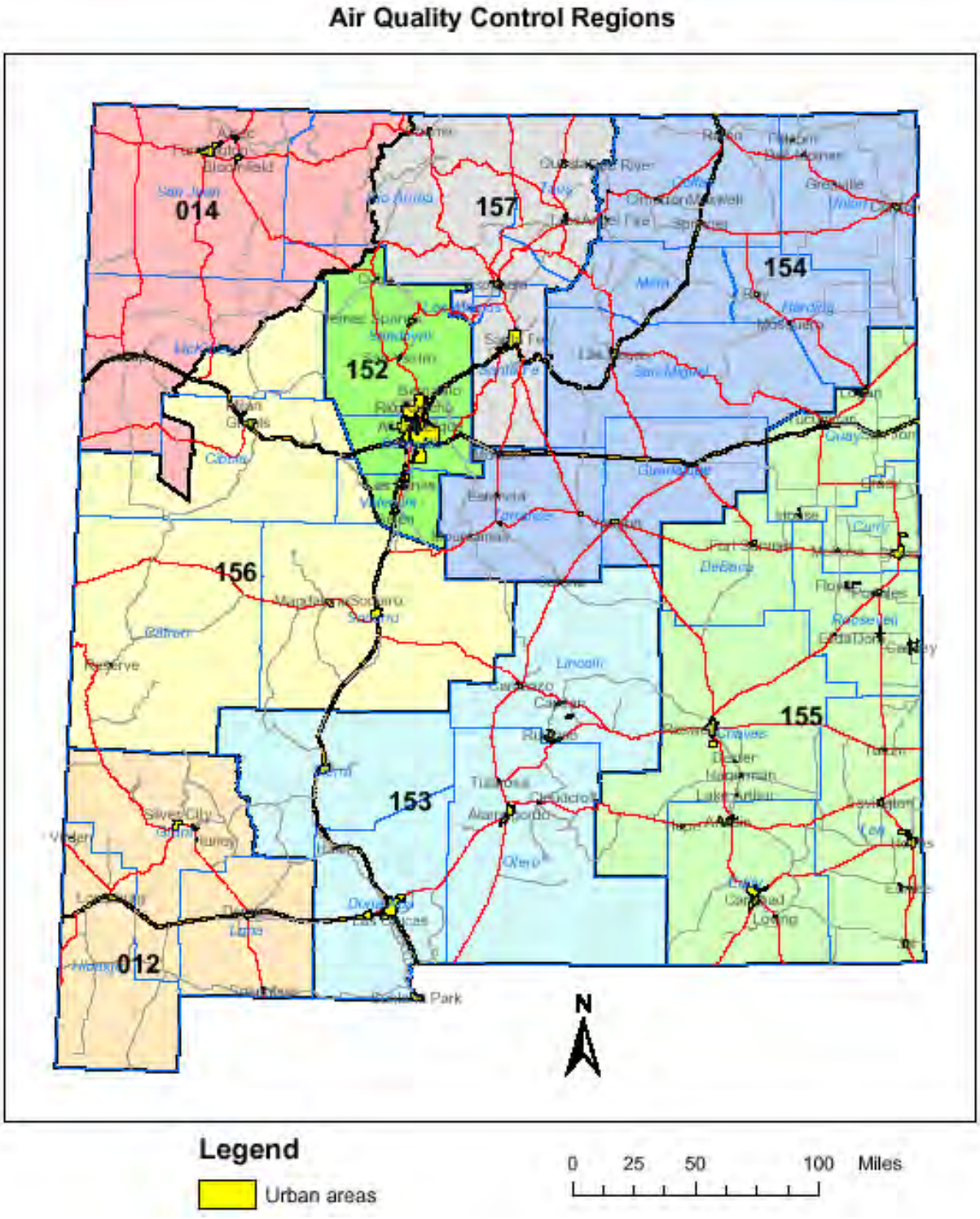


Figure 2: Air quality control regions (each AQCR has a different color)

Table 11: Stack Height Release Correction Factor (adapted from 20.2.72.502 NMAC)

Release Height in Meters	Correction Factor
0 to 9.9	1
10 to 19.9	5
20 to 29.9	19
30 to 39.9	41
40 to 49.9	71
50 to 59.9	108
60 to 69.9	152
70 to 79.9	202
80 to 89.9	255
90 to 99.9	317
100 to 109.9	378
110 to 119.9	451
120 to 129.9	533
130 to 139.9	617
140 to 149.9	690
150 to 159.9	781
160 to 169.9	837
170 to 179.9	902
180 to 189.9	1002
190 to 199.9	1066
200 or greater	1161

The table below lists a few of the commonly encountered State Air Toxics in New Mexico. This is not the complete list, which is too expansive to reprint here.

Table 12: A few common state air toxics and modeling thresholds (from 20.2.72.502 NMAC)

Pollutant	OEL (mg/m^3)	1% OEL ($\mu g/m^3$)	Emission Rate Screening Level (pounds/hour)
Ammonia	18	180	1.20
Asphalt (petroleum) fumes	5.00	50	0.333
Carbon black	3.50	35	0.233
Chromium metal	0.500	5.00	0.0333
Glutaraldehyde	0.700	7.0	0.0467
Nickel Metal	1.00	10.0	0.0667
Wood dust (certain hard woods as beech & oak)	1.00	10.0	0.0667
Wood dust (soft wood)	5.00	50.0	0.333

If modeling shows that the maximum eight-hour average concentration of each toxic pollutant is less than one one hundredth of its Occupational Exposure Level (OEL) listed in **20.2.72.502 NMAC**, then the analysis is finished. For a source of any known or suspected human carcinogens (per **20.2.72.502 NMAC**) which will cause an impact greater than one-one hundredth of the OEL, the source must demonstrate that best available control technology will be used to control the carcinogen. If modeling shows that the impact

of a toxic which is not a known or suspected human carcinogen (per **20.2.72.502 NMAC**) is greater than one-one hundredth of the OEL, the application must contain a health assessment for the toxic pollutant that includes: source to potential receptor data and modeling, relevant environmental pathway and effects data, available health effects data, and an integrated assessment of the human health effects for projected exposures from the facility.

2.9 Hazardous Air Pollutants

Hazardous Air Pollutants (HAPs) do not require modeling, as they are regulated by means other than air quality standards. Sources should be aware of the Title V major source thresholds of 10 tons/year for any Hazardous Air Pollutants (HAP) and 25 tons/year for total HAPs, which will require an operating permit to be obtained from the department under **20.2.70 NMAC**- Operating Permits.

2.10 Nonattainment and Maintenance Areas

In nonattainment areas and for those sources outside of the nonattainment area that significantly contribute to concentrations in a nonattainment area, the modeling analysis required is a demonstration of an air quality benefit. Regular modeling is required in maintenance areas, however. Further information on nonattainment area modeling is in section 7.4, Nonattainment Area Requirements. Nonattainment areas are described at https://www.env.nm.gov/air-quality/nonattainment-areas/.

3.0 MODEL SELECTION

3.1 What dispersion models are available?

The Bureau accepts the use of EPA approved models for dispersion analysis. Commercial or parallel versions of these models are fine as long as they produce the same results. This section of the modeling guidelines is designed to describe the models that are available and provide some guidance on which situations are the most appropriate for which regulatory modeling situations.

Two types of models are currently in use for air dispersion modeling: probability density function (PDF) models, and puff models. Probability density function models apply a probability function from each emission release point to calculate the concentration at a receptor based on the location of the receptor, wind speed and direction, stability of the atmosphere, and other factors. The plume is assumed to extend all the way out to the most distant receptor, no matter how far that receptor is from the emission source. Because of this characteristic, PDF models suffer in accuracy when modeling distant concentrations or unstable conditions. SCREEN3, ISCST3, ISC_OLM, CTSCREEN, ISC-PRIME, and AERMOD are all PDF models. All but AERMOD use a Gaussian, or normal, distribution for their probability density function. AERMOD uses a PDF that varies depending on nearby terrain and other factors. Currently, AERMOD and CTSCREEN are EPA-approved models for near-field modeling. As of November 9, 2006, SCREEN3, ISCST3, and ISC_OLM are no longer considered EPA-approved models. The Federal Register notice detailing the promulgation of AERMOD is located at: http://www.epa.gov/scram001/guidance/guide/appw_05.pdf

CALPUFF is a puff model, meaning that it tracks puffs, or finite elements of pollution, after they are released from their source. This strategy makes the model ideal for tracking pollution over long distances or in conditions that are not stable, and also allows chemical reactions within the plume to be modeled. Unfortunately, puff models require large amounts of computing time. CALPUFF is an EPA-approved model for modeling long range transport and/or complex non-steady-state meteorological conditions.

3.2 EPA Modeling Conferences and Workshops

EPA Modeling Conference presented a wealth of information about recent regulatory modeling developments. The EPA web page with the details is http://www3.epa.gov/ttn/scram/conferenceindex.htm.

3.3 Models Most Commonly Used in New Mexico

Most analyses reviewed by the Bureau will begin with an AERMOD analysis, and possibly CALPUFF for Class I analyses. For dispersion modeling within 50 kilometers of the source, AERMOD should be used. CALPUFF should be used only for PSD Class I area analyses, per the Interagency Workgroup Air Quality Modeling (IWAQM) Phase II report, but may be approved for use on a case-by-case basis for other analyses.

3.3.1 AERMOD

- AERMOD is intended to be the standard regulatory model. The PRIME building downwash algorithm is used by the model. Both the Ozone Limiting Method (OLM) and the Plume Volume Molar Ratio Method (PVMRM) algorithms for nitrogen conversion are built into the model.
- AERMOD has greater accuracy in complex terrain than CTSCREEN.
- AERMOD is suggested for extremely complex terrain.

See the section on nitrogen oxides for more information and options.

3.3.2 CALPUFF

- CALPUFF is a puff model designed to calculate concentrations at distances up to and beyond 50 kilometers. The model is significantly more difficult to run than the other models discussed in these guidelines. Use of CALPUFF for NAAQS, NMAAQS, or PSD increment modeling must be approved by the Bureau before submitting the modeling.
- CALPUFF is required for additional impact analyses when Federal Land Managers require additional impact analyses for Class I areas near PSD major sources. Typically, CALPUFF light is used for this modeling.

3.3.3 CTSCREEN

- CTSCREEN is applicable only for modeling receptors above stack height.
- CTSCREEN is a difficult model to run because of the difficulty in obtaining hill contour profiles.
- CTSCREEN uses screening meteorology.
- AERMOD produced greater accuracy than CTDMPLUS (the full implementation of CTSCREEN) when modeling the data that was used to develop CTSCREEN/CTDMPLUS.
- CTSCREEN is typically used to model the terrain on top of a hill that did not pass when using AERMOD.

The following list can be used to correct 1-hour CTSCREEN concentrations to 3-hour, 24-hour and annual concentrations by multiplying by the appropriate conversion factor for the averaging period.

Table 13: CTSCREEN Correction factors for 1-hour concentration.

Averaging Period	Correction factor
3-hour	0.7
24-hour	0.15
Annual	0.03

3.3.4 AERSCREEN

- AERSCREEN is a screening version of AERMOD.

4.0 MODEL INPUTS AND ASSUMPTIONS

Models should be used with the technical options recommended in the Guideline on Air Quality Models (http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf) except as noted in this document or approved by the Bureau.

Unless otherwise noted, information and procedures in this section refer to all of the models listed above.

4.1 Operating Scenarios

4.1.1 Emission Rates

All averaging periods shall be modeled using the maximum short-term emission rate allowed in the permit. The preferred method of modeling all averaging periods is to use maximum short-term emission rates and to use the hours of operation model input option to limit the facility's emissions.

4.1.2 Hours of Operation

If the facility is limited to operating certain hours of the day or has other operating restrictions, limiting the operating hours in the model can normally reduce the concentration produced by the model. Hours of operation can only be modeled by models that use actual meteorology, but not by screening models. Use screening models only to model facilities as if the maximum operating rate were emitting continuously.

4.1.3 Time Scenarios

Sometimes a facility has unusual operating times, for example, if the facility is allowed to operate 12 hours per day, but the hours are not specified. The facility may model as if it operates continuously, but as an option, the facility can model different time periods at the amount of time allowed per day as different operating scenarios, making sure that the maximums are modeled. In the 12 hour example, the facility might model three scenarios: 7AM to 7PM. 7PM to 7AM. And 5PM to 5AM. This way, all the hours of the day were modeled, and the modeler can be fairly certain that the maximum was modeled because the worst-case scenarios would occur when the calm blocks of time were modeled together. All scenarios should be modeled at maximum hourly emission rates.

4.1.4 Operating at Reduced Load

Some sources (like engines and boilers) can produce higher concentrations of pollution in ambient air when they are operating below maximum load than when they are at maximum load. The applicant shall analyze various feasible operating scenarios (100%, 75%, and 50% are typical) to determine the worst-case impacts, and then use that worst-case scenario for the entire modeling analysis. This requirement is in section 8.1 of Appendix W of EPA's Guideline.

4.1.5 Alternate Operating Scenario

If the permit application contains multiple operating scenarios (such as use of different fuels or different engines) then the applicant shall model each of the scenarios for the radius of impact analysis. Whichever scenario produces the greatest impacts on ambient air shall be used for the cumulative analysis, if required. If it is unclear which operating scenario produces the greatest impacts, each scenario shall be modeled for cumulative impact analysis.

4.1.6 Startup, Shutdown, Maintenance (SSM), and Other Short-term Emissions

If startup, shutdown, maintenance, or other temporary events have the potential for producing short-term impacts greater than the normal operating scenarios, then the applicant shall model each of the scenarios to demonstrate compliance with the ambient air quality standard.

If it is probable that an adjacent facility will have emissions higher than normal operation during the time the applicant's facility has increased emissions, then those emissions should also be accounted for in the modeling. Otherwise, model surrounding sources at their normal operating rate. Because of the short nature of the SSM emissions, modeling does not have to demonstrate compliance with annual standards or annual increment consumption. Highest hourly SSM emission rate should be modeled for NAAQS, NMAAQS and for increment consumption modeling.

Whichever scenario produces the greatest impacts on ambient air shall be used for the cumulative analysis, if required. If it is unclear which operating scenario produces the greatest impacts, each scenario shall be modeled for cumulative impact analysis.

4.2 Plume Depletion and Deposition

Dry plume depletion may be used to reduce concentrations of particulate matter. Appropriate particle characteristics for the specific type of source being modeled should be used. Check the web page for sample particle size distributions. Because of the length of time required to run a model with plume depletion, the Bureau recommends only applying plume depletion to receptors that are modeled to be above standards when the model is run without plume depletion.

The wet deposition option should not be used for the modeling analysis unless data are available and the use of wet deposition has been previously approved.

4.3 Meteorological Data.

4.3.1 Selecting Meteorological Data.

The meteorological data used in the modeling analysis should be representative of the meteorological conditions at the specific site of proposed construction or modification, or else use screening meteorological data, which contains worst-case data.

Representative, on-site data is obviously the best data to use; however, for many sources on-site data is not available. Bureau modeling staff can supply preferred meteorological data sets for various locations around the state. The National Weather Service also collects data throughout the country. These data sets are available through the National Climatic Data Center. It is mandatory that Bureau modeling staff approve the chosen meteorological data before the analysis is submitted. PSD permits contain more rigorous requirements relating to the collection of representative, on-site meteorological data. Either 1 year of representative data which serves as on-site data or 5 years of appropriate off-site data must be used. Please contact the Bureau as soon as possible if you anticipate the need to collect on-site meteorological or ambient monitoring data for a PSD permit.

Setback distance modeling for portable sources may require separate meteorological data than that used in the rest of the modeling for that facility. Preliminary analysis indicates that the Substation meteorological data set is appropriate for locations throughout the State. Contact the Bureau for guidance on relocation meteorological data selection.

The goal of modeling is to use site-specific meteorological data. In cases where the form of the standard allows the standard to be exceeded a number of times per year, this is based on site-specific data. If the equivalent of site-specific data is not available, then the highest concentration estimate should be considered the design value unless multiple years of data are used. (68238 Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005 / Rules and Regulations)

For example, no meteorological monitoring stations are available near Raton, New Mexico, and there are terrain features that may make Raton meteorology different from other places. The Bureau will still recommend meteorological data to use for modeling in Raton, but the PM_{10} standard is not allowed to be exceeded at all because the meteorological data is not completely representative of the area.

For concentration monitoring data, proximity to the monitor is normally the driving factor for selection of a representative monitor. For meteorological data, the similarity of the terrain (including canyon and valley directions) is more important than finding the closest monitor. Unless otherwise noted, AQB staff will need the exact location of the facility to select or approve a set of meteorological data representative of the location. Staff will compare wind roses with prominent terrain features that influence drainage patterns or otherwise influence wind directions.

Processed meteorological data is available on the web page: https://www.env.nm.gov/air-quality/meteorological-data/.

4.4 Background Concentrations

> "Background concentrations should be determined for each critical (concentration) averaging time." (68242 Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005 / Rules and Regulations)

The background concentrations listed below were derived from information downloaded from http://aqsdr1.epa.gov/aqsweb/aqstmp/airdata/download_files.html.

4.4.1 Uses of Background Concentrations

Background concentrations are added to the modeled concentrations or are used for stoichiometric modeling applications such as OLM or PVMRM. Normally, a background concentration associated with the averaging period being modeled is added after the model (with all facility and nearby sources) is completed. Sometimes this approach proves too conservative to demonstrate compliance with standards. If so, monthly, daily, or hourly concentration profiles can be developed using representative sets of monitoring data appropriate for the modeling domain. Adding refined background concentrations normally requires post-processing of hourly output files.

It is very important to use recent monitoring data, because concentration trends are likely to change over time (much more so than weather patterns). If hourly meteorological data does not match hourly monitoring data, then the following methods can be used to produce a concentration profile for the refined modeling exercise.

Choose the highest background for each period for the region that best describes the modeling domain, unless adequate justification can be made that a specific monitor is most representative. For rural areas that do not match the regional descriptions above, use a monitor from Eastern NM or Southwestern NM.

4.4.1.1 Refined background concentrations

Background concentrations may be refined to take into account patterns in daily and monthly fluctuations in concentration. Since background concentrations are added to the model after dispersion is complete, there is no point mathematically in determining refined background concentrations shorter than the averaging period of the air quality standard. 24-hour concentrations do not need 1-hour background concentrations (except for ozone limiting of NO_2 concentrations, which happens during dispersion).

4.4.1.2 Developing 24-hour refined background concentrations

Each of the 12 months is represented by the maximum 24-hour concentration occurring during that month. If three years of data are available, average the three values for each month and use the average for the background. If a given month has a low maximum concentration due to the small number of samples collected that month, then the concentration from that month is not used and the average of the maximums of the two other years will be used as the 24-hour background for that month.

Example: Roswell $PM_{2.5}$ (This example uses outdated data and should not be used for new modeling).

$PM_{2.5}$ has a 24-hour averaging period and an annual averaging period. The annual average uses the annual value in the standard background tables, but it is appropriate to use refined background concentrations for the 24-hour period. The Partisol sampler in Roswell is a Federal Reference Method sampler for $PM_{2.5}$. The filters are collected about every three days, so there is not data available for every day. Over three years of data are available, and 2007 through 2009 are presented in the following table.

January, 2007 had a maximum reported concentration of 10.0 $\mu g/m^3$. January 2008 and 2009 had maximum concentrations of 18.0 and 11.7, respectively. The average of these three values is 13.2. After the model has run, every day in January adds a background concentration of 13.2 $\mu g/m^3$. Care must be taken to identify the greatest sum of modeled concentration plus background, since background concentration varies each month – the highest modeled concentration may no longer be the highest when the background values are added.

Table 14: Roswell $PM_{2.5}$ Monitoring Data (2007-2009)

Year	Month	$PM_{2.5}$ concentration. ($\mu g/m^3$)											Max	3-year avg.
2007	1	2.33	3.67	9.50	6.25	10.00	6.25	4.67	5.58	7.25			10.00	**13.2**
2007	2	5.92	5.50	25.5	9.00	13.75	2.67	2.42	5.67	2.25			25.50	**14.7**
2007	3	1.67	2.92	4.42	4.17	3.42	12.25	8.00	9.29	2.67	5.58	2.67	12.25	**12.8**
2007	4	4.75	9.58	4.83	5.86	3.67	5.75	8.00	2.75	5.83	6.00		9.58	**9.2**
2007	5	4.58	3.42	4.00	8.33	6.08	4.00	3.75	4.33				8.33	**10.0**
2007	6	7.00	6.92	8.25	4.00	5.19	5.67	9.29	13.7	6.58			13.67	**11.5**
2007	7	8.58	8.28	8.17	5.75	7.92	8.67	7.33	7.28				8.67	**9.2**
2007	8	11.92	3.08	7.50	11.83	18.50	8.67	7.92	6.33	6.00	7.83		18.50	**13.2**
2007	9	11.75	4.00	4.75	6.75	9.17	4.08	4.08	3.17	4.42	4.08		11.75	**11.1**
2007	10	5.25	6.00	6.08	6.92	4.33	5.08						6.92	**7.0**
2007	11	7.75	7.58	8.75	7.25	5.42	8.33	7.83	7.25	18.58	8.33		18.58	**10.4**
2007	12	3.17	4.08	4.25	3.17	5.83	10.50	5.58	4.33	2.25			10.50	**10.8**
2008	1	5.3	8.2	3.6	4.4	3.0	4.9	18.0	13.4	4.2	2.6		18.0	
2008	2	2.2	3.8	3.3	3.3	7.4	3.5	9.3	4.6				9.3	
2008	3	6.8	3.7	14.8	4.9	5.8	5.8						14.8	
2008	4	3.7	5.5	10.7	2.9	6.7	6.2	5.2	9.5				10.7	
2008	5	6.8	7.4	4.3	5.2	11.6	6.2	6	5.3				11.6	
2008	6	6.3	7.1	4.8	5.2	6.3	14	4.9	4.9				14.0	
2008	7	6.7	6.4	4.8	4.0	7.0	6.1	9.2	9.2	9.8			9.8	
2008	8	6.5	6.7	9.2	3.6	5.6	4.3	5.2	7.8				9.2	
2008	9	7.6	7.6	2.3	4.8	5.0	8.8	8.8	11.1	8.9			11.1	
2008	10	7.2	2.8	4.6	4.8	3.2	4.3	7.9	3.5	4.0			7.9	
2008	11	5.5	6.2	4.1									6.2	
2008	12	3.8	4.6	7.8	5.2								7.8	
2009	1	5.2	3.7	1.8	11.7	10.0	5.6	4.1	7.3				11.7	
2009	2	5.8	5.6	9.3	3.4	8.1	9.0	4.2	5.4	4.7			9.3	
2009	3	4.1	6.0	11.4	2.8	4.1	3.8	11.3	6.2	9.7	4.0	4.2	11.4	
2009	4	7.2	4.4	6.2	1.8	4.8	1.8	3.1	6.6				7.2	
2009	5	6.4	3.2	10.0	6.7	3.9							10.0	
2009	6	6.4	3.9	4.7	5.0	6.7	5.3						6.7	
2009	7	4.8	8.9	4.5	5.7	6.0	8.6	9.2	5.8	8.5	8.1	8.4	9.2	
2009	8	8.4	10.5	7.6	5.0	6.1	11.8	7.0	4.3				11.8	
2009	9	7.9	3.9	4.9	5.3	10.3	1.7	6.5					10.3	
2009	10	2.2	6.2	1.9	1.9	3.0	3.6						6.2	
2009	11	6.2	5.3	6.1	2.8	5.5	5.0	6.3	2.6				6.3	
2009	12	14.2	5.5	4.3	7.7	4.9	5.3						14.2	

4.4.1.3 Developing 1-hour refined background concentrations

From the geographically nearest full set of monitoring data to the facility to be modeled, determine the maximum one-hour concentration that occurs during each hour of the day for each month. The result will be twelve different 24-hour profiles that will be repeated for the entire month that each represents. This profile can be used for all averaging periods. If three years of data are available, average the three values for each month and use the average for the background. POST files may be used to add hourly background concentrations to receptors.

Example: Determine the maximum concentration for hour 1 (midnight to 1AM) in January. Use this for hour 1 for each day in January. Determine the maximum concentration for hour 2 (1AM to 2AM) in January. Use this for hour 2 for each day in January. … Determine the maximum concentration for hour 24 (11PM to midnight) in December. Use this for hour 24 for each day in December. Complete the entire year in this manner, with hour and month-specific data.

4.4.1.4 Eliminating double-counting of emissions in background

In some cases the addition of a background concentration may result in double-counting of some of the emissions, if the reference monitor is very close to the modeling domain. This effect may be reduced by placing a receptor at the monitor location and modeling the sources in the model that existed at the time of the monitoring. The modeled concentration at the monitor may be subtracted from the background (with a minimum background of zero). The averaging period should be the same as the one used for the background calculation, and must be temporally correlated if the maximum monitored concentration is not being used.

4.4.2 CO Background Concentration

Ambient CO monitors to represent New Mexico are very limited. Concentrations near Sunland Park are best represented by monitors in El Paso. Monitors operated by Albuquerque should be conservative for the rest of New Mexico.

Table 15: Carbon Monoxide Background Concentration

Region	ID	Location	1-hour ($\mu g/m^3$)	8-hour ($\mu g/m^3$)	Latitude	Longitude	Notes
The rest of New Mexico	350010023	Del Norte High School	2203	1524	35.1343	-106.585	4700a San Mateo NE, Albuquerque, NM
Albuquerque	350010029	South Valley	2746	1566	35.01708	-106.657	201 Prosperity SE, Albuquerque, NM
Sunland Park	481410044	El Paso Chamizal	4677	2834	31.76569	-106.455	800 S San Marcial Street, El Paso, TX

Concentrations are the average of the maximum concentrations for 2015-2017.

4.4.3 H_2S Background Concentration

NMED has no H_2S monitors. The standards are generally designed to protect against noticeable changes in concentration above the background concentration for the region, and no background concentration is added.

4.4.4 Lead Background Concentration

Reformulation of gasoline and other control measures have virtually eliminated ambient lead concentrations. NMED has no lead monitors. Treat as zero background.

4.4.5 NO_2 Background Concentration

Note: No 24-hour averages were calculated. Compliance with 1-hour NAAQS automatically demonstrates compliance with 24-hour NMAAQS.

Table 16: NO_2 Background Concentration

Region	ID	Location	1-hour Background ($\mu g/m^3$)	1-hour 98th %ile ($\mu g/m^3$)	Annual Background ($\mu g/m^3$)	Latitude	Longitude	Address
4-Corners	1ZB, 350450009	Bloomfield	85.1	67.3	19.6	36.74222	-107.977	162 Hwy 544, Bloomfield NM 87413
4-Corners	1NL, 350450018	Navajo Dam	62.2	52.1	11.0	36.80973	-107.652	423 Hwy 539, Navajo Dam, NM 87419
4-Corners	350451233	Dine College	73.3	54.9	11.3	36.8071	-108.695	Dine College, GIS Lab
Albuquerque	350010023	Del Norte High School	94.2	83.8	20.2	35.1343	-106.585	4700A San Mateo NE
South Central	6ZM, 350130021	Sunland Park	100.4	85.7	12.5	31.79611	-106.584	5935A Valle Vista, Sunland Park, NM
South Central	6ZN, 350130022	US-Mexico Border Crossing	102.9	77.5	8.5	31.78778	-106.683	104-2 Santa Teresa International Blvd, NM
Eastern NM	5ZR, 350151005	Outside Carlsbad	60.3	38.7	5.0	32.38	-104.262	Holland St, SE of Water Tank, Carlsbad, NM
Eastern NM	5ZS, 350250008	Hobbs-Jefferson	83.2	64.2	8.1	32.72666	-103.123	2320 N. Jefferson St, Hobbs, NM
Southwestern NM[1]	7E, 350290003	Deming	62.052	53.277	6.966	32.2558	-107.723	310 Airport Road, Deming, NM88030

Annual background is the average of three annual averages of monitoring data from 2015 to 2017. The maximum 1-hour NO_2 concentrations from each of three years were averaged to determine the 1-hour background concentration, using monitoring data from 2015 to 2017

Refined 1-hour background profiles may be developed using the guidance described in "Refined Background Concentrations", above.

[1]Based on 2013 -2015 averages.

4.4.6 Total Reduced Sulfur Background Concentration

NMED has no total reduced sulfur monitors. The standards are generally designed to protect against noticeable changes in concentration above the background concentration for the region, and no background concentration is added.

4.4.7 Ozone Background Concentration

Ozone background concentrations are required for NO_2 modeling using PVMRM or OLM.

Table 17: Ozone Background Concentration

Region	ID	Location	1-hour Background (µg/m^3)	Latitude	Longitude	Address
4-Corners	1ZB, 350450009	Bloomfield	146.1	36.74222	-107.977	162 Hwy 544, Bloomfield NM 87413
4-Corners	1NL, 350450018	Navajo Dam	156.9	36.80973	-107.652	423 Hwy 539, Navajo Dam, NM 87419
4-Corners[1]	350450020	Chaco Culture National Historical Park	144.8	36.03022	-107.910	1808 County Road 7950, Nageezi, NM 87037
4-Corners	1H, 350451005	Shiprock Substation	145.4	36.79667	-108.473	Usbr Shiprock Substation (Farmington)
4-Corners	350451233	Dine College	151.8	36.8071	-108.695	Dine College, GIS Lab
Albuquerque	2ZJ, 350431001	Highway Department, Bernalillo	148.6	35.29944	-106.548	Highway Dept. Yard Near Bernalillo
Albuquerque	2LL, 350610008	Los Lunas	140.4	34.8147	-106.74	1000 W. Main St, Los Lunas, NM 87031
Albuquerque	350010023	Del Norte High School	153.1	35.1343	-106.585	4700A San Mateo NE
Albuquerque	350010029	South Valley	145.4	35.01708	-106.657	201 Prosperity SE
Albuquerque	350011012	Foothills	152.4	35.1852	-106.508	8901 Lowell NE
South Central	6O, 350013008	La Union	161.3	31.93056	-106.631	St Lukes Episcopal Ch Rt 1 (La Union)
South Central	6ZK, 350130020	Chaparral Middle School	170.2	32.04111	-106.409	680 McCombs, Chaparral, NM
South Central	6ZM, 350130021	Desert View Elementary School	175.9	31.79611	-106.584	5935A Valle Vista, Sunland Park
South Central	6ZN, 350130022	US-Mexico Border Crossing	169.0	31.78778	-106.683	104-2 Santa Teresa International Blvd, NM
South Central	6ZQ, 350130023	NM Highway Dept. Yards In Las Cruces	149.9	32.3175	-106.768	750 N. Solano Drive, Las Cruces, NM
Southwestern NM[2]	7T, 350171003	Hurley Smelter	139.294	32.69194	-108.124	Chino Blvd near Hurley Park, Hurley, NM
Eastern NM	5ZS, 350025008	Hobbs-Jefferson	150.5	32.72666	-103.123	2320 N. Jefferson St, Hobbs, NM
Eastern NM	5ZR, 350151005	Outside Carlsbad	155.6	32.38	-104.262	Holland St, SE of Water Tank, Carlsbad, NM
Eastern NM	350153001	Carlsbad Caverns	145.4	32.1783	-104.441	Carlsbad Caverns National Park
North Central	350390026	Coyote	140.4	36.18774	-106.698	21 New Mexico 96, Coyote, NM, 87012
North Central	3SFA, 350490021	Santa Fe Airport	139.7	35.61975	-106.08	2001 Aviation Drive, Santa Fe, New Mexico 87507

[1]Based on 2017 only
[2]Based on 2013-2015 averages.

The hourly maximum ozone concentration from the nearest ozone monitor may be used for ozone limiting. Unless otherwise noted, the maximum 1-hour O_3 concentrations from each of three years were averaged to determine the 1-hour background concentration, using monitoring data from 2015 to 2017.

Refined 1-hour background profiles may be developed using the guidance described in "Refined Background Concentrations", above. Ozone files typically use the format, "(4I2,5X,F8.3)". Hourly concentrations use µg/m^3 to avoid elevation errors.

4.4.8 $PM_{2.5}$ Background Concentration

Table 18: $PM_{2.5}$ Background Concentration

Region	ID	Location	24-hour Background 100th%ile ($\mu g/m^3$)	24-hour Background 98th%ile ($\mu g/m^3$)	Annual Background ($\mu g/m^3$)	Latitude	Longitude	Address
Albuquerque	350010023	Del Norte High School	11.5	10.8	4.6	35.1343	-106.5852	4700A San Mateo NE
Albuquerque[1]	350010029	South Valley	22.6	18.20	7.43	35.01708	-106.6574	201 Prosperity SE
South Central[2]	6CM, 350130016	Anthony	18.4	17.0	7.6	32.00361	-106.5992	SE Corner Of Anthony Elem. School Yard
South Central	6ZM, 350130021	Sunland Park	25.9	24.3	7.3	31.79611	-106.5839	5935A Valle Vista, Sunland Park
South Central	6Q, 350130025	Las Cruces District Office of NMED	16.1	14.9	5.1	32.32194	-106.7678	2301 Entrada Del Sol, Las Cruces
Eastern NM	5ZS, 350250008	Hobbs-Jefferson	15.8	13.4	5.9	32.72666	-103.1229	2320 N. Jefferson St, Hobbs
4-Corners[1]	1FO, 350450019	Farmington Environment Department Office	14.13	11.77	4.19	36.77416	-108.165	3400 Messina Drive Suite 5000 Farmington
North Central[1]	3HM, 350490020	Santa Fe	16.55	9.45	4.32	35.67111	-105.9536	Runnels Bldg. 1190 St. Francis Dr.

[1]Based on 2013-2015 averages

[2]Based on average of 2013, 2014, and 2017

Concentrations are the average of three years of maximum data from 2015 to 2017. Some monitors may not represent background concentrations. Anomalously high values were eliminated before calculating aggregate concentrations. Use the highest 98th percentile background concentration from the region in which the facility is located, unless another monitor is more representative of the local area. Refined 24-hour background profiles may be developed using the guidance described in "Refined Background Concentrations", above.

Monthly background concentrations for Southeastern New Mexico from Hobbs are listed below. These were collected from January 2015 to December 2018.

Table 18B: Hobbs Refined $PM_{2.5}$ Background Concentration

Month	Monthly 24-hour Maximum ($\mu g/m^3$)
1	**12.1**
2	**10.2**
3	**21.1**
4	**17.5**
5	**16.5**
6	**16.1**
7	**17.6**
8	**13.3**
9	**15.6**
10	**10.3**
11	**13.2**
12	**17.7**

4.4.9 PM_{10} Background Concentration

Table 19: PM_{10} Background Concentration

Region	ID	Location	Annual Background ($\mu g/m^3$)	24-hour Background Maximum ($\mu g/m^3$)	24-hour Background Second High ($\mu g/m^3$)	Latitude	Longitude	Address
Albuquerque	350010026	Jefferson	24.3	74.0	70.3	35.1443	-106.6047	3700 Singer
Albuquerque	350010029	South Valley	33.7	152.0	132.2	35.01708	-106.6574	201 Prosperity SE
4-Corners[1]	1ZB, 350450009	Bloomfield	13.0	55.0	50.0	36.74222	-107.977	162 Hwy 544, Bloomfield NM 87413
South Central	6CM, 350130016	Anthony	22.0	50.7	44.7	32.003611	-106.5992	SE Corner of Anthony Elem. School Yard
South Central	6ZK, 350130020	Chaparral Middle School	25.3	120.0	112.3	32.041111	-106.4092	680 McCombs, Chaparral
South Central[1]	6ZM, 350130021	Sunland Park	26.0	78.0	73.0	31.796111	-106.5839	5935A Valle Vista, Sunland Park
South Central	6WM, 350130024	Las Cruces City Well #46	15.3	94.7	83.3	32.278056	-106.8644	South of I-10 at Las Cruces Well #46
Southwestern[2]	7D, 350029001	Deming	16.2	56.5	46.5	32.267222	-107.7553	Post Office Pine St
Southwestern[2]	7E, 350029003	Deming Airport	22.7	128.7	109.3	32.2558	-107.7227	310 Airport Road, Deming
Eastern NM	5ZS, 350250008	Hobbs-Jefferson	24.0	100.7	37.3	32.726656	-103.1229	2320 N. Jefferson St, Hobbs
North Central[2]	3HM, 350490020	Santa Fe	9.0	23.0	20.7	35.671111	-105.9536	Runnels Bldg. 1190 St. Francis Dr.
North Central[2]	3ZD, 350055005	Taos	14.2	52.0	40.5	36.383333	-105.5833	Fire Station Santiago Road

Concentrations are averaged from 2015 to 2017. Some monitors, such as 350010026 and 350010029, are located near industrial sources or in disturbed areas and do not represent ambient background concentrations.

[1]Monitor 350450009 was missing 2015 data. Monitor 350130021 was missing 2016 data. These monitors used two year averages.

[2]Based on 2013-2015 averages

Refined 24-hour background profiles may be developed using the guidance described in "Refined Background Concentrations", above.

Anomalously high values were eliminated before calculating aggregate concentrations.

Monthly background concentrations for Southeastern New Mexico from Hobbs are listed below. These were collected from July 2011 to June 2014. The monitor was discontinued after June 2014.

Table 20: Hobbs Refined PM_{10} Background Concentration

Month	**Monthly 24-hour Maximum** ($\mu g/m^3$)
1	43.0
2	46.0
3	62.7
4	58.0
5	62.3
6	82.3
7	86.7
8	61.3
9	60.0
10	74.3
11	48.7
12	39.7

4.4.10 SO_2 Background Concentration

Table 21: SO_2 Background Concentrations

Region	ID	Location	1-hour Background ($\mu g/m^3$)	1-hour Background 99th Percentile ($\mu g/m^3$)	Annual ($\mu g/m^3$)	Latitude	Longitude	Address
Albuquerque	350010023	Del Norte High School	15.8	13.2	1.75	35.1343	-106.585	4700A San Mateo NE
Southwest New Mexico[1]	7T, 350171003	Hurley Smelter	6.11	1.75	0.0183	32.69194	-108.124	Chino Blvd Near Hurley Park, Hurley, NM
The rest of New Mexico	1ZB, 350450009	Bloomfield	8.84	5.31	0.219	36.74222	-107.977	162 Hwy 544, Bloomfield NM 87413
Between Farmington and Shiprock	1H, 350451005	Shiprock Substation	41.6	22.1	0.389	36.79667	-108.473	Usbr Shiprock Substation (Farmington)
4-Corners west of Shiprock	350451233	Dine College	37.3	19.5	1.48	36.8071	-108.695	Dine College, GIS Lab
Eastern New Mexico	483751025	Amarillo, 24th Ave	68.3	47.0	0.670	35.2367	-101.787	4205 NE 24th Ave, Amarillo TX

Background concentrations are from 2015 to 2017
[1]Based on 2013-2015 averages

Refined 1-hour background profiles may be developed using the guidance described in "Refined Background Concentrations", above.

4.5 Location and Elevation

Important: Use the same UTM zone and datum for the entire facility. Facilities on the border between two UTM zones must convert all information into one zone or the other.

Make sure that the source location and parameters are the same as those listed in the application form!! This is the most common mistake we see.

4.5.1 Terrain Use

Terrain classifications are defined as follows:

- **Flat terrain** – Terrain with all elevations equal to the base of the source
- **Simple terrain** – Terrain with elevations below stack height
- **Complex terrain** – Terrain with elevations above stack height

- **Intermediate (Complex) terrain** – Terrain with elevations between stack height and plume height (a subset of complex terrain).

Flat terrain should be used if the source base is higher than all the surrounding terrain or if the facility consists primarily of non-buoyant fugitive sources. Simple and complex terrain should be used for all other scenarios.

4.5.2 Obtaining Elevation

Elevation data for receptors, sources, and buildings should be obtained from Digital Elevation Model (DEM) files or National Elevation Dataset (NED) files with a resolution of 30 meters or better. USGS DEMs are available for New Mexico in either 7.5-minute or 1-degree formats. It is strongly suggested that the 7.5-minute data be used in dispersion modeling rather than the coarse resolution 1-degree data. Keep in mind that the USGS DEMs can be in one of two horizontal datums. Older DEMs were commonly in NAD27 (North American Datum of 1927) while many of the latest versions in NAD83 (North American Datum of 1983). It is important to use the same source of data for all elevations. Even USGS 7.5-minute maps and USGS 7.5-minute DEM data may differ. Surrounding sources' elevations provided by the Bureau have been determined using 7.5-minute DEM data (NAD83), where available, and 1-degree DEM data elsewhere.

Elevations should be included for at least all receptors within 10 km of your facility or within your facility's ROI (whichever is smaller). Your source's elevation may be used for receptors beyond 10 km, but it may be wiser to use actual DEM elevations for the entire ROI because surrounding sources are provided with actual elevations.

4.6 Receptor Placement

4.6.1 Elevated Receptors on Buildings

Elevated receptors should be placed on nearby buildings at points of public access where elevated concentrations may be predicted. Use flagpole receptors in areas with multi-story buildings to model state and federal standards. In cases where nearby buildings have publicly accessible balconies, rooftops, or similar areas, the applicant should consult with the Bureau modeling staff to ensure proper receptor placement. PSD increment receptors are limited to locations at ground level.[6]

4.6.2 Ambient Air

Ambient air is defined as any location at or beyond the fence line of the facility. The fence line must restrict public access by a continuous physical barrier, such as a fence or a wall. If plant property is accessible to the public or if any residence is located within the restricted area, receptors should be located on-property.[7] Public access is interpreted to include housing, schools, hospitals, and similar areas that are frequented by family members of employees, but the remainder of the restricted area is excluded from public access if such family members do not have access to excluded areas. For example, receptors would not be placed in dormitories on military bases, but would be placed in family housing areas.

4.6.3 Receptor Grids

"Receptor sites for refined modeling should be utilized in sufficient detail to estimate the highest concentrations and possible violations of a NAAQS or a PSD increment. In designing a receptor network,

[6] NSR Workshop Manual, page C.42
[7] NSR Workshop Manual, Page C.42

the emphasis should be placed on receptor resolution and location, not total number of receptors." (68238 Federal Register / Vol. 70, No. 216 / Wednesday, November 9, 2005 / Rules and Regulations)

The modeling domain can be defined using a Cartesian grid with 1000 meter spacing. Fine grids or fence line receptors with 50 to 100 meter spacing should fill any areas of the domain with potential to contain the highest concentration and/or any possible exceedances of NMAAQS, NAAQS, or PSD increment for the refined modeling. 50 meter spacing is recommended for fence line receptors for most sources, but 100 meters is recommended for expansive sources like coal mines, copper mines, or large military bases. (Grids with 50 meter spacing and 2 km side width are recommended for medium or large neighboring point sources. 50 meter spacing and 1 km width grids are recommended for hilltops or small neighboring sources.) Once these areas of potential high concentrations have been refined, the remaining receptors may be discarded.

For sources with an ROI greater than 50 kilometers, the grid should not extend beyond 50 km, as is noted in the NSR Workshop Manual.

4.6.4 PSD Class I Area Receptors

A modeling analysis of the PSD increment consumed at the nearest Class I areas must be performed by increment-consuming sources in AQCRs where the PSD minor source baseline date has been established, or in any AQCR where a new PSD-major source is to be installed. One receptor at the near boundary of the Class I area is normally sufficient for modeling to compare with Class I significance levels. 1000 meter spacing is recommended within the Class I areas for facilities with significant concentrations. If concentrations are above 75% of the PSD increment, then 50 to 100 meter spacing should be used near the hot spots. See Figure 1 for locations of Class I areas.

4.6.5 PSD Class II Area Receptors

Other than areas that are designated as PSD Class I areas, the entire state of New Mexico is a Class II area. The receptor grid for the PSD Class II increment analysis should be the same as the one for the cumulative run.

4.7 Building Downwash and Cavity Concentrations

Building downwash should be included in the analysis when stack height is less than good engineering practice (GEP) stack height and there are buildings, tanks, fans or other obstacles near the facility. All buildings and structures should be identified and analyzed for potential downwash effects. NMED requires the use of BPIP-Prime or equivalent for this analysis. GEP stack height should be determined as per 40 CFR 51.100. For receptors very near buildings, a cavity region analysis may be required. Modelers should consult with the Bureau modeling staff.

As summarized from 40 CFR 51.100:
GEP stack height is the greater of:

1) 65 meters, measured from the ground-level elevation at the base of the stack

or

2) H + 1.5L

Where

H = Height of nearby structure(s) measured from the ground-level elevation at the base of the stack.

L = The lesser of the height or the projected width (width seen by the stack) of nearby structures.
Nearby structures can be as far as 5 times the lesser of the width or height dimension of the structure, but not greater than 0.8 km.
Stacks taller than GEP stack height should be modeled as if they were GEP stack height.

4.8 Neighboring Sources/Emission Inventory Requirements

> "The number of nearby sources to be explicitly modeled in the air quality analysis is expected to be few except in unusual situations. In most cases, the few nearby sources will be located within the first 10 to 20 km from the source(s) under consideration." (Federal Register / Vol. 82, No. 10 / Tuesday, January 17, 2017 / Rules and Regulations)

4.8.1 Neighboring Sources Data

The Emissions Inventory of neighboring sources is used as input data in air quality models. This data will be provided by the Bureau within a few days of request. E-mail the UTM coordinates of the location(s) to be modeled to the Bureau to request source data.

4.8.1.1 Determining which sources to include

This section functions as a definition for "nearby sources" as used in this document. The definition varies based on context, as illustrated below.

The contributions of distant sources are included in the background concentration. If the background concentration is added and includes all neighboring sources or a conservative approximation of them, then surrounding source modeling is not required for modeling of NAAQS or NMAAQS. For particulate matter or cases where the background concentration does not include all neighboring sources, then include all sources within 10 km of the facility in the model, and discard sources beyond 10 km from the facility. PSD increment is modeled, not monitored. (PSD increment may optionally add a background concentration instead of modeling the more distant sources.) For cases where background concentrations are not added, retain all sources within 25 km of the facility, plus sources emitting over 1000 pounds per hour within 50 km of the facility. For PSD Class I increment analysis, retain all sources within 25 km of the Class I area, plus sources emitting over 1000 pounds per hour within 50 km of the Class I area.

Table 22: Surrounding Source Retention Example for a Source Near Bloomfield.

Pollutant and averaging period	Neighboring source notes:
NO_2 1-hour NAAQS	Do not include surrounding sources. (Optionally, instead of adding background concentrations, include all sources within 25 km of the facility, plus sources emitting over 1000 pounds per hour within 50 km of the facility.)
$PM_{2.5}$ 24-hour NAAQS	Retain sources within 10 km of facility.
NO_2 annual Class II PSD increment	Retain sources within 25 km of the facility, plus sources emitting over 1000 pounds per hour within 50 km of the facility..
NO_2 annual Class I PSD increment	Retain sources within 25 km of Mesa Verde National Park, plus sources emitting over 1000 pounds per hour within 50 km of Mesa Verde.

4.8.1.2 Surrounding source format

The Bureau provides AERMOD input files with the surrounding sources (*.INP) and reference tables (*.XLS) to describe the sources in more detail. The AERMOD input files can be imported in GUI programs or edited manually. The Excel files are for reference only, and should not be used as the basis for modeling.

Sources numbered 0-49,999 belong in the NAAQS/NMAAQS analysis. Sources numbered 10,000 and above belong in the PSD increment analysis. (Notice overlap of two groups). Numbering in the reference tables may not include the 50,… or 10,… prefix for the counting numbers.

Unless otherwise noted, units of measure used in the surrounding sources files are the metric units associated with model input format. Emissions designated as NO_2 are actually total oxides of nitrogen (NO_X).

4.8.1.3 Handling errors in surrounding source files

Please contact the Bureau if you see suspicious data in the inventory. We know that there are errors in our database and we would like to correct them.

If you find a piece of equipment that has unusual stack parameters, document the error and corrected values in your modeling report. Please also report the error to Joe Kimbrell (Joseph.Kimbrell@state.nm.us) as well for database correction. Include MASTER_AI_ID, SUBJECT_ITEM_CATEGORY_CODE, and SUBJECT_ITEM_ID in the documentation. Please document the reason the error is suspected.

The following parameters may be substituted for missing or invalid data. Determine the type of source that best matches the types below. For example, engines use the "other" category. Find the smallest emission rate in the table that is greater than or equal to the emission rate of the emission unit. That column contains the parameters that may be used for the parameters that are missing. (These parameters are based on modeling for general construction permits or on existing source data for control devices.)

Table 23: Missing Stack Parameter Substitutions for Turbines.

NO_2 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
21.7	7	588	10	0.7
21	6	588	10	0.7
20	5	588	10	0.7
19	5	588	10	0.6
18	4.5	588	10	0.6
17	4.5	588	10	0.6
16	4.5	588	10	0.5
15	4.5	588	10	0.5
14	4.5	588	10	0.5
13	4	588	10	0.5
12	4	588	10	0.5

NO_2 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
11	3.5	588	10	0.5
10	3.5	588	10	0.5
9	3.5	588	10	0.5
8	3.5	588	10	0.4
7	3	588	10	0.4
6	3	588	10	0.4
5	2.5	588	10	0.4
4	2.5	588	10	0.4
3	2	588	10	0.35
2	1.8	588	10	0.24
1	1.8	588	10	0.24

Table 24: Missing Stack Parameter Substitutions for Flares.

SO_2 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
5000	18	1273	20	20.80618
4500	16	1273	20	19.73848
4000	14	1273	20	18.60962
3500	12	1273	20	17.4077
3000	9	1273	20	16.1164
2500	6	1273	20	14.71219
2100	6	1273	20	13.48395
2000	6	1273	20	13.15899
1900	6	1273	20	12.82579
1800	6	1273	20	12.48371
1700	6	1273	20	12.13198
1600	6	1273	20	11.76975
1500	6	1273	20	11.39602
1400	6	1273	20	11.0096
1300	6	1273	20	10.60911
1200	6	1273	20	10.19291
1100	6	1273	20	9.758965
1050	6	1273	20	9.534591
1000	6	1273	20	9.304808
950	6	1273	20	9.069204
900	6	1273	20	8.827315
850	6	1273	20	8.578609
800	6	1273	20	8.322474
750	6	1273	20	8.0582
700	6	1273	20	7.784961
650	6	1273	20	7.501776
600	6	1273	20	7.207473
550	6	1273	20	6.90063
500	6	1273	20	6.579493
450	6	1273	20	6.241855
400	6	1273	20	5.884877
350	6	1273	20	5.504798
300	6	1273	20	5.096453
250	6	1273	20	4.652404
200	6	1273	20	4.161237
150	6	1273	20	3.603737
100	6	1273	20	2.942439

SO_2 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
90	6	1273	20	2.791442
80	6	1273	20	2.631797
70	6	1273	20	2.461821
60	6	1273	20	2.279203
50	6	1273	20	2.080618
40	6	1273	20	1.860962
30	6	1273	20	1.61164
29	6	1273	20	1.584552
28	6	1273	20	1.556992
27	6	1273	20	1.528936
26	6	1273	20	1.500355
25	6	1273	20	1.471219
24	6	1273	20	1.441495
23	6	1273	20	1.411144
22	6	1273	20	1.380126
21	6	1273	20	1.348395
20	6	1273	20	1.315899
19	4	1273	20	1.282579
18	4	1273	20	1.248371
17	4	1273	20	1.213199
16	4	1273	20	1.176975
15	4	1273	20	1.139602
14	4	1273	20	1.10096
13	4	1273	20	1.060911
12	4	1273	20	1.019291
11	4	1273	20	0.9758965
10	4	1273	20	0.9304808
9	3.5	1273	20	0.8827316
8	3.5	1273	20	0.8322473
7	3.5	1273	20	0.7784961
6	3.5	1273	20	0.7207473
5	3.5	1273	20	0.6579493
4	3	1273	20	0.5884877
3	3	1273	20	0.5096453
2	2.5	1273	20	0.4161237
1	2	1273	20	0.2942439

Table 25: Missing Stack Parameter Substitutions for Particulate Control Devices.

PM10 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
22	19	0	28	4.6
21	18	0	27	4.6
20	17	0	26	4.4
19	16	0	25	4.2
18	15	0	24	4
17	14	0	23	3.8
16	14	0	22	3.6
15	13	0	21	3.4
14	13	0	20	3.2
13	12	0	19	3
12	12	0	18	2.8
11	11	0	17	2.6
10	11	0	16	2.4
9	10	0	15	2.2
8	10	0	14	2
7	10	0	13	1.8
6	9	0	12	1.6
5	9	0	11	1.4
4	9	0	10	1.2
3	9	0	9	1
2	9	0	8	0.8
1	9	0	7	0.6

Table 26: Missing Stack Parameter Substitutions for Other Point Sources.

NO_2 Rate (lb/hr)	Height (m)	Temperature (K)	Velocity (m/s)	Diameter (m)
21.7	7	730	28	0.3
21	6	730	28	0.3
20	5.5	730	28	0.3
19	4.5	730	28	0.3
18	4.5	730	27	0.3
17	4.5	730	27	0.3
16	4.5	730	27	0.25
15	4.5	730	27	0.25
14	4.5	700	22	0.25
13	4.5	700	22	0.25
12	4.5	700	22	0.2
11	4.5	700	22	0.2
10	4.5	700	22	0.2
9	4.5	700	20	0.2
8	4.5	700	18	0.2
7	4.5	700	14	0.2
6	4.5	650	14	0.2
5	4.5	500	5	0.2
4	4	500	5	0.1
3	3.5	500	5	0.1
2	3	500	5	0.0762
1	2	500	5	0.0762

For GCP 2, 3, and 5 permits with 95 tons/year of $PM_{2.5}$ emissions, use the following values:

TSP emission rate = 95 TPY
PM_{10} emission rate = 71.25 TPY (TSP X 0.75)
$PM_{2.5}$ emission rate = 17.875 TPY (PM_{10} X 0.25) = (TSP X 0.1875)

For volume sources with missing parameters:

Maximum release height = 10 m
Minimum release height = 1 m
Missing release height = PM10 Rate x 20 m/(lb/hr)
Initial vertical dimension = release height x 0.93
No limit to the maximum lateral dimension.
Lateral dimension = PM10Rate x 10 m/(lb/hr)
Minimum Lateral Dimension = 0.47 m

4.8.1.4 Refining Surrounding Sources

In some cases, it will be possible to use actual emissions to model surrounding sources instead of the maximum values allowed in the permit. If actual emission rates from the most recent two years is available, then the following optional technique may be used.

Annual averaging period: For the most recent two consecutive years of operation, if that period is representative of normal operation, the emission rate for each hour (in pounds per hour) is the total tons emitted for those two years divided by 8.76 (lb x year/ton x hour).

Other averaging periods: The unit is assumed to operate continuously unless there is a permit condition or physical limitation that prevents it from operating certain hours of the day or days of the year. If data is available for the most recent two years (Continuous Emissions Monitoring (CEM) data, for example) then a temporally representative level when operating may be used. For example, a generator that provides more power during peak hours could be modeled such that the maximum emission rate would be emitted during the peak hours of the day and the minimum operating emission rate would be emitted during the lowest-demand hours and the hours the unit would normally be off.[8]

4.8.2 Source Groups

It often saves considerable analysis time to set the model up to run with multiple source groups. The following groups are recommended.

- **Source alone group** – contains the sources at the facility that are used to compare with significance levels for the pollutant and averaging period being modeled. This group determines if the facility is above significance levels at the location and time.
- **Cumulative sources group** – contains all allowable emissions of the source and surrounding sources. This group is used to determine compliance with NAAQS and NMAAQS.
- **PSD sources group** – contains all sources that consume or expand PSD increment. This group is used to determine compliance with PSD increment regulations.

Impacts from different groups can be compared to determine if a source contributes significant concentrations if there is a problem complying with air quality standards.

4.8.3 Co-location with a GCP for aggregate processing facilities, asphalt plants, or concrete batch plants

At this time, General Construction Permits (GCPs) for aggregate processing facilities, asphalt plants, and concrete batch plants currently have the requirement that no visible emissions shall cross the fence line, which has been demonstrated to show compliance with all particulate matter air quality standards and PSD increments. NMED has allowed co-located facilities operating under a GCP to rely upon the GCP modeling demonstration for when co-located facilities operate at the same time, since all facilities at the location are required to have the same, no visible emissions, requirement at the fence line. However, if a source operating under a regular construction permit, and not a GCP, co-locates with a GCP source, it must show compliance with all particulate matter air quality standards through air dispersion modeling. The modeling for the source operating under a regular construction permit shall include all sources other than the co-located GCP sources. Gaseous pollutant modeling shall include the co-located GCP(s).

[8] **Federal Register,** Vol. 82, No. 10, pg. **5220** / Tuesday, January 17, 2017 / Rules and Regulations

5.0 EMISSIONS SOURCE INPUTS

This section describes appropriate modeling for many types of sources. Additional guidance can be found in the User's Guide for the AMS/EPA Regulatory Model - AERMOD (EPA, 2004, http://www.epa.gov/scram001/dispersion_prefrec.htm).

5.1 Emission Sources

There are two general types of sources:

Sources that come from a stack or vent – stack sources, or point sources;
And sources that don't – fugitive sources.

5.2 Stack Emissions/Point Sources

All stacks should be modeled as point sources, as detailed below.

5.2.1 Vertical Stacks

Stacks that vent emissions vertically should be modeled as point sources with stack parameters that will simulate the manner in which emissions are released to the atmosphere:

Stack exit velocity, V_s = average upward velocity of emissions at the top of the stack;
Stack diameter, d_s = stack exit diameter;
Stack exit temperature, T_s = average temperature of emissions at the top of the stack;
Stack height, H_s = stack release height.

5.2.2 Stacks with Rain Caps and Horizontal Stacks

Stacks that vent emissions horizontally and/or have rain caps should be modeled as point sources with stack parameters that will simulate the manner in which emissions are released to the atmosphere:

Stack exit velocity, V_s = 0.001 m/s;
Stack diameter, d_s = 1m;
Stack exit temperature, T_s = 0 K, or optionally actual temperature for stacks with high temperature;
Stack height, H_s = release height.

AERMOD will set the temperature to ambient temperature if the stack exit temperature is set to 0 K. If the model being used does not do this, then set the temperature to ambient temperature or to a close approximation thereof.

If modeling only horizontal stacks that are not capped, turn stack tip downwash off, whether there are buildings or not. Stack tip downwash calculations are inappropriate for horizontal stacks. If only some stacks have rain caps or are horizontal and others release upward without caps, use stack tip downwash.

Optionally, for modeling only vertical stacks that are capped, turn stack tip downwash off and reduce the stack height by three times the actual stack diameter. The cap will probably force stack tip downwash most of the time. The maximum amount of the stack tip downwash (as calculated in ISC2) is three times the stack diameter. Reducing the stack height by this amount, while turning off the stack tip downwash option, causes the maximum stack tip downwash effect. (Joseph A. Tikvart, 1993)

AERMOD beta options using the POINTCAP and POINTHOR may also be used.

5.2.3 Flares

Both process and emergency flares should be modeled for comparisons with NAAQS and NMAAQS. If parts of the facility will be shut down when the flare operates then those emission units may be omitted from the flare modeling.

Flares should be treated as point sources with the following parameters:

Stack velocity = 20 m/s = 65.617 ft/s
Stack temperature = 1000°C = 1832°F
Stack height = height of the flare in meters
Effective stack diameter in meters= $D = \sqrt{10^{-6} q_n}$
where $q_n = q(1 - 0.048\sqrt{MW})$
and q is the gross heat release in cal/sec
MW is the weighted by volume average molecular weight of the mixture being burned.
(SCREEN3 Model User's Guide, 1995)

Flares in the surrounding sources inventory from the Bureau should already have an effective diameter calculated; so the parameters in the inventory can be entered directly into your model input "as is". There are other methods for analyzing impacts of flares; if you wish to use another method, check with the Bureau modeling staff first.

NOTE: The NAAQS cannot be violated, even during upset conditions. All emergency flares should be modeled to show compliance with the NAAQS short-term standards under upset conditions. Emergency flares should be modeled with surrounding sources, but not including neighboring emergency flares and other sources that operate less than 500 hours per year.

5.3 Fugitive Sources

5.3.1 Aggregate Handling

Aggregate handling emissions consist of three separate activities, namely: loading material to and from piles, transportation of material between work areas, and wind erosion of storage piles.

Loading material to and from piles should be modeled as volume sources representative of the loading or unloading operation. Emissions for loading and unloading are calculated using AP-42 Section 13.2.4. The loading and unloading each involve dropping the material onto a receiving surface, whether being dropped by a dump truck, a front-end loader, or a conveyor. Each drop should be modeled as described in Fugitive Equipment Sources, below.

Transportation of material between work areas should be modeled according to haul road methodology if vehicles are used to transport the material, or using transfer point methodology if conveyors are used to transport the material, as described in Fugitive Equipment Sources, below.

Modeling of wind erosion of storage piles is optional, as it says in AP42 not to use the equations for wind erosion in a steady state model.

For the following example facility, aggregate is handled 6 times:

1- a pile in front of the mine face is created,
2- a pile in front of the mine face is loaded into trucks or conveyors,

3- a pile in front of the processing equipment (crusher or HMA) is created,
4- loading the equipment (crusher or HMA),
5- a pile after the equipment, and
6- loading the truck

1 and 2 would not apply if on-site mining does not occur.
5 may be considered a transfer point (conveyor) instead of aggregate handling if controls are applied.
5 and 6 may not apply for HMA plant, as material is bound in asphalt.
6 would not apply if the waste pile is left on site.

5.3.2 Fugitive Equipment Sources

Emissions coming from equipment such as crushers, screens, or material transfer points should be modeled as volume sources. Emission rates are normally calculated using AP42 factors.

The release height (H) is the distance from the center of the volume to the surface of the ground. The base of each volume source must be square. For elongated sources, use a series of volume sources with square bases. Determine the apparent size of a volume source by estimating how large the plume would look to an observer. Consider the movement of the plume source during the course of an hour when determining the apparent size. For example, if the source of emissions is from disturbances on a pile, and the entire pile is disturbed at some point in the hour, then use the size of the pile as the apparent size instead of the area of the pile that would be disturbed at any one instant. The reason for this is that the model operates in one-hour blocks of time, so using instantaneous sizes could inaccurately target nearby receptors with elevated emission concentrations.

For a single volume source, divide the apparent length by 4.3 to determine the initial lateral dimension (σ_{Yo}) to input into the model. For a line source represented by a series of volume sources, divide the distance between the centers of adjacent sources by 2.15 to determine σ_{Yo}.

For a source on the ground, divide the vertical dimension of the source by 2.15 to determine the initial vertical dimension (σ_{Zo}) to input into the model. For a source on or connected to a building, divide the height of the building by 2.15 to determine the σ_{Zo}. For an isolated elevated source, divide the vertical dimension of the source by 4.3 to determine the σ_{Zo}.

Example sources are described in the table below. Some sources will vary from the characteristics listed in the table.

Table 27: Example Dimensions of Fugitive Sources

Source Type	Height of Volume (m)	σ_{Zo} (m)	Release Height (m)	Width of Volume (m)	σ_{Yo} (m)
Crusher	5	2.33	6	5	1.16
Screen	5	2.33	4	5	1.16
Transfer point	2	0.93	2	2	0.47
Elevated transfer point	4	0.93	4	2	0.47
High Elevated transfer point	4	0.93	8	2	0.47
Concrete truck loading	5	2.33	4	5	1.16

5.3.3 Haul Roads

Traffic carrying materials mined or processed at the facility must be modeled as part of the facility. Haul roads to be modeled include the portion of roads that are not publicly accessible. The Bureau recommends haul road modeling to be consistent with Regional/State/Local Haul Road Workgroup Recommendations, as described below. Haul road emissions should be modeled as a series of adjacent volume sources, except that area sources should be used for modeling haul roads where receptors located within source dimensions are important. A procedure to develop model input parameters follows. The applicant can use other procedures on a case-by-case basis but must demonstrate that those procedures would be appropriate.

Road Source Characterization: Follow the instructions described below.

Plume height:

The height of the volume (H) or plume height will be equal to 1.7 times the height of the vehicle generating the emissions. Use the same for top of plume height for area sources.
The initial vertical sigma (σ_{Zo}) is determined by dividing the height of the plume by 2.15.
The release height is determined by dividing the height of the volume by two. This point is in the center of the volume.

Table 28: Example Haul Road Vertical Dimensions

Vehicle size	Truck Height	Height of Volume	σ_{Zo}	Release Height
Large trucks	4 m (13.1 ft)	6.8 m (22.3 ft)	3.16 m (10.4 ft)	3.4 m (11.1 ft)
Small trucks	2 m (6.6 ft)	3.4 m (11.2 ft)	1.58 m (5.2 ft)	1.7 m (5.6 ft)

RH = H/2 = Release Height above the ground (m). It's the center of the volume source. Also use this for the source height of the area source, if using the area source alternative.
σ_{Zo} = H/2.15 = initial vertical dimension of the volume (m)

Road width:

The adjusted width of the road (W) is the actual width of the road plus 6 meters. The additional width represents turbulence caused by the vehicle as it moves along the road. This width will represent a side of the base of the volume. Use W for the width of the area source, if using the area source alternative.

The initial horizontal sigma (σ_{Yo}) for each volume is determined as follows:

- If the road is represented by a single volume, divide W by 4.3.
- If the road is represented by adjacent volumes, divide W by 2.15.
- If the road is represented by alternating volumes, divide the distance between the center point of one volume to the center point of the next volume by 2.15. σ_{Yo} = 2W/2.15 This representation is only recommended for very long roads.
- If using area sources, the aspect ratio (i.e., length/width) should be less than 100 to 1. Subdivide the sources if they are too long.
- If using area sources, model each road segment as a straight line. Do not create a road segment with a bend in the road – divide the road into different segments when bends occur.

Road length:

The sum of the length of all volume sources should be about equal to the actual road length, unless the road is very long and half the segments are skipped to save time. The volume sources should be evenly spaced along the road and should be of equal size for a given road. It is acceptable to artificially end the haul road up to 50 meters before the intersection with a public road. The reduced length of the road is due to the observation that vehicles normally slow down or stop before exiting the property. All emissions from haul roads must be modeled, however. Emissions from the reduced road length are added to other road segments.

The two lateral dimensions (length and width) of a volume source should be equal. The number of volume sources, N, is determined by dividing the length of the road (optionally minus 50 meters) by W. The result is the maximum number of volume sources that could be used to represent the road. If N is very large, modeling time can be reduced by using alternating volume sources to reduce the number of sources.

Table 29: Example Haul Road Horizontal Dimensions

Vehicle size	Width of Volume	Length of Volume	σ_{Yo}
Large trucks	13 m (42.65 ft)	13 m (42.65 ft)	W/2.15 = 6.05 m (19.85 ft)
Small trucks	10 m (32.8 ft)	10 m (32.8 ft)	W/2.15 = 4.65 m (15.26 ft)

Road location:

The UTM coordinates for the volume source are in the center of the base of the volume. This location must be at least one meter from the nearest receptor.

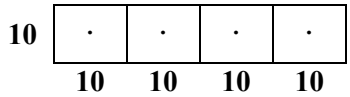
Emission Rate:

Divide the total emission rate equally among the individual volumes used to represent the road, unless there is a known spatial variation in emissions. Use the emissions calculated from the entire road length, even if you artificially end the road volume sources early before exiting the facility.

Example sources:

Use of the following modeling parameters should result in acceptable haul road modeling. Different facilities have different sized trucks, roads, and other variables. It is acceptable to use facility-specific parameters

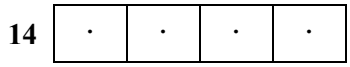
Example One-Way Road Source



(looking from above)
Width = W = 10 m (32.8 ft)
σ_{Yo} = W/2.15 = 4.65 m (15.26 ft)

Figure 3: One-Way Road Source

Two-Way Road Source



(looking from above)
Width = W = 14 m (45.9 ft)
σ_{Y_0} = W/2.15 = 6.51 m (21.4 ft)
Figure 4: Two-Way Road Source

Additional guidance can be found in Volume II of the User's Guide for ISC3 model (EPA, 1995).

5.3.4 Area Sources

Sources that have little plume rise may be modeled as area sources. Examples are: storage pile emissions, waste lagoon emissions, or gaseous emissions from landfills. Area source types include rectangle, circle, and irregularly shaped polygon. The model uses only the portion of the area source that is upwind of the receptor for calculating emissions for the hour, so it is safe to put receptors inside the area source without overly magnifying concentrations. The ISC input file uses emissions per area, but front-end programs for developing input files may calculate this for you based on total emissions from the source. For additional information, see the ISC User's Guide (EPA, 1995d).

Extremely long or odd-shaped (like a giant "L") area sources should be broken up into smaller area sources or modeled as a series of volume sources, because they may misrepresent emissions. Area sources, such as AREACIRC sources, may require many times as long to run the model as do volume or point sources in AERMOD.

5.3.5 Open Pits

The open pit source type should only be used to model open pits (not elevated trash dumpsters or anything else that somewhat resembles an open pit). The elevation of the pit entered into the model is the elevation of the top of the pit, which should be ground level.

The model calculates the effective depth of the pit by dividing the pit volume by the length and width of the pit. Release height above the base of the pit must be smaller than this value. Emissions from the bottom of the pit are expressed with a release height of zero.

Pit length should be less than 10 times the pit width. However, a pit cannot be sub-divided because the model needs to calculate mixing done throughout the pit. If the pit is irregular in shape, use the actual area of the top of the pit to calculate a rectangular shape with the same area.

Do not place receptors inside a pit.

The model input file requires pit emission rates to be expressed in mass per time per area [i.e., $g/(s \cdot m^2)$]. Model input front-end programs may convert actual emission rate into area-based emission rates automatically, however.

5.3.6 Landfill Offgas

Decomposition of landfill material can result in the release of gasses such as H_2S. If these gases are not collected using a negative pressure system and flared, then the area of the landfill that is releasing gas can be modeled as an area or a circular area source. If gas is collected by a negative pressure collection

system and flared, then model the flare the same way other flares are modeled. Place large area sources in areas that have little effect from the negative pressure collection system. In either case, elevation of the source should be equal to that of the surface, and release height should be zero because they are released from the ground and are not significantly affected by turbulence caused by vehicles traveling over the off-gasses.

6.0 MODELING PROTOCOLS

6.1 Submittal of Modeling Protocol

A modeling protocol should be submitted prior to the performance of a dispersion modeling analysis. For PSD applications, a modeling protocol is mandatory, and must be sent to NMED/AQB for review and comment. Consultation with Bureau modeling staff regarding appropriate model options, meteorological data, background concentrations, and neighboring sources is recommended for minor sources also, and can be accomplished in writing or by phone. The applicant should allow two weeks for the Bureau to review and respond to the written protocol. To avoid delays caused by misinterpretation or misunderstanding, we strongly recommend consultation with our staff on the following topics:

a.) Choice of models;
b.) Model input options;
c.) Terrain classification (flat or simple and complex);
d.) Receptor grids;
e.) Source inventory data;
f.) Minor source baseline dates for modeling increment consumption;
g.) Nearby Class I areas;
h.) Appropriate meteorological data;
i.) Background concentrations;
j.) Setback distance calculation if a proposed facility is a portable fugitive source;
k.) Any possible sources of disagreement;

Important: Modeling that substantially deviates from guidelines may be rejected if it is not accompanied by a written approved modeling protocol.

The input data to the models will be unique to the source. Data will usually consist of 1) emission rates and stack parameters for the proposed source at maximum load capacity and at reduced load capacity; 2) emission parameters of sources in the area; 3) model options; 4) suitable meteorological data; 5) definition of source operation which creates the greatest air quality impacts if other than maximum load conditions; and 6) terrain information, if applicable. Very important: **The emission parameters used in the modeling analysis of the proposed source are normally the same as those in the permit application. Any difference between the two should be clearly documented and explained.** Failure to adhere to this rule may result in an incomplete analysis.

6.2 Protocol ingredients

The shortest acceptable modeling protocol would be a statement that the modeling guidelines will be followed and a statement of what meteorological data will be used. Ask the modeling section or check the web page for the latest sample protocols.

6.3 How to submit the protocol

E-mail the modeling protocol to the modeling manager: Sufi.Mustafa@state.nm.us

7.0 DISPERSION MODELING PROCEDURE

Note: The basic steps for performing the modeling are presented in sequential format. Sometimes, it will make sense to perform some of the steps out of order. The sequential modeling steps are designed as an aid to modeling, not a mandatory requirement.

It is important to have an approved modeling protocol before proceeding. Modeling that substantially deviates from guidelines may be rejected if it is not accompanied by a written approved modeling protocol.

7.1 Step 1: Determining the Radius of Impact

A facility's significance area is defined as all locations outside of its fence line where the source produces concentrations that are above the significance levels listed in Table 6. The source is deemed culpable for concentrations that exceed air quality standards or PSD increments that occur at a receptor if the source's contribution is above the significance level at the same time that the exceedance of air quality standards or PSD increments occurs.

The Bureau uses the Radius of Impact (ROI) to make sure the entire significance area is analyzed. The ROI is defined as the greatest distance from the center of the facility to the most distant receptor where concentrations are greater than significance levels.

An illustration of determining an ROI from modeling output is shown in Figure 5, below. Note that the entire ROI is completely contained within the receptor grid, as required.

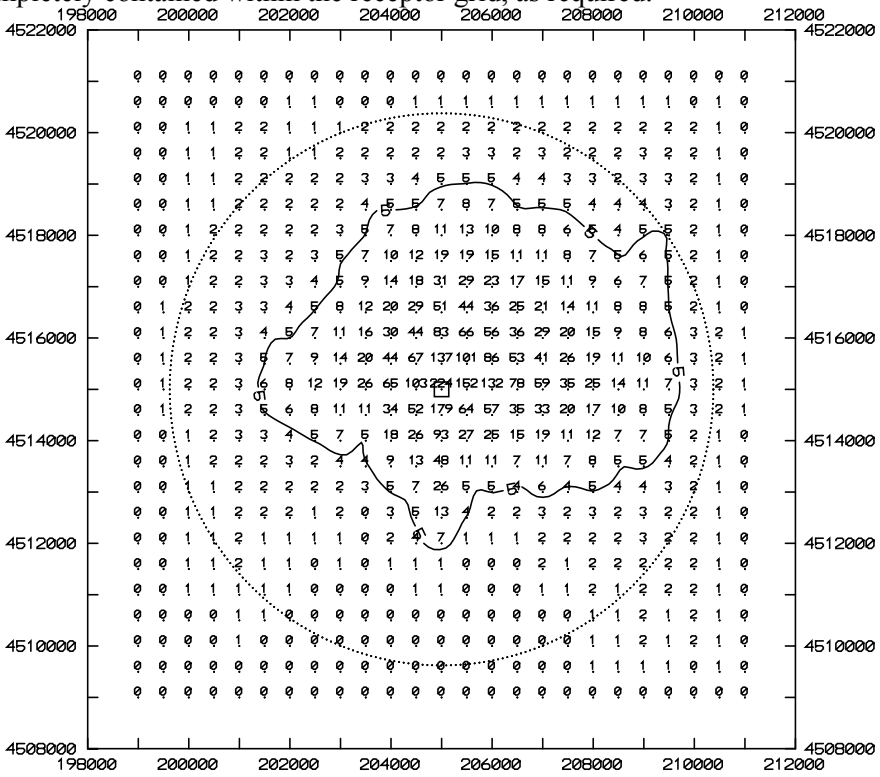


Figure 5. Plot of pollutant concentrations showing the 5 μg/m^3 significance level and the radius of impact (dashed line circle), determined from the greatest lineal extent of the significance level from the source.

7.1.1 Prepare the ROI analysis as follows:

I. Select the model that will be used for the analysis. It is usually quicker in the long run to use the same model for the radius of impact analysis as will be used for the refined analysis.
II. Model the entire source, as defined in section 2.4.1. Suggestion: Plot your sources to verify locations and identify typographical errors.
III. Set up the receptors as described above. Make sure the receptor grid extends far enough in every direction to capture the entire ROI, subject to the maximum radius of 50km.
IV. Optional step: Calculate the elevations of all sources, receptors, and buildings. This complex terrain analysis is optional for the ROI run, but it may save time to do it now.
V. Optional step: Add buildings and analyze them with BPIP or equivalent programs. This building downwash analysis is optional for the ROI run, but it may save time to do it now.
VI. Choose modeling options, as appropriate.
VII. Make sure that all sources and operating scenarios are modeled according to the guidelines in sections 4 and 5, above.
VIII. Run the model.

7.1.2 Analyze modeling results to determine ROI

I. Determine a radius of impact for each pollutant for each applicable averaging period. The largest ROI may be designated as the ROI for that pollutant, or each averaging period determined independently.
II. The ROI for NO_2 may be determined using Ambient Ratio Method 2 (ARM2).
III. Concentrations inside the facility's fence line can be ignored when determining the ROI.
IV. If no concentrations of a pollutant are above the significance levels for that pollutant, then the ROI for that pollutant is 0. Skip to Step 3 for that pollutant.
V. It is acceptable to scale impacts from one pollutant to determine impacts from another pollutant if several pollutants vent from the same stack and the ratios of emission rates and the averaging periods are the same.

Proceed to Step 2 for each pollutant with an ROI greater than zero.

7.2 Step 2: Refined Analysis

The entire area of significance must be included in the analyses for all averaging periods for each pollutant. If the ROI was determined using coarse grids, then add fine grid spacing to the potential areas of maximum concentration or concentrations above standards. If the ROI was determined using appropriate grid spacing, elevations, and building downwash (if applicable), then only the significant receptors need to be modeled for the refined analysis.

Once the ROI is determined for a specific source, neighboring sources need to be included and a cumulative impact analysis needs to be performed. As the ROI analysis is concerned with significance levels, the refined analysis is concerned with NAAQS, NMAAQS, and PSD Class I and Class II increments. The concentrations produced by the facility plus surrounding sources must be demonstrated to be below these levels in order to issue a permit under the regular permitting process.

7.2.1 Prepare the Refined Analysis as Follows:

I. If a screening model was used to determine ROI, the modeler may wish to use a refined model to reduce the area of significant impact. If so, return to *Step 1* and repeat the step with the new model.
II. Prepare a new modeling input file from the ROI file.

III. Fill the ROI with receptors with appropriate spacing (or discard receptors below significance levels if appropriate spacing was used for the ROI analysis).
IV. Add receptors near areas of high concentration if these areas are not contained within a fine grid. The modeling run must definitively demonstrate that the maximum impact has been identified. Concentrations should "fall off" from the center of the fine grid.
V. Add surrounding sources to the input file, if appropriate, as described in *Neighboring Sources/Emission Inventory Requirements*, above. Include $PM_{2.5}$ surrounding sources if particulate modeling is required. Suggestion: set up source groups so that impacts from the source alone, from the PSD increment consuming sources, and from all sources can be analyzed in a single run and compared with each other for determination of culpability.
VI. Building downwash analysis must be included in the refined analysis, if applicable.
VII. Terrain elevations must be included in the refined analysis, if applicable.

7.2.2 Analyze the Refined Modeling Results

I. Make sure the maximum impacts for each averaging period fall within a fine enough receptor grid to identify true maximums. Include fine grids near adjacent sources and in "hot spots".
II. Compare the highest short-term and annual impacts from all sources with NAAQS and NMAAQS.
III. Determine if there is an exceedance of PSD Class II increment within the area defined by the radius of impact by the group containing all PSD increment consuming sources.
IV. Determine if there is an exceedance of PSD Class I increment within any Class I area.
V. If the facility alone will violate any NAAQS, NMAAQS, or PSD increment, then the permit cannot be issued through the normal process. Please contact the Bureau for further information.
VI. If there are exceedances of the NMAAQS or NAAQS at any receptors within the ROI, the next step is to determine if the facility being modeled significantly contributes (see significance levels in Table 6) to the exceedance at those receptors during the same time period(s) that the exceedance occurs. If so, the permit cannot be issued through the normal process. See nonattainment area requirements, below.
VII. If no exceedances are found, or if the facility does not contribute amounts above significance levels to the exceedances, then the facility can be permitted per the modeling analysis.

7.2.3 NMAAQS and NAAQS

All sources are required to submit NMAAQS and NAAQS modeling. The total concentrations of all facilities and background sources are required to be below the NAAQS. The steps required for this analysis are outlined above.

7.2.4 PSD Class II increment

PSD Increment modeling applies to both minor and major sources. If the minor source baseline date has been established in the Air Quality Control Region (AQCR) in which the facility will be located, then PSD increment consumption modeling must be performed. If the minor source baseline date has not been established in that region, then only PSD major sources must perform this analysis.

Portable sources that are not located at a single location continuously for more than one year are not required to model PSD increment consumption.

The steps required for this analysis are outlined above.
The same significance levels that apply to NAAQS and NMAAQS standards are assumed to apply to PSD Class II increment as well.

7.2.5 PSD Class I increment

If a PSD Class II increment analysis is required and the proposed construction of a minor source is within 50 km of a Class I area (see Figure 1), then PSD increment consumption at the Class I area(s) must be determined and compared with the Class I PSD increment. If the proposed construction of a PSD major source is within 100 km of a Class I area, then PSD increment consumption at the Class I area(s) must be determined and compared with the Class I PSD increment. The PSD permit process requires a more thorough Class I analysis, which is described in *Step 6*.

See *Receptor Placement*, above, for receptor instructions.

Proceed with the Class I area analysis similarly to the other analyses described above. Class I significance levels apply for determining whether or not a facility contributes significantly to an exceedance in a PSD Class I area and for determining the Class I ROI.

7.3 Step 3: Portable Source Fence Line Distance Requirements for Initial Location and Relocation

Skip this step if the facility is not a portable source.

Portable sources should model fence line distance requirements for relocation purposes and for setback distances within the initial property. If the facility wants to be able to move equipment around within the property, or move to a new location, permit conditions will be required to ensure the facility continues to demonstrate compliance with air quality standards as it moves. For this modeling, use meteorological data that the Bureau has approved for relocation modeling, which may be different from that used for the rest of the modeling for the facility. Model the facility with a haul road length at least as long as the setback distance and a number of truck trips equal in number to the count at the original location. Surrounding sources may be ignored, but include co-located facilities if the desire is to be able to co-locate with other facilities at the new locations. To determine setback distance, draw a line connecting the concentrations where they drop off to the point that are just under the ambient air standard or PSD increment. Make sure to add background concentration before determining the isopleths for ambient air standards. From each point on the isopleth line, determine the distance to the nearest source (excluding haul road sources). The setback distance is the largest of these distances. Setback distance is typically rounded up to the nearest meter that is above the calculated value. An example setback distance determination is pictured in Figure 6, below.

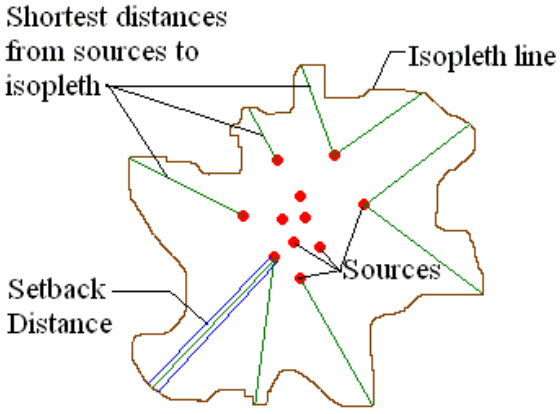


Figure 6: Setback Distance Calculation

Fine spacing is suggested within the property boundary for relocation requirement modeling.

If the applicant does not perform fence line distance modeling, relocation distance will be assumed to be the distance from the edge of a facility operations to the most distant point on the initial fence line. An irregular or elongated fence line shape can result in relocation requirements that require very large properties to be fenced off in order to relocate there without submitting modeling for each new location of the facility.

7.4 Step 4: Nonattainment Area Requirements

Skip this step if all modeled concentrations are below NAAQS, NMAAQS, and PSD Increments.

If the modeling analysis of a source predicts that the impact from any regulated air contaminant will exceed the significance level concentrations at any receptor which does not meet the NMAAQS or NAAQS, the source will be required to demonstrate a net air quality benefit and meet the requirements of 20.2.72.216 NMAC or 20.2.79 NMAC. The net air quality benefit is a reduction of at least 20% of the maximum modeled concentration from the facility or the emission sources being modified. The 20 percent reduction shall be calculated as the projected impact subtracted from the existing impact divided by the existing impact. The existing impact for the net air quality benefit must be based on the lowest enforceable emission rate, or the actual emission rate if a unit has no enforceable emission rate. The offsets used to meet the net air quality benefit must be quantifiable, enforceable, and permanent. For more information regarding nonattainment permit requirements, see **20.2.72.216 NMAC** and **20.2.79 NMAC** – Nonattainment Areas.

7.5 Step 5: Modeling for Toxic Air Pollutants

Skip this step if there are no toxics to model at this facility. See section 2, "New Mexico State Air Toxics Modeling", to determine if modeling of toxics is required and for other details about toxics regulatory requirements.

I. Model the toxic air pollutants similar to the way the other pollutants were modeled, as described above in steps 1 and 2. Use an 8-hour averaging period, complex terrain, and building downwash.
II. No surrounding source inventory exists for the toxics, so model only your source.
III. Make sure a fine grid is used in the area of maximum concentration.
IV. If more than one toxic pollutant is being modeled and they use the same stacks at the same ratio of emission rates, it is allowable to scale the results of the first pollutants by the emission rate ratio to determine the concentration of the other toxics.

If modeling shows that the maximum eight-hour average concentration of all toxics is less than one percent of the Occupational Exposure Level (OEL) for that toxic, then the analysis of that toxic pollutant is finished. Report details about the maximum concentrations in the modeling report. Otherwise, perform BACT analysis or health assessments, as required. Contact the Bureau on how to proceed if the $1/100^{th}$ of the OEL is exceeded.

7.6 Step 6: PSD Permit Application Modeling

Skip this step if the facility is not a PSD major source.

PSD sources and requirements are defined in NMAC 20.2.74.303 to 305. New PSD major sources and major modifications to PSD major sources must submit the following modeling requirements in addition to the NSR minor source modeling requirements. Minor modifications to PSD major sources

are only subject to NSR minor source modeling requirements listed above, as required under NMAC 20.2.72.

Due to a court ruling, the use of the $PM_{2.5}$ significant monitoring concentration for PSD major modifications or new PSD major sources is not allowed. This significant ambient concentration level may still be used for minor source and nonattainment permitting.

Sources subject to PSD requirements should consult with the Bureau to determine how to proceed in the application process. For PSD applications, a modeling protocol is required for review. Please refer to EPA's *New Source Review Workshop Manual.* The following items are required for PSD permit applications and supersede other modeling requirements in this document.

7.6.1 Meteorological Data

Applicants may need to collect one year of on-site meteorological and ambient data to satisfy PSD requirements. In some cases, it may be advantageous to begin collecting on-site meteorological and ambient data to ensure that it is available at a site that may become PSD in the future. A company considering a monitoring program is advised to consult with the Bureau as early as possible so that an acceptable data collection process, including instrument parameters, can be started. Generally, the following meteorological parameters will be measured: wind direction, wind speed, ambient air temperature, solar insolation, ΔT, and σ_θ. For further information on meteorological monitoring Refer to EPA's *Guideline on Air Quality Models* and *On-Site Meteorological Program Guidance for Regulatory Modeling Applications*. Refer to *Ambient Monitoring Guidelines for Prevention of Significant Deterioration (PSD)* for ambient monitoring guidance. In addition, a monitoring protocol and QA plan **must** be submitted and approved prior to beginning collection of data for a PSD application if these data are to be used for the analysis.

In the absence of actual on-site data, the Bureau may approve the use of off-site data that the Bureau believes mimics on-site data for that location or the Bureau may approve the use of data produced by the model MM5.

7.6.2 Ambient Air Quality Analysis

The ambient air quality analysis is the same as described above, with the exception of the following points.

- The PSD project is defined as the future potential emission rate minus the past actual emission rate.
- If the maximum ambient impact is less than EPA's significant concentration levels (see Table 6), then a full analysis is not required.
- Nearby sources must be considered. Discarding sources is discussed in the section on "neighboring sources data".
- A total air quality analysis must also be performed for each appropriate Class I area if the facility produces concentrations greater than the Class I significance levels in Table 6. All sources near the Class I area must be considered. The inventories for the analysis near the facility and the inventory for the analysis near Class I areas may be quite different because they are centered on different locations.
- If subject to 20.2.74.403 NMAC (Sources impacting Federal Class I Areas), an analysis of Air Quality Related Values must be included in the PSD application. If the facility will have no impact on the AQRV, then that must be stated in the application (NSR Workshop Manual, Chapter D).
- There may be additional analyses required by the Federal Land Managers (FLM) for Air Quality Related Values (AQRVs). See **F**ederal **L**and **M**anagers' **A**ir Quality Related Values Work

Group (FLAG) for more information at:
http://www2.nature.nps.gov/air/Permits/flag/index.cfm

7.6.3 Additional Impact Analysis (NMAC 20.2.74.304)

The owner or operator of the proposed major stationary source or major modification shall provide an analysis of the impact that would occur as a result of the source or modification and general commercial, residential, industrial, and other growth associated with the source or modification. This analysis is in addition to the Class I analysis, but may use some of the same techniques that were used in the Class I analysis. The analysis required for a National Environmental Policy Act (NEPA) review may work to satisfy some requirements of this section.

- Visibility Analysis: A Class II Visibility Analysis is required to determine impact the facility will have upon Class II areas. Analyze the change in visibility of a nearby peak or mountain for this analysis. In the absence of nearby mountains, analyze the visibility of clear sky from nearby state or local parks.
- Soils analysis: What changes will occur to soil pH, toxicity, susceptibility to erosion, or other soil characteristics as a result of the project and indirect growth related to the project?
- Vegetation analysis: What changes will occur to type, abundance, vulnerability to parasites, or other vegetation characteristics as a result of the project and indirect growth related to the project? The owner or operator need not provide an analysis of the impact on vegetation having no significant commercial or recreational value.
- Growth analysis: The owner or operator shall also provide an analysis of the air quality impact projected for the area as a result of general commercial, residential, industrial, and other growth associated with the source or modification.

7.6.4 Increment Analysis

- If the facility produces ambient concentrations greater than the significance levels in Table 6, then the Class II PSD increment analysis for the facility must use the inventory of all increment consuming sources near the facility. Sources in other states should be obtained from the agency in the surrounding state.
- If there is a Class I area within 100 km of the facility (or any distance, if requested by the FLM), then receptors must be located at the Class I area.
- If the facility produces ambient concentrations greater than the Class I significance levels in Table 6 in a Class I area, then the increment analysis for the Class I areas should use the inventory of all increment consuming sources near the Class I area, including those sources in other states. Sources in other states should be obtained from the agency in the surrounding state.

7.6.5 Emission Inventories

- The most current inventory of sources must be used. It should contain all sources currently under review by the Bureau that would be located within the appropriate inventory area. The applicant should check with the modeling staff to ensure that the inventory is up to date.

7.6.6 BACT analysis

- The analysis must follow current EPA procedures and guidelines.

7.7 Step 7: Write Modeling Report

A narrative report describing the modeling performed for the facility is required to be submitted with the permit application using Universal Application form 4 (UA4). This report should be written to provide the

public and the Bureau with sufficient information to determine that the proposed construction does not cause or contribute to exceedances of air quality standards. The report needs to contain enough information to allow a reviewer to determine that modeling was done in a manner consistent and defensible with respect to available modeling guidance. Do not include raw modeling output in the report, only summaries and descriptions of the output or input.

This outline may be used as a checklist to determine if the analysis is complete.

I. Applicant and consultant information
   a. Name of facility and company.
   b. Permit numbers currently registered for the facility.
   c. Contact name, phone number, and e-mail address for the Bureau to call in case of modeling questions.

II. Facility and operations description
   a. A narrative summary of the purpose of the proposed construction, modification, or revision.
   b. Brief physical description of the location.
   c. Duration of time that the facility will be located at this location.
   d. A map showing UTM coordinates and the location of the proposed facility, on-site buildings, emission points, and property boundaries. Include UTM zone and datum.

III. Modeling requirements description
   a. List of pollutants at this facility requiring NAAQS and/or NMAAQS modeling.
   b. AQCR facility is located in and resulting list of pollutants requiring PSD increment (Class I and II) modeling. Include distances to Class I areas in discussion.
   c. List of State Air Toxic pollutants requiring modeling.
   d. PSD, NSPS, and NESHAP applicability and any additional modeling requirements that result if those regulations are applicable to the facility.
   e. State whether or not the facility is in a federal Nonattainment area, and any special modeling requirements or exemptions due to this status.
   f. Any special modeling requirements, such as streamline permit requirements.

IV. Modeling inputs
   a. General modeling approach
      i. The models used and the justification for using each model.
      ii. Model options used and why they were considered appropriate to the application.
      iii. Ozone limiting model options discussion, if used for NO_2 impacts.
      iv. Background concentrations.
   b. Meteorological data
      i. A discussion of the meteorological data, including identification of the source of the data.
      ii. Discussion of how missing data were handled, how stability class was determined, and how the data were processed, if the Bureau did not provide the data.
   c. Receptor and terrain discussion
      i. Description of the spacing of the receptor grids.
      ii. List fence line coordinates and describe receptor spacing along fence.
      iii. PSD Class I area receptor description.
      iv. Flat and complex terrain discussion, including source of elevation data.
   d. Emission sources
      i. Description of sources at the facility, including:

1. A cross-reference from the model input source numbers/names to the sources listed in the permit application for the proposed facility.
2. Determination of sigma-Y and sigma-Z for fugitive sources.
3. Description and list of PSD increment consuming sources, baseline sources, and retired baseline sources.
4. Describe treatment of operating hours
5. Particle size characteristics, if plume depletion is used.
6. If the modeled stack parameters are different from the stack parameters in the application, an explanation must be provided as to what special cases are being analyzed and why.
7. Partial operating loads analysis description.
8. Flare calculations used to determine effective stack parameters.
9. In-stack NO_2/NO_X ratio determination, if using OLM or PVMRM.

ii. Surrounding sources:

1. The date of the surrounding source retrieval.
2. Details of any changes or corrections that were made to the surrounding sources.
3. Description of adjacent sources eliminated from the inventory.

e. Building downwash

i. Dimensions of buildings

V. Modeling files description

a. A list of all the file names in the accompanying CD and description of these files.
b. Description of the scenarios represented by each file.

VI. Modeling results

a. A discussion of the radius of impact determination.
b. A summary of the modeling results including the maximum concentrations, location where the maximum concentration occurs, and comparison to the ambient standards.
c. Source, cumulative, and increment impacts.
d. Class I increment impact.
e. A table showing concentrations and standards corrected for elevation.
f. If ambient standards are exceeded because of surrounding sources, please include a culpability analysis for the source and show that the contribution from your source is less than the significance levels for the specific pollutant.
g. Toxics modeling results, if needed.

VII. Summary/conclusions

a. A statement that modeling requirements have been satisfied and that the permit can be issued.

Ask the modeling section or check the web page for a sample modeling reports. The modeling report documents details the standard format for the modeling report.

7.8 Step 8: Submit Modeling Analysis

Submit the following materials to the Bureau:

A CD containing the following:

I. An electronic copy (in MS Word format) of the modeling report.
II. Input and output files for all model runs. Include BEEST, ISC-View, or BREEZE files, if available.
III. Building downwash input and output files.

IV. Fence line coordinates.
V. Meteorological data, if not Bureau-supplied.
VI. A list of the surrounding sources at the time the facility was modeled.
VII. An electronic copy of the approved modeling protocol.

Do not include paper copies of modeling input and output files.

8.0 List of Abbreviations

Table 30: List of Abbreviations

ACRONYM	DESCRIPTION
AQB	Air Quality Bureau
AQCR	Air Quality Control Region
AQCR	Air Quality Control Regulation (CURRENTLY NOT USED)
AQRV	Air Quality Related Values
ARM2	Ambient Ratio Method 2
BACT	Best Available Control Technology
CO	Carbon monoxide
DEM	Digitized Elevation Model
EPA	Environmental Protection Agency
FLAG	**F**ederal **L**and **M**anagers' **A**ir Quality Related Values Work **G**roup
FEM	Federal Equivalent Method
FRM	Federal Reference Method
GEP	Good Engineering Practice
H_2S	Hydrogen sulfide
ISCST3	Industrial Source Complex Short Term Model version 3
NAAQS	National Ambient Air Quality Standards
NED	National Elevation Dataset
NO_2	Nitrogen dioxide
NO_X	Nitrogen oxides
NMAAQS	New Mexico Ambient Air Quality Standards
NMAC	New Mexico Administrative Code
O_3	Ozone
OEL	Occupational Exposure Level
OLM	Ozone limiting method
Pb	Lead
PDF	Probability density function
$PM_{2.5}$	Particulate matter equal to or under 2.5 μm in aerodynamic diameter
PM_{10}	Particulate matter equal to or under 10 μm in aerodynamic diameter
PPM	Parts per million (volume ratio)
PSD	Prevention of Significant Deterioration
PVMRM	Plume Volume Molar Ratio Method
ROI	Radius of Impact
SO_2	Sulfur dioxide
TSP	Total suspended particulates
UTM	Universal Trans Mercator
VOC	Volatile organic compounds

9.0 References

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Federal **L**and **M**anagers' **A**ir Quality Related Values Work **G**roup (FLAG) Phase I Report: http://www2.nature.nps.gov/air/Permits/flag/index.cfm–
New Mexico Administrative Code (NMAC)

EPA, 1995d*: User's Guide for the Industrial Source Complex (ISC3) Dispersion Models*, EPA-454/B-95-003a, September, 1995. U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, NC.

Texas 1999: ***Air Quality Modeling Guidelines***, TNRCC-New Source Review Permits Division, RG-25 (Revised), February 1999

"The Plume Volume Molar Ratio Method [(PVMRM)] for Determining NO_2/NOx Ratios in Modeling", by Pat Hanrahan of the Oregon DEQ. The paper appeared in the November 1999 issue of the AWMA journal.

Links:

Environmental Protection Agency, 40 CFR Part 51, Revision to the Guideline on Air Quality Models Appendix W: http://www.epa.gov/ttn/scram/guidance/guide/appw_05.pdf

NSR Workshop Manual 1990 Draft: http://www.epa.gov/ttn/nsr/gen/wkshpman.pdf

Modeling Procedures for Demonstrating Compliance with PM2.5 NAAQS memo from Stephen Page, March 23, 2010:
http://www.epa.gov/ttn/scram/Official%20Signed%20Modeling%20Proc%20for%20Demo%20Compli%20w%20PM2.5.pdf

10.0 INDEX

Appendix A: Recent changes to the NM Modeling Guidelines

Note of changes made in 2019:

February 7, 2019: An error in summary Table 6C was corrected to make it match the full text in section 2.6.4.4.

Note of changes since 2016 version:

Source definition was changed to better match EPA definitions.

Original:

> Modeling significance levels are thresholds below which the source is not considered to contribute to any predicted exceedance of air quality standards or PSD increments. The definition of 'source' can apply to the whole facility or to the modifications at the facility. In cases where a particular averaging period has not been modeled for a pollutant, or was modeled, but predicted concentrations were above 95% of air quality standards or PSD increments, then NMED considers the entire facility to be the 'source' for those pollutants and periods. For other cases, 'source' includes only the modification described in the current application plus all contemporaneous emissions increases in the past 5 years since the entire facility was last modeled.

New:

> Modeling significance levels are thresholds below which the source is not considered to contribute to any predicted exceedance of air quality standards or PSD increments. The definition of 'source' can apply to the whole facility or to the modifications at the facility. For a new facility or an unpermitted facility, NMED considers the entire facility to be the 'source'. For other cases, 'source' includes only the new equipment or new emissions increases described in the current application. Equipment that replaces other equipment is part of the new equipment.

Meteorological data recommendations have changed to reflect recent data. AQB has processed new meteorological data and has retired some old data that may be out of date. The processed data is available on the meteorological data webpage (https://www.env.nm.gov/air-quality/meteorological-data/). At the time of this writing, Substation has replaced Bloomfield data for permitting sources to be located in unknown locations (portable source relocation modeling). This change was based on a comparison of modeling results for existing sets of meteorological data.

NO_2 conversion using Ambient Ratio Method (ARM) has been replaced with Ambient Ratio Method 2 (ARM2). EPA no longer mentions the use of ARM in Appendix W. Instead, that appendix described details about what ratios can be used for the ARM2 method, which is now built into AERMOD as a default option.

Title V sources that have not demonstrated compliance with NAAQS or PSD increments are required to model for these standards and increments or produce a compliance plan to come into compliance.

SO_2 background concentrations were added for the annual averaging period.

PM2.5 Class I significance levels were updated.

TSP standards were repealed November 30, 2018.

Background concentrations were updated to 2015-2017.

Areas Where Streamlined Permits Are Restricted were updated.

Secondary formation of ozone and PM2.5 were updated to reflect current Appendix W and MERP guidance.

Note of changes that were made in 2016:

1-hour NO_2 and SO_2 modeling is now required for all sizes of facilities with NO_2 or SO_2 emissions.

ARM2 method of NO_2 modeling has been added to the approved options.

AERMOD output is considered to be expressed at Standard Temperature and Pressure (STP), eliminating most of the need for concentration conversion.

Emission rates for the very small emission rate modeling waivers have changed.

The modeling report form, Universal Application 4 (UA4), is available.

Background concentrations have been updated to 2013-2015 monitoring results.

(Hobbs PM2.5 background concentration was corrected from the July 8, 2016 version).
(September 1, 2016: PM2.5 annual standard was corrected in Table 5F)

Errors in summary Tables 6A and 6C that did not match the instructions in the pollutant-specific standards sections were corrected.

NMED
EXHIBIT 4

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
RESEARCH TRIANGLE PARK, NC 27711

FEB 10 2020

OFFICE OF
AIR QUALITY PLANNING
AND STANDARDS

MEMORANDUM

SUBJECT: DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling

FROM: Richard A. Wayland, Division Director Richard A. Wayland
Air Quality Assessment Division

TO: Regional Air Division Directors, Regions 1 – 10

The Environmental Protection Agency (EPA) is providing the attached *DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling* to the state, local, and tribal air agencies, as well as the public, for consideration, review and comment. This guidance document reflects the EPA's recommendations for how a stationary source seeking a Prevention of Significant Deterioration (PSD) permit may demonstrate that it will not cause or contribute to a violation of the National Ambient Air Quality Standards (NAAQS) for ozone (O_3) and fine particulate matter ($PM_{2.5}$) and PSD increments for $PM_{2.5}$, as required under Section 165(a)(3) of the Clean Air Act (CAA) and 40 CFR sections 51.166(k) and 52.21(k).

This document does not substitute for provisions or regulations of the CAA, nor is it a regulation itself. As the term "guidance" suggests, it provides recommendations on how to implement the modeling requirements of a PSD compliance demonstration. Thus, it does not impose binding, enforceable requirements on any party, nor does it assure that the EPA will approve all instances of its application, as the guidance may not apply to a particular situation based upon the circumstances. Final decisions by the EPA regarding a particular PSD compliance demonstration will only be made based on the statute and applicable regulations, and will only be made following a final submission by air agencies and after notice and opportunity for public review and comment.

BACKGROUND

The EPA is providing this *DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling* to fulfill an outstanding need for additional guidance on demonstrating compliance with the NAAQS for O_3 and $PM_{2.5}$ and PSD increments for $PM_{2.5}$. Because of the complex chemistry of secondary formation of O_3 and $PM_{2.5}$, the EPA's judgment in the past was that it was not technically sound to specify with "reasonable particularity" air quality models that must be used to assess the impacts of a single source on O_3 and secondary $PM_{2.5}$ concentrations. Instead, the EPA employed a case-by-case process for determining analytical techniques that

NMED Exhibit 4

should be used for these secondary pollutants. However, as discussed in the preamble of the 2017 revisions to the EPA's *Guideline on Air Quality Models*[1]:

> "…the EPA has determined that advances in chemical transport modeling science indicate it is now reasonable to provide more specific, generally-applicable guidance that identifies particular models or analytical techniques that may be used under specific circumstances for assessing the impacts of an individual or single source on ozone and secondary $PM_{2.5}$. For assessing secondary pollutant impacts from single sources, the degree of complexity required to appropriately assess potential impacts varies depending on the nature of the source, its emissions, and the background environment. In order to provide the user community flexibility in estimating single-source secondary pollutant impacts that allows for different approaches to credibly address these different areas, the EPA proposed a two-tiered demonstration approach for addressing single-source impacts on ozone and secondary $PM_{2.5}$."

This recommended two-tiered demonstration approach was promulgated as part of the 2017 *Guideline* revisions.

This draft guidance provides an update to the previous *Guidance for PM2.5 Permit Modeling*[2] to reflect the 2017 revisions to the *Guideline* and incorporate appropriate sections for O_3. As experience is gained with these types of PSD compliance demonstrations, the EPA expects to update this and related guidance and provide further specificity on procedures for assessing the impacts of a single source on O_3 and secondary $PM_{2.5}$ concentrations.

REVIEW AND COMMENT

The EPA is requesting that comments on the draft guidance be provided by **Friday, March 27, 2020**. This allows at least 45 days for consideration, review, and comment on the material presented in the draft guidance. Comments should be electronically submitted to Mr. George Bridgers of the EPA's Air Quality Modeling Group at *bridgers.george@epa.gov*.

Following the close of the comment period, the EPA will take into consideration all the feedback and comments submitted and will further engage with the regulatory air quality modeling community at the 2020 Regional, State, and Local Modelers' Workshop currently scheduled for May 5-7, 2020, at the Minneapolis Central Library in Minneapolis, MN. This workshop will allow for an open dialogue on further clarifications, potential amendments, and considerations for additions to the final guidance documentation to be released later this year.

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[1] *Guideline on Air Quality Models*. 40 CFR part 51, Appendix W (82 FR 5182, Jan. 17, 2017). https://www3.epa.gov/ttn/scram/guidance/guide/appw_17.pdf. Also know as the "2017 *Guideline*."

[2] *Guidance for PM2.5 Modeling*. May 20, 2014. Publication No. EPA-454/B-14-001. Office of Air Quality Planning and Standards, Research Triangle Park, NC. https://www3.epa.gov/ttn/scram/guidance/guide/Guidance_for_PM25_Permit_Modeling.pdf.

The EPA will also conduct a webinar providing an overview of the *DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling* allowing for an open exchange on the guidance documentation on Thursday, March 12th at 3pm EDT. Additional information on how to connect to the webinar is posted on the EPA's SCRAM website, https://www.epa.gov/scram, under the Recent Additions section and will be shared with the regulatory air quality modeling community through typical email distributions.

For convenience, the draft guidance document is available electronically on the EPA's SCRAM website at:
https://www3.epa.gov/ttn/scram/guidance/guide/Draft_Guidance_for_O3_PM25_Permit_Modeling.pdf.

If there are any questions regarding the draft guidance, please contact George Bridgers of EPA's Air Quality Modeling Group at (919) 541-5563 or *bridgers.george@epa.gov*.

cc: Air Program Managers, EPA Regions 1 – 10
Peter Tsirigotis, OAQPS
Mike Koerber, OAQPS
Scott Mathias, OAQPS, AQPD
Raj Rao, OAQPS, AQPD
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Attachment

DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling

EPA-457/P-20-002
February 2020

DRAFT Guidance for Ozone and Fine Particulate Matter Permit Modeling

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

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TABLE OF CONTENTS

I. Introduction

The U.S. Environmental Protection Agency (EPA) is providing this "Guidance for Ozone and Fine Particulate Matter Permit Modeling" to fulfill a need for additional guidance on demonstrating compliance with the ozone (O_3) and fine particulate matter ($PM_{2.5}$) National Ambient Air Quality Standards (NAAQS) and the Prevention of Significant Deterioration (PSD) increments for $PM_{2.5}$. Because of the complex chemistry of secondary formation of O_3 and $PM_{2.5}$, the EPA's judgment in the past was that it was not technically sound to specify with "reasonable particularity" air quality models that must be used to assess the impacts of a single source on O_3 and secondary $PM_{2.5}$ concentrations. Instead, the EPA employed a case-by-case process for determining analytical techniques that should be used for these secondary pollutants. Under the former process, EPA recommended that the "[c]hoice of methods used to assess the impact of an individual source depends on the nature of the source and its emissions. Thus, model users should consult with the Regional Office to determine the most suitable approach on a case-by-case basis" (2005 *Guideline on Air Quality Models,* U.S. EPA, 2005; hereafter referred to as 2005 *Guideline*; sections 5.2.1.c and 5.2.2.1.c). As such, under the 2005 *Guideline*, the appropriate methods for assessing O_3 and secondary $PM_{2.5}$ impacts were determined as part of the normal consultation process with the appropriate permitting authority.

On January 4, 2012, the EPA granted a petition submitted on behalf of the Sierra Club on July 28, 2010 (U.S. EPA, 2012), which requested that the EPA initiate rulemaking regarding the establishment of air quality models for O_3 and $PM_{2.5}$ for use by all major sources applying for a PSD permit. In granting that petition, the EPA committed to engage in rulemaking to evaluate whether updates to the 2005 *Guideline* were warranted and, as appropriate, incorporate new analytical techniques or models for O_3 and secondarily formed $PM_{2.5}$. As discussed in the

preamble of the 2017 revisions to the EPA's *Guideline on Air Quality Models* (U.S. EPA, 2017a; hereafter referred to as 2017 *Guideline*), "the EPA has determined that advances in chemical transport modeling science indicate it is now reasonable to provide more specific, generally-applicable guidance that identifies particular models or analytical techniques that may be used under specific circumstances for assessing the impacts of an individual or single source on ozone and secondary $PM_{2.5}$. For assessing secondary pollutant impacts from single sources, the degree of complexity required to appropriately assess potential impacts varies depending on the nature of the source, its emissions, and the background environment. In order to provide the user community flexibility in estimating single-source secondary pollutant impacts that allows for different approaches to credibly address these different areas, the EPA proposed a two-tiered demonstration approach for addressing single-source impacts on ozone and secondary $PM_{2.5}$." This recommended two-tiered demonstration approach was promulgated as part of the 2017 *Guideline* revisions.

As presented in section 5.2 of the 2017 *Guideline*, the first tier involves use of technically credible relationships between precursor emissions and a source's impacts. Such information may be published in the peer-reviewed literature; developed from modeling that was previously conducted for an area by a source, a governmental agency, or some other entity that is deemed sufficient; or generated by a peer-reviewed reduced form model. To assist permitting authorities, the EPA released the "Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program" (U.S. EPA, 2019a; hereafter referred to as MERPs Guidance) that provides a framework to develop MERPs for consideration and use as a Tier 1 demonstration tool, as described in the preamble of the 2017 *Guideline*.

The second tier, also presented in section 5.2 of the 2017 *Guideline*, involves application of more sophisticated case-specific chemical transport models (CTMs), *e.g.*, photochemical grid models, to be determined in consultation with the EPA Regional Offices. The EPA provided guidance to permitting authorities on procedures for applying CTMs in the "Guidance on the Use of Models for Assessing the Impacts of Emissions from Single Sources on the Secondarily Formed Pollutants: Ozone and $PM_{2.5}$" (U.S. EPA, 2016a; hereafter Single-source Modeling Guidance). The Single-source Modeling Guidance is intended to inform that second tier approach by providing appropriate technical methods to assess O_3 and secondary $PM_{2.5}$ impacts associated with the precursor emissions from the new or modifying source. The appropriate tier for a given application should be selected in consultation with the appropriate permitting authority and be consistent with EPA guidance.

This guidance provides an update to the previous "Guidance for $PM_{2.5}$ Permit Modeling" (U.S. EPA, 2014a) to reflect the 2017 revisions to the *Guideline* and incorporate appropriate sections for O_3. As experience is gained with these types of PSD compliance demonstrations, the EPA expects to update this and related guidance and provide further specificity on procedures for assessing the impacts of a single source on O_3 and secondary $PM_{2.5}$ concentrations.

This guidance document is organized in three primary areas:

1. Guidance Overview – Section II provides a general overview of the steps that a permit applicant would take under the PSD program for demonstrating compliance with the O_3 NAAQS and/or the $PM_{2.5}$ NAAQS and PSD increments.
2. PSD Compliance Demonstrations for the O_3 and $PM_{2.5}$ NAAQS – Sections III and IV provide a detailed framework for conducting a source impact analysis and

a cumulative impact analysis, respectively, to appropriately address O_3 and $PM_{2.5}$ impacts from the proposed source[1] in determining whether it may cause or contribute to a NAAQS violation.

3. PSD Compliance Demonstrations for $PM_{2.5}$ Increments – Section V provides a detailed discussion of the assessment of primary and secondary $PM_{2.5}$ impacts of a new or modifying source with respect to the $PM_{2.5}$ increments.

This document recommends procedures for permit applicants and permitting authorities to follow to show that they have satisfied some of the criteria for obtaining or issuing a permit under applicable PSD regulations. This document is not a rule or regulation, and the guidance it contains may not apply to a particular situation based upon the individual facts and circumstances. This guidance does not change or substitute for any law, regulation, or any other legally binding requirement, may refer to regulatory provisions without repeating them in their entirety, and is not legally enforceable. The use of non-mandatory language such as "guidance," "recommend," "may," "should," and "can," is intended to describe EPA policies and recommendations. Mandatory terminology such as "must" and "required" are intended to describe requirements under the terms of the CAA and EPA regulations, but this document does not establish or alter any legally binding requirements in and of itself.

This guidance does not create any rights or obligations enforceable by any party or impose binding, enforceable requirements on any PSD permit applicant, PSD permitting authority, EPA, or any other person. Since each permitting action will be considered on a case-by-case basis, this document does not limit or restrict any particular justifiable approach that

[1] The term "proposed source" is used throughout this guidance document and should be taken to mean the "proposed source or modification" to which the compliance demonstration is being assessed.

permit applicants and permitting authorities may take to conduct the required compliance demonstrations. Each individual decision to issue a PSD permit must be supported by a record sufficient to demonstrate that the proposed construction and operation of a stationary source will not cause or contribute to a violation of the applicable NAAQS and PSD increments. While this document illustrates a particular approach that the EPA considers appropriate and acceptable as a general matter, permit applicants and permitting authorities should examine all relevant information regarding air quality in the area that may be affected by a proposed new or modified source and evaluate whether alternative or additional analysis may be necessary in a given case to demonstrate that the regulatory criteria for a PSD air quality analysis are satisfied. This document does not represent a conclusion or judgment by EPA that the technical approaches recommended in this document will be sufficient to make a successful compliance demonstration in every permit application or circumstance.

Permitting authorities retain the discretion to address particular issues discussed in this document in a different manner than the EPA recommends so long as the approach is adequately justified, supported by the permitting record and relevant technical literature, and consistent with the applicable requirements in the CAA and implementing regulations, including the terms of an approved State Implementation Plan (SIP). Furthermore, this guidance is not a final agency action and does not determine applicable legal requirements or the approvability of any particular permit application. To improve the quality of this guidance, the EPA is soliciting public comment and will consider the comments received.

The EPA Regional Offices may seek clarification from the EPA's Office of Air Quality Planning and Standards (OAQPS) on issues and areas of concern in a modeling protocol or PSD compliance demonstration. Through these interactions and subsequent resolutions of specific

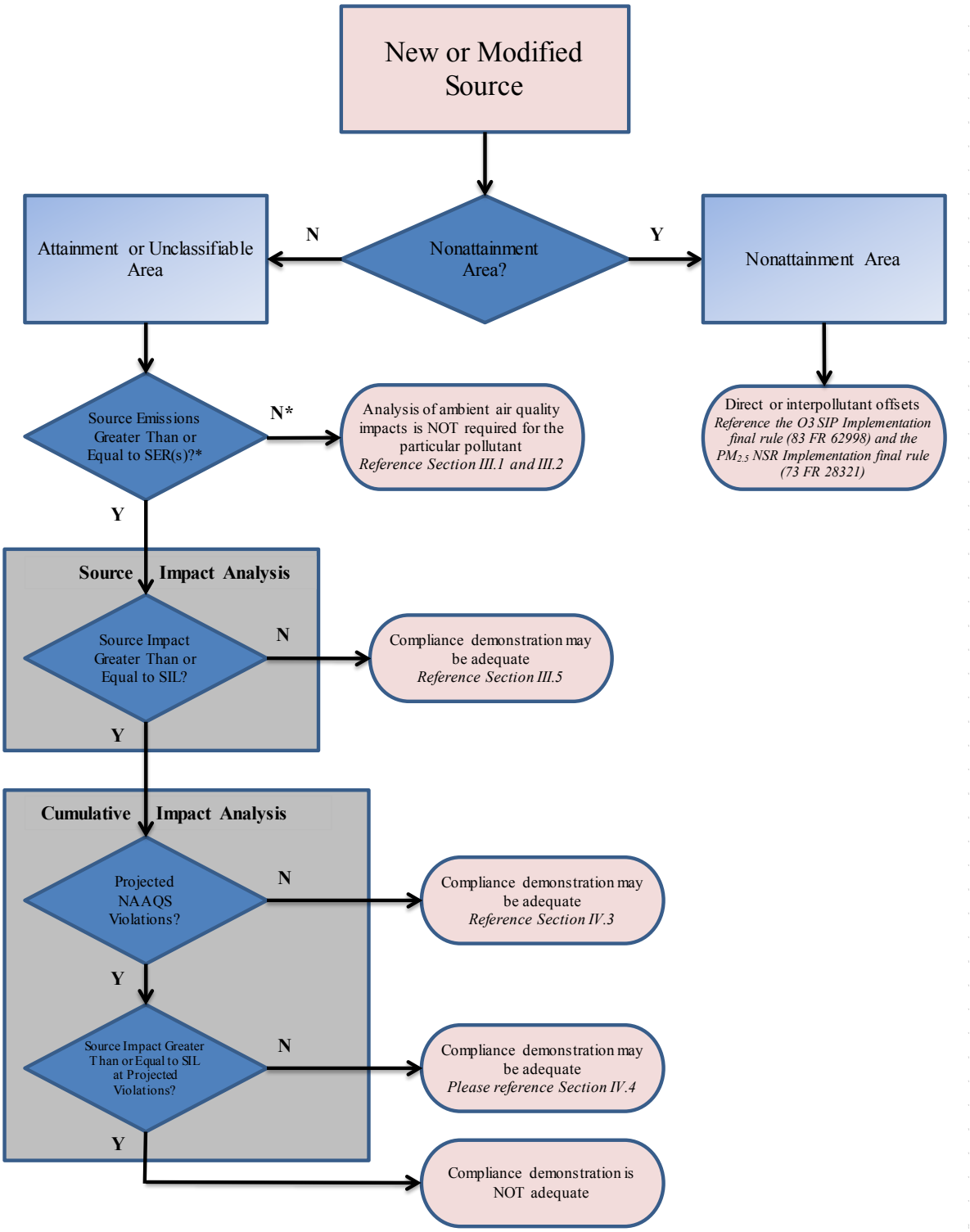
issues, clarifications of preferred modeling procedures can become additional EPA guidance. This can happen in several ways: 1) the preferred procedures are published as regulations or guidelines; 2) the preferred procedures are formally transmitted as guidance to the Air Division Directors in the EPA Regional Offices; 3) the preferred procedures are formally transmitted as guidance to the EPA Regional Office modeling contacts; or 4) the preferred procedures are relied upon in decisions by the EPA's Model Clearinghouse that establish national precedent that the approach is technically sound. The Model Clearinghouse is the EPA focal point for the review of the technical adequacy of pollutant modeling to satisfy regulatory criteria and other NAAQS compliance demonstration techniques. Model Clearinghouse memoranda involving interpretation of modeling guidance for specific applications, as well as other clarification memoranda addressing modeling more generally, are available at the Support Center for Regulatory Atmospheric Modeling (SCRAM) website at: https://www.epa.gov/scram/air-quality-model-clearinghouse.

II. Guidance Overview

This guidance is appropriate for proposed new or modifying sources locating or located in an area classified as attainment or unclassifiable for O_3 and/or $PM_{2.5}$. It is intended to provide recommendations on how to conduct compliance demonstrations for the O_3 NAAQS and the $PM_{2.5}$ NAAQS and PSD increments under the PSD program following the progressive steps shown in Figure II-1 (for O_3 and $PM_{2.5}$ NAAQS) and Figure II-2 (for $PM_{2.5}$ increments). Since each permitting action is considered on a case-by-case basis, this guidance does not limit or restrict any particular justifiable approach that permit applicants and permitting authorities may take to conduct the required compliance demonstrations. Prospective permit applicants should recognize the importance of the consultation process with the appropriate permitting authority. This process will help identify the most appropriate analytical techniques to be used for conducting a compliance demonstration for the O_3 NAAQS and the $PM_{2.5}$ NAAQS and PSD increments.

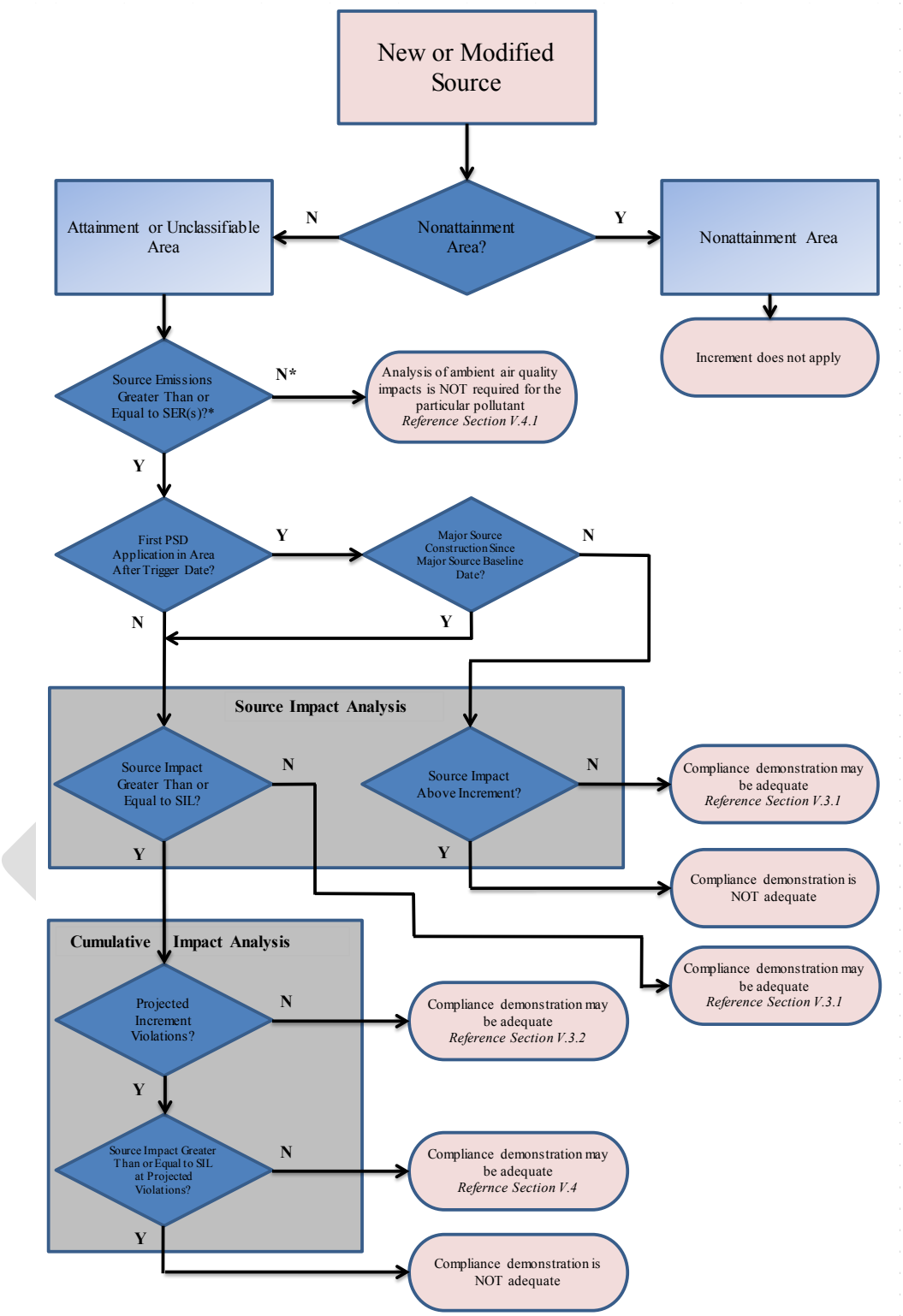
The EPA has historically supported the use of screening tools to help facilitate the implementation of the PSD program and streamline the permitting process in circumstances where proposed construction is projected to have an insignificant impact on air quality. These screening tools include significant emission rates (SERs) and significant impact levels (SILs). The use of these screening tools at each progressive step on the left side (attainment or unclassifiable areas) of Figure II-1 and Figure II-2 are described in more detail throughout Section II.

Figure II-1. Overview of O_3 and $PM_{2.5}$ NAAQS Compliance Demonstration for New or Modifying Sources under NSR/PSD Programs



* Any emissions rate or any net emissions increase associated with a major stationary source or major modification, which would construct within 10 kilometers of a Class I area, and have an impact on such area equal to or greater than 1 µg/m 3, (24-hour average) is considered significantand should proceed with an appropriate air quality assessment. *See* 40 CFR 52.21(b)(23)(iii).

Figure II-2. Overview of $PM_{2.5}$ PSD Increments Compliance Demonstration for New or Modifying Sources under NSR/PSD Programs



* Any emissions rate or any net emissions increase associated with a major stationary source or major modification, which would construct within 10 kilometers of a Class I area, and have an impact on such area equal to or greater than 1 µg/m 3, (24-hour average) is considered significantand should proceed with an appropriate air quality assessment. *See* 40 CFR 52.21(b)(23)(iii).

II.1 Significant Emissions Rates for O_3 and $PM_{2.5}$

O_3 and $PM_{2.5}$ are "regulated NSR pollutant[s]" as that term is defined in the PSD regulations.[2] Pursuant to that definition, ambient concentrations of O_3 are generally addressed through the regulation of its two precursors, nitrogen oxides (NO_X) and volatile organic compounds (VOC), while ambient concentrations of $PM_{2.5}$ are generally addressed through the regulation of direct $PM_{2.5}$ and its precursors NO_X and sulfur dioxide (SO_2).[3] "Significant," with respect to O_3 and $PM_{2.5}$, is defined in EPA regulations at 40 CFR 52.21(b)(23) in reference to a source's potential to emit (or in the case of a modification, the emissions increase[4] and net emissions increase) either direct emissions of the pollutant or emissions of a precursor pollutant. The regulations state that an increase in emissions of either O_3 precursor (NO_X or VOC) is significant if the increase of the particular precursor equals or exceeds 40 tons per year (tpy). For direct emissions of $PM_{2.5}$, the significance level is 10 tpy; for $PM_{2.5}$ precursor emissions, the significance level is 40 tpy for SO_2 and 40 tpy for NO_X.[5]

[2] 40 CFR 52.21(b)(50).

[3] See 73 FR at 28333. The EPA's PSD regulations do not presumptively require VOC to be treated as precursors to $PM_{2.5}$ in the PSD program. However, a state or the EPA may demonstrate that VOC emissions in a specific area are a significant contributor to that area's ambient $PM_{2.5}$ concentrations and, thus, should be treated as a regulated NSR pollutant subject to the PSD permitting requirements. 40 CFR 52.21(b)(50)(i)(*b*)(*4*).

[4] While section 52.21(b)(23) explicitly defines "significant" for purposes of a net emissions increase or potential to emit, section 52.21(b)(40) defines "significant emissions increase" by reference to the definition of "significant" found in paragraph (b)(23).

[5] A significance rate for VOC as a $PM_{2.5}$ precursor is not defined in the PSD regulations. However, the EPA's final rulemaking action promulgating regulations for implementing the PSD permitting requirements for $PM_{2.5}$ and its precursors indicated that any state required to regulate VOC emissions as a $PM_{2.5}$ precursor "would be required to adopt the 40-tpy significant emissions rate unless it demonstrates that a more stringent significant emissions rate (lower rate) is more appropriate." 73 FR at 28333.

II.2 PSD Pollutant Applicability for O_3 and $PM_{2.5}$

The EPA's PSD regulations apply specific permitting requirements (*e.g.*, Best Available Control Technology (BACT) and air quality analysis) to regulated New Source Review (NSR) pollutants that would be emitted in a significant amount by a proposed new or modified major stationary source.[6] For a new major stationary source, PSD permitting requirements apply to any regulated NSR pollutant for which the source would have the potential to emit a significant amount. For a modification at an existing major stationary source, PSD permitting requirements apply to any regulated NSR pollutant for which the modification would result in a significant emissions increase *and* a significant net emissions increase (*i.e.*, a "major modification") of that pollutant.

The provisions at 40 CFR 52.21(m)(1) and (k)(1) comprise the preconstruction air quality analysis requirements of the PSD program and apply to each regulated NSR pollutant that the source or modification would emit in a significant amount. Paragraph (m)(1) provides that any PSD permit application shall contain an analysis of ambient air quality for each such pollutant, and paragraph (k)(1) provides that the owner or operator "shall demonstrate that allowable emission increases from the proposed source or modification . . . would not cause or contribute to air pollution in violation of [any NAAQS or PSD increment]."[7] EPA interprets the term "allowable emission increases" as it is used in paragraph (k)(1) to mean those emission increases authorized by the PSD permit, so that, consistent with paragraph (m)(1), the requirement applies to regulated NSR pollutants that would be emitted in a significant amount.

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[6] See 40 CFR 52.21(a)(2) for applicability procedures for new or modified major stationary sources.

[7] In accordance with CAA § 165(e)(2), one purpose of the monitoring requirements contained in 40 CFR 52.21(m) is to provide information relevant to the determination of whether emissions from a proposed source or modification will exceed a NAAQS or PSD increment. Therefore, EPA reads paragraphs (m) and (k) of 40 CFR 52.21 together.

With respect to the unique nature of the criteria pollutants O_3 and $PM_{2.5}$ emissions of individual O_3 and $PM_{2.5}$ precursors (*i.e.*, NO_X, VOC, SO_2, and direct $PM_{2.5}$ are not summed when determining a significant emissions increase for either criteria pollutant.[8] Only precursors of O_3 or $PM_{2.5}$ that would by themselves be emitted by the source in a significant amount are included in the air quality analysis.

II.3 Significant Impact Levels for O_3 and $PM_{2.5}$

The EPA has issued guidance recommending that permitting authorities consider the use of appropriate pollutant-specific concentration levels known as "significant impact levels" (earlier referred to as SILs) as a compliance demonstration tool for O_3 and $PM_{2.5}$ air quality assessments on case-by-case basis in PSD permitting actions (U.S. EPA 2018a). The "SILs Guidance" identified recommended SIL values for the O_3 and $PM_{2.5}$ NAAQS and the $PM_{2.5}$ PSD increments and included a policy document, as well as supporting technical and legal analyses, that EPA and other permitting authorities may use in case-by-case PSD permitting actions. As explained in the guidance, if a permitting authority chooses to use a recommended SIL value to support a PSD permitting decision, it should justify the values and their use in the administrative record for the permitting action and may choose to adopt EPA's SILs Guidance, including the supporting technical and legal documents, in doing so.

The EPA's recommended SIL values from the SILs Guidance for the O_3 and $PM_{2.5}$ NAAQS are presented in Table II-1 and for the $PM_{2.5}$ PSD increments in Table II-2. It is important to note that the $PM_{2.5}$ NAAQS has two averaging periods: 24-hour and annual. There

[8] See 57 FR 55620, 55624 (Nov. 25, 1992); 80 FR 65292, 65441 (Oct. 26, 2015); see also 73 FR 28321, 28331 (May 16, 2008).

are no PSD increments established for O_3 and, thus, no O_3 increments SIL values. For a full discussion of the basis and purpose of the recommended O_3 and $PM_{2.5}$ SIL values, see the SILs Guidance and supporting documents (U.S. EPA 2018a).

Table II-1. EPA Recommended SIL Values for O_3 and $PM_{2.5}$ NAAQS

Criteria Pollutant (NAAQS Level)	NAAQS SIL Concentration
Ozone 8-hour (70 ppb)	1.0 ppb
$PM_{2.5}$ 24-hour (35 μg/m^3)	1.2 μg/m^3
$PM_{2.5}$ Annual (12 μg/m^3 or 15 μg/m^3)	0.2 μg/m^3

Table II-2. EPA Recommended SIL Values for $PM_{2.5}$ PSD Increments

Criteria Pollutant	PSD Increment SIL Concentration		
	Class I	Class II	Class III
$PM_{2.5}$ 24-hour	0.27 μg/m^3	1.2 μg/m^3	1.2 μg/m^3
$PM_{2.5}$ Annual	0.05 μg/m^3	0.2 μg/m^3	0.2 μg/m^3

As explained in the SILs Guidance, SILs are designed to have a role throughout the PSD air quality compliance demonstration. A permitting authority that chooses to use SILs would initially compare the modeled concentrations resulting from the proposed source's emissions increase to the appropriate SIL. This initial comparison is the "Source Impact Analysis." Where the proposed source's projected impacts on air quality concentrations are found at this first stage to be greater than or equal to the level of the applicable SIL, the analysis should then proceed to a second stage, which involves a cumulative assessment of the air quality in the affected area. The "Cumulative Impact Analysis" considers the combined impact of the proposed source or modification and other relevant sources in determining whether there would be a violation of any NAAQS or PSD increment in the affected area and, if so, whether the proposed source or modification would cause or contribute to such violation based on the applicable SIL.

II.4 Source Impact Analysis

As described in section 9.2.3 of the 2017 *Guideline*, the EPA's recommended procedure for conducting a PSD air quality assessment is a multi-stage approach. The first step is a source impact analysis that quantifies the air quality concentration increase expected to result from a new or modifying source's significant emissions increase as proposed in the PSD permit application.[9] The source impact analysis is used to assess the potential of a proposed new or modifying source to cause or contribute to a NAAQS or PSD increment violation.

In a source impact analysis, as illustrated in Figure II-1 and Figure II-2 and further explained in this guidance, a permitting authority compares the modeled concentrations resulting from the proposed source's emissions increase to an appropriate O_3 or $PM_{2.5}$ SIL. If the proposed source's maximum modeled impacts are found to be below the level of the O_3 or $PM_{2.5}$ SIL at every modeled receptor, the findings of the source impact analysis may be sufficient to demonstrate that the source will not cause or contribute to a violation of the O_3 NAAQS, $PM_{2.5}$ NAAQS, or the $PM_{2.5}$ PSD increment, as necessary to receive a PSD permit. On the other hand, where the proposed source's projected impacts on air quality concentrations are estimated to be greater than or equal to the level of an appropriate O_3 or $PM_{2.5}$ SIL at any modeled receptor, the demonstration should proceed to the next step of conducting a cumulative impact analysis.

[9] This is consistent with EPA's overall approach for the use of screening techniques in air quality modeling. See 40 CFR part 51, Appendix W, sections 2.2 ("Levels of Sophistication of Air Quality Analyses and Models") and 4.2.1 ("Screening Models and Techniques"). In section 2.2.a, the *Guideline* observes that "[it] is desirable to begin an air quality analysis by using simplified and conservative methods followed, as appropriate, by more complex and refined methods. The purpose of this approach is to streamline the process and sufficiently address regulatory requirements by eliminating the need of more detailed modeling when it is not necessary in a specific regulatory application. For example, in the context of a PSD permit application, a simplified and conservative analysis may be sufficient where it shows the proposed construction clearly will not cause or contribute to ambient concentrations in excess of either the NAAQS or the PSD increments."

II.5 Cumulative Impact Analysis

This section provides an overview of cumulative impact analyses for O_3 and $PM_{2.5}$ NAAQS, as well as, PSD increments compliance. The cumulative impact analysis is illustrated in Figure II-1 and Figure II-2 and further explained in this guidance.

II.5.1 O_3 and $PM_{2.5}$ NAAQS Compliance

For either O_3 or $PM_{2.5}$, where the source impact analysis described in Section II.4 is insufficient to show that a proposed PSD source will not cause or contribute to a violation of the respective NAAQS, a cumulative impact analysis is then necessary to make the required NAAQS demonstration, as described in section 9.2.3 of the 2017 *Guideline*. A cumulative impact analysis should account for the combined impacts of the following:

1. Direct and/or precursor emissions that the new or modifying source would emit in significant amounts;[10]
2. Direct emissions from nearby sources (for primary $PM_{2.5}$ only), as appropriate; and
3. Monitored background levels that account for secondary impacts from regional background sources, secondary impacts from precursor emissions from nearby sources, and, in the case of primary $PM_{2.5}$, $PM_{2.5}$ impacts from direct emissions from background sources, nearby sources not explicitly modeled.[11]

[10] For a new major stationary source, this includes any direct/precursor pollutant with the potential to emit greater than or equal to the SER and for a modification to an existing major stationary source any direct/precursor pollutant for which the modification results in a significant emissions increase and a significant net emissions increase.

[11] The emissions impact of any nearby source that has received a permit but is not yet operational should be included in the air quality assessment. In such cases, consultation with the appropriate permitting authority on the appropriate assessment approach is recommended.

Once all of these appropriate direct and/or precursor emissions impacts are taken into account, the estimated cumulative impact is then compared to the NAAQS to determine if there is a modeled violation. If not, then the NAAQS compliance demonstration is sufficient. If there are projected NAAQS violations, then the impacts of the emissions increase from the new or modifying source at those locations are compared to the appropriate SIL to determine whether that increase will cause or contribute to a violation of the NAAQS. Several aspects of the cumulative impact analysis for O_3 and $PM_{2.5}$ will be comparable to analyses conducted for other criteria pollutants, while other aspects will differ due to the issues identified earlier.

II.5.2 $PM_{2.5}$ PSD Increments Compliance

For $PM_{2.5}$, where the source impact analysis described in Section II.4 is insufficient to show that a source will not cause or contribute to a violation of any $PM_{2.5}$ PSD increment, a cumulative impact analysis is necessary to make the PSD increment demonstration, as described in section 9.2.3 of the 2017 *Guideline*. A cumulative impact analysis for an increment differs from the NAAQS cumulative impact analysis in that the increment assessment only accounts for the combined impact of the new or modifying source's emissions increase and certain previous emissions changes from sources (including the modifying source) that affect the PSD increment under the EPA's PSD regulations. A more complete description of the types of emissions that affect increment consumption and other aspects of the PSD increment system is contained in Section V.1 of this guidance document. The cumulative impacts are then compared to the appropriate $PM_{2.5}$ PSD increments to determine whether the new or modifying source emissions will cause or contribute to a violation of any $PM_{2.5}$ PSD increment.

For $PM_{2.5}$ PSD increments, since the requirement for calculating the amount of increment consumed was established relatively recently in comparison to the increments for other pollutants, a new or modified source being evaluated for $PM_{2.5}$ PSD increments compliance may still find that it is the first source, or one of only a few sources, with increment-consuming emissions in a particular attainment or unclassifiable area. As shown in Figure II-2, for such situations, a permitting authority may have sufficient reason (based on the approach for conducting source impact analysis described below) to conclude that the impacts of the new or modified source may be compared directly to the allowable increments, without the need for a cumulative modeling analysis. This would be the case where it can be shown that any other increment-consuming sources in the same baseline area, if any, do not have much or any overlapping impact with the proposed new or modified source.[12]

Another important consideration for $PM_{2.5}$ PSD increments is the differences in the EPA recommended SIL values for Class I and Class II / III areas, as presented in Table II-2. Given substantially smaller recommended SIL values for Class I areas, there is a greater likelihood that a proposed new or modifying source would cause or contribute to a PSD increment violation in a Class I area, even at distances beyond the nominal 50 km near-field application distance. Section 4.2 of the 2017 *Guideline* provides screening and compliance assessment approaches for near-field (50 km or less) and long-range transport (beyond 50 km) situations. The MERPs Guidance (*i.e.*, Tier 1 Assessment Approach) and the Single-source Modeling Guidance (*i.e.*, Tier 2 Assessment Approach) should be referenced for assessing secondary $PM_{2.5}$ impacts. There is also distance-weighted empirical relationship information (*i.e.*, precursor contributions to

[12] The term "increment-consuming source," as used in this guidance, is intended to refer to any type of source whose emissions changes (increases or decreases) affects the amount of increment consumed or expanded.

secondary impacts by distance from source) provided within the MERPs Guidance that may be particularly useful for assessing secondary $PM_{2.5}$ impacts in long-range transport situations. Consultation with the appropriate permitting authority and the appropriate EPA Regional Office is highly recommended for any permit applicants demonstrating long-range Class I area increment compliance per the requirements of section 4.2.c.ii of the 2017 *Guideline*.

III. PSD Compliance Demonstrations for the O_3 and $PM_{2.5}$ NAAQS: Source Impact Analysis

This section provides details regarding the EPA's recommended approaches for conducting the source impact analysis as part of a PSD compliance demonstration for the O_3 and/or $PM_{2.5}$ NAAQS.

III.1 O_3 NAAQS

This section provides details regarding the EPA's recommended approaches for conducting the source impact analysis for the O_3 NAAQS associated with each of the two assessment cases presented in Table III-1. In each of the assessment cases, the analysis should begin by evaluating the impacts of each O_3 precursor (VOC and/or NO_X) that would be emitted in a significant amount, *i.e.*, equal to or greater than the respective SER (40 tpy).

Table III-1. EPA Recommended Approaches for Assessing O_3 Impacts by Assessment Case

Assessment Case	Description of Assessment Case		Secondary Impacts Approach*
Case 1: No Air Quality Analysis	NO_X emissions and VOC emissions < 40 tpy SER		N/A
Case 2*: Secondary Air Quality Impacts	NO_X emissions and/or VOC emissions ≥ 40 tpy SER		Include each precursor of O_3 emitted in a significant amount, see Section II.2. • **Tier 1 Approach** (*e.g.*, MERPs) • **Tier 2 Approach** (*e.g.*, Chemical Transport Modeling)
* In unique situations (*e.g.*, in parts of Alaska where photochemistry is not possible for portions of the year), it may be acceptable for the applicant to rely upon a qualitative approach to assess the secondary impacts. Any qualitative assessments should be justified on a case-by-case basis in consultation with the appropriate permitting authority and the appropriate EPA Regional Office.			

For Case 1, a modeled O_3 NAAQS compliance demonstration is not required since neither O_3 precursor (NO_X or VOC) is proposed to be emitted in an amount equal to or greater than the applicable SER. For Case 2, where NO_X and/or VOC precursor emissions are greater than the applicable SER, the permit applicant would need to conduct a compliance demonstration for secondary O_3 impacts for the precursor(s) with emissions equal to or greater than the SER based on the two-tiered demonstration approach in EPA's 2017 *Guideline*.

III.2 $PM_{2.5}$ NAAQS

This section provides details regarding the EPA's recommended approaches for conducting the source impact analysis for the $PM_{2.5}$ NAAQS associated with each of the four assessment cases presented in Table III-2. In each of the assessment cases, the analysis should begin by evaluating the primary $PM_{2.5}$ impacts of direct emissions that would be emitted in a significant amount, *i.e.*, equal to or greater than the SER (10 tpy), and each precursor NO_X and/or SO_2 that would be emitted in a significant amount, *i.e.*, equal to or greater than the respective SER (40 tpy).

Table III-2. EPA Recommended Approaches for Assessing Primary and Secondary $PM_{2.5}$ Impacts by Assessment Case

Assessment Case	Description of Assessment Case		Primary Impacts Approach	Secondary Impacts Approach*
Case 1: No Air Quality Analysis	Direct $PM_{2.5}$ emissions < 10 tpy SER NO_X emissions and SO_2 emissions < 40 tpy SER		N/A	N/A
Case 2: Primary Air Quality Impacts Only	Direct $PM_{2.5}$ emissions ≥ 10 tpy SER NO_X emissions and SO_2 emissions < 40 tpy SER		**Appendix W preferred or approved alternative dispersion model**	N/A
Case 3*: Primary and Secondary Air Quality Impacts	Direct $PM_{2.5}$ emissions ≥ 10 tpy SER NO_X emissions and/or SO_2 emissions ≥ 40 tpy SER		**Appendix W preferred or approved alternative dispersion model**	Include each precursor of $PM_{2.5}$ emitted in a significant amount, see Section II.2. • **Tier 1 Approach** (*e.g.*, MERPs) • **Tier 2 Approach** (*e.g.*, Chemical Transport Modeling)
Case 4*: Secondary Air Quality Impacts Only	Direct $PM_{2.5}$ emissions < 10 tpy SER NO_X emissions and/or SO_2 emissions ≥ 40 tpy SER		N/A	Include each precursor of $PM_{2.5}$ emitted in a significant amount, see Section II.2. • **Tier 1 Approach** (*e.g.*, MERPs) • **Tier 2 Approach** (*e.g.*, Chemical Transport Modeling)

* In unique situations (*e.g.*, in parts of Alaska where photochemistry is not possible for portions of the year), it may be acceptable for the applicant to rely upon a qualitative approach to assess the secondary impacts. Any qualitative assessments should be justified on a case-by-case basis in consultation with the appropriate EPA Regional Office or other applicable permitting authority.

A $PM_{2.5}$ NAAQS compliance demonstration is not required for Case 1 since neither direct $PM_{2.5}$ emissions nor any $PM_{2.5}$ precursor (NO_X or SO_2) emissions is proposed to be emitted in a significant amount. Case 1 is the only assessment case that does not require a NAAQS compliance demonstration. Each of the remaining three assessment cases would include

conducting a source impact analysis.

Case 2, where only direct $PM_{2.5}$ emissions are greater than or equal to the applicable SER: In this case, the permit applicant may be able to demonstrate that primary $PM_{2.5}$ impacts from the proposed increase in direct $PM_{2.5}$ emissions are below an appropriate SIL based on dispersion modeling using AERMOD or another appropriate preferred model listed in Appendix A of the 2017 *Guideline*, or an alternative model subject to the provisions of section 3.2 of the 2017 *Guideline*.

Case 3, where direct $PM_{2.5}$ emissions and NO_X and/or SO_2 precursor emissions are greater than or equal to the applicable SER: In this case, consistent with Case 2, the primary $PM_{2.5}$ impacts from direct $PM_{2.5}$ emissions can be estimated based on application of AERMOD or an approved alternative model. However, AERMOD does not account for secondary formation of $PM_{2.5}$ associated with the source's precursor emissions. Since the source also proposes to emit quantities of one or both $PM_{2.5}$ precursors in significant amounts, an assessment of their potential impact on secondary $PM_{2.5}$ is necessary. The assessment of NO_X and/or SO_2 precursor emission impacts on secondary $PM_{2.5}$ formation should be conducted based on the two-tiered demonstration approach in EPA's 2017 *Guideline*.

Case 4, where only NO_X and/or SO_2 precursor emissions are greater than or equal to the applicable SER: In this case, since direct $PM_{2.5}$ emissions are insignificant, *i.e.*, below the applicable SER, the analysis would only address the secondary $PM_{2.5}$ impacts from NO_X and/or SO_2 precursor emissions. Similar to Case 3, the assessment of the precursor emission impacts on secondary $PM_{2.5}$ formation for Case 4 would be conducted based on the two-tiered demonstration approach in EPA's 2017 *Guideline*.

III.3 Assessing Primary $PM_{2.5}$ Impacts

The assessment of primary $PM_{2.5}$ impacts from the proposed new or modifying source is generally the same for the $PM_{2.5}$ NAAQS and PSD increments. Section 4.2.3.5 of the 2017 *Guideline* identifies the AERMOD modeling system as the preferred model for addressing direct $PM_{2.5}$ emissions unless another preferred model listed in the *Guideline* is more appropriate, such as the Offshore and Coastal Dispersion Model (OCD), or the use of an alternative model is justified consistent with section 3.2 of the 2017 *Guideline*.

The AERMOD modeling system includes the following regulatory components:

- AERMOD: the dispersion model (U.S. EPA, 2019b);
- AERMAP: the terrain processor for AERMOD (U.S. EPA, 2018b); and
- AERMET: the meteorological data processor for AERMOD (U.S. EPA, 2019c).

Other components that may be used, depending on the application, are:

- BPIPPRIME: the building input processor (U.S. EPA, 2004);
- AERSURFACE: the surface characteristics processor for AERMET (U.S. EPA, 2008);
- AERSCREEN: a screening version of AERMOD (U.S. EPA, 2016b; U.S. EPA, 2011a); and
- AERMINUTE: a pre-processor to calculate hourly average winds from ASOS 2-minute observations (U.S. EPA, 2015).

Before applying AERMOD, the applicant should become familiar with the user's guides associated with the modeling components listed above and the most recent version of the AERMOD Implementation Guide (U.S. EPA, 2019d). In addition to these documents, detailed guidance on the use of the AERMOD modeling system for estimating primary $PM_{2.5}$ impacts is

provided in Appendix B. Because AERMOD is limited to modeling direct $PM_{2.5}$ emissions, additional or alternative approaches are used to provide an assessment of secondary $PM_{2.5}$ impacts from the proposed new or modifying source, as discussed in more detail in the following sections.

III.4 Assessing O_3 and Secondary $PM_{2.5}$ Impacts

This section provides more detail on the EPA's recommended approaches for assessing the impacts of precursor emissions on O_3 and/or secondary $PM_{2.5}$ formation.

III.4.1 Conceptual Model

Each NAAQS compliance demonstration is unique and may require multiple factors to be considered and assumptions to be thoroughly justified as a part of the technical assessment. A well-developed modeling protocol that includes a detailed conceptual description of the current air pollutant concentrations in the area (see Appendix A for examples of elements of a conceptual description) and of the nature of the emissions sources within proximity of the new or modifying emissions source is essential for determining the necessary components of an acceptable assessment of the impact from O_3 and/or secondary $PM_{2.5}$ formation.[13] With timely

[13] For more detailed information on the development of such conceptual descriptions for an area, please refer to the following:

Chapter 10 of "Particulate Matter Assessment for Policy Makers: A NARSTO Assessment." P. McMurry, M. Shepherd, and J. Vickery, eds. Cambridge University Press, Cambridge, England (NARSTO, 2004).

Section 11, "How Do I Get Started? 'A Conceptual Description'" of "Guidance on the Use of Models and Other Analyses for Demonstrating Attainment of Air Quality Goals for Ozone, $PM_{2.5}$, and Regional Haze." U.S. Environmental Protection Agency, Research Triangle Park, North Carolina (U.S. EPA, 2007a).

In addition, relevant regional examples include: "Conceptual Model of $PM_{2.5}$ Episodes in the Midwest," January 2009, Lake Michigan Air Directors Consortium; and "Conceptual Model of Particulate Matter Pollution in the California San Joaquin Valley," Document Number CP045-1-98, September 8, 1998.

and appropriate consultation between the applicant and the appropriate permitting authority, along with the submittal and subsequent approval, if required, of the modeling protocol by the appropriate permitting authority, many potential problems and unintended oversights in the technical assessment can be resolved early in the process or avoided all together.

In the development of an appropriate conceptual description to support an assessment, it is important to fully characterize the current O_3 and/or $PM_{2.5}$ concentrations in the region where the new or modifying source is to be located and not just the most current design values, which historically has been used as used as background concentrations in a cumulative modeling demonstration. For O_3, this characterization should take into consideration episodic high O_3 concentrations and any trends in the area. For $PM_{2.5}$, this characterization should take into consideration the seasonality and speciated composition of the current $PM_{2.5}$ concentrations and any long-term trends that may be occurring. It may also be important to describe the typical background concentrations of certain chemical species that participate in the photochemical reactions that form O_3 and secondary $PM_{2.5}$. It is possible that there are mitigating factors for secondary $PM_{2.5}$ formation given limitations of other chemical species important in the photochemical reactions, *e.g.*, minimal NH_3 in the ambient environment that could limit any precursor pollutant from readily reacting to form secondary $PM_{2.5}$. This understanding of the atmospheric environment will provide important insights on the potential for secondary formation and highlight aspects that will need to be accounted for in the source impact and/or cumulative impact assessment.

A good conceptual description will also characterize the meteorological conditions that are representative of the region and are associated with periods and/or seasons of higher and lower ambient O_3 and/or 24-hour $PM_{2.5}$ concentrations. For example, identification of

meteorological phenomena that typically occur during periods of high daily 8-hour O_3 or 24-hour $PM_{2.5}$ concentrations, such as low-level temperature inversions, stagnant high pressure systems, low-level jets, etc., can be extremely important in understanding the importance, or lack thereof, of photochemistry and secondary $PM_{2.5}$ formation for the higher ambient O_3 and $PM_{2.5}$ concentrations. The analysis and understanding of meteorological conditions will also inform the assessment of high O_3 episodes and seasonal 24-hour $PM_{2.5}$ concentrations in the region.

III.4.2 Tier 1 Assessment Approach

As discussed in the section 5.2 of the 2017 *Guideline*, the EPA has determined that advances in chemical transport modeling science make it reasonable to provide more specific, generally-applicable guidance that identifies particular models or analytical techniques that may be appropriate for use under specific circumstances for assessing the impacts of an individual proposed source on O_3 and secondary $PM_{2.5}$ concentrations. There is not a preferred model or technique for estimating O_3 or secondary $PM_{2.5}$ for specific source impacts. Instead, for assessing secondary pollutant impacts from individual proposed sources, the degree of complexity required to appropriately assess potential single-source impacts varies depending on the nature of the source, its proposed emissions, and the background environment. In order to provide the user community flexibility in estimating single-source secondary pollutant impacts, which allows for different approaches to credibly address these different areas, the 2017 *Guideline* recommends a two-tiered demonstration approach for addressing single-source impacts on ambient concentrations of O_3 and secondary $PM_{2.5}$.

To inform a Tier 1 assessment,[14] the existing air quality model-based information that is used should be appropriate in terms of representing the type of source, its precursor emissions, and its geographic location, in addition to those elements of the conceptual description discussed above. The air quality modeling information may be available from past or current SIP attainment demonstration modeling, published modeling studies, or peer-reviewed literature with estimates of model responsiveness to precursor emissions in contexts that are relevant to the new or modifying source. The estimates of model responsiveness, such as impact on O_3 concentrations per ton of NO_X or impact on $PM_{2.5}$ concentrations per ton of SO_2 emissions, could then be used in conjunction with the precursor emissions estimates for the proposed new or modifying source to provide a quantitative estimate of the impact of such precursor emissions on the formation of O_3 and/or secondary $PM_{2.5}$ concentrations. The estimates of responsiveness should be technically credible in representing such impacts and it may be advisable for the estimate to reflect an upper bound of potential impacts.

To assist in the development of appropriate Tier 1 demonstration tools, the EPA developed the MERPs Guidance to provide a framework for permitting authorities to develop area-specific MERPs. The MERPs Guidance illustrates how permitting authorities may appropriately develop MERPs for specific areas and use them as a Tier 1 compliance demonstration tool for O_3 and secondary $PM_{2.5}$ under the PSD permitting program. The MERPs guidance also addresses the appropriate use of MERPs to reflect the combined ambient impacts

[14] A Tier 1 assessment involves the use of technically credible relationships between precursor emissions and a source's secondary impacts, *e.g.*, as demonstrated in modeling for a source impact analysis, that may be published in the peer-reviewed literature, developed from modeling that was previously conducted for an area by a source, a governmental agency, or some other entity and that is deemed sufficient for evaluating a proposed source's impacts, or generated by a peer-reviewed reduced form model. In such cases, the EPA expects that existing air quality model-based information regarding the potential for NO_X and VOC precursor emissions to form O_3 and for SO_2 and NO_X precursor emissions to form secondary $PM_{2.5}$ concentrations may be used to establish an appropriate estimate of O_3 and/or secondary $PM_{2.5}$ impacts from the proposed new or modifying source.

across O_3 or $PM_{2.5}$ precursors and, in the case of $PM_{2.5}$, the combined primary and secondary ambient impacts. Such an approach includes flexibility with respect to the use of Tier 1 demonstration tools to generate information relevant for specific regions or areas and representative of secondary formation in a particular region or area.

Specifically, the MERPs Guidance provides information about how to use CTMs to estimate single-source impacts on O_3 and secondary $PM_{2.5}$ and how such model simulation results for specific areas can be used to develop empirical relationships between a source's O_3 and $PM_{2.5}$ precursor emissions and its secondary impacts that may be appropriate for use as a Tier 1 demonstration tool. It also provides results from EPA photochemical modeling of a set of more than 100 hypothetical sources across geographic areas and source types that may be used in developing MERPs as discussed in the guidance. This flexible and scientifically credible approach allows for the development of area-specific Tier 1 demonstration tools that better represent the chemical and physical characteristics and secondary pollutant formation within that region or area.

As discussed in the MERPs Guidance, the EPA's Single-source Modeling Guidance provides information to stakeholders about how to appropriately address the variety of chemical and physical characteristics regarding a project scenario and key receptor areas in conducting photochemical modeling to inform development of MERPs. The development of MERPs for O_3 and secondary $PM_{2.5}$ precursors is just one example of a suitable Tier 1 demonstration tool. The EPA will continue to engage with the modeling community to identify credible alternative approaches for estimating single-source secondary pollutant impacts, which provide flexibility and are less resource intensive for PSD permit demonstrations.

As an example, a Tier 1 assessment of secondary O_3 and $PM_{2.5}$ impacts was developed by

a permit applicant, the Tennessee Valley Authority (TVA), for a major modification at their Gleason facility in Tennessee in 2018. The TVA and the Tennessee Department of Environment and Conservation (TDEC) worked closely with EPA Region 4 to ensure that the ambient impacts analysis was technically sound and consistent with applicable PSD regulations and EPA guidance. The PSD air quality modeling analysis was submitted to TDEC in late 2018 using an approach that was consistent with the EPA's MERPs Guidance to relate facility emissions to potential downwind impacts of secondary O_3 and $PM_{2.5}$. A more detailed discussion of the TVA's technical assessment is provided in Appendix C.

The National Association of Clean Air Agencies (NACAA) Workgroup final report (NACAA, 2011) provides details on potential approaches to quantify the secondary $PM_{2.5}$ impacts from a proposed new or modifying source that may be appropriate to inform a Tier 1 assessment of $PM_{2.5}$ impacts (see Appendix C and D of NACAA, 2011). One suggested method in the final report is to convert emissions of precursors into equivalent amounts of direct $PM_{2.5}$ emissions using "pollutant offset ratios" and then use a dispersion model to assess the impacts of the combination of direct $PM_{2.5}$ emissions and the equivalent direct $PM_{2.5}$ emissions. The "pollutant offset ratios" referenced in that final report were those put forth by the EPA in the 2008 "Implementation of the New Source Review (NSR) Program for Particulate Matter Less Than 2.5 Micrometers ($PM_{2.5}$)" final rule (73 Fed. Reg. 28321) concerning the development and adoption of interpollutant trading (offset) provisions for $PM_{2.5}$ under state nonattainment area NSR programs for $PM_{2.5}$.[15] The EPA's July 23, 2007, technical analysis titled "Details on

[15] In the preamble to the 2008 final rule (73 FR 28321), the EPA included preferred or presumptive offset ratios, applicable to specific $PM_{2.5}$ precursors that state/local air agencies may adopt in conjunction with the new interpollutant offset provisions for $PM_{2.5}$, and for which the state could rely on the EPA's technical work to demonstrate the adequacy of the ratios for use in any $PM_{2.5}$ nonattainment area. In a July 21, 2011 memorandum, EPA changed its policy and stated that it no longer supported the ratios provided in the preamble to the 2008 final

Technical Assessment to Develop Interpollutant Trading Ratios for $PM_{2.5}$ Offsets," describes the method used to establish the original "preferred" precursor offset ratios (U.S. EPA, 2007b).

We do not support using the specific results from the EPA's 2007 technical assessment in this context without additional technical demonstration specific to the source(s) and area(s) for which the ratios would be applied. As described in the EPA's July 21, 2011 memorandum addressing reconsideration of the "preferred" interpollutant offset trading ratios included in the preamble to the 2008 final rule, the EPA acknowledged that existing models and techniques are adequate to "conduct local demonstrations leading to the development of area-specific ratios for $PM_{2.5}$ nonattainment areas" and provided a general framework for efforts that may be relevant in developing appropriate "pollutant offset ratios" for use in hybrid qualitative/quantitative assessment of secondary $PM_{2.5}$ impacts (U.S. EPA, 2011b). In the context of PSD compliance demonstrations, a similar general framework is embodied in the MERPs Guidance in which the EPA addresses how to conduct modeling to inform the development of a MERP for a particular area.

The EPA also notes that the NACAA Workgroup "considered, but rejected, other methods for assessing secondary $PM_{2.5}$ impacts, including use of a simple emissions divided by distance (Q/D) metric and use of AERMOD with 100 percent conversion of SO_2 and NO_X concentrations to $(NH_4)_2SO_4$ and $(NH_4)NO_3$." The EPA has reviewed the detailed discussion provided in Appendix E of the NACAA Workgroup final report and agrees with these conclusions.

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rule as presumptively approvable ratios for adoption in SIPs containing nonattainment NSR programs for $PM_{2.5}$. Memorandum from Gina McCarthy, Assistant Administrator, to Regional Air Division Directors, "Revised Policy to Address Reconsideration of Interpollutant Trading Provisions for Fine Particles ($PM_{2.5}$)" (U.S. EPA, 2011b).

III.4.3 Tier 2 Assessment Approach

As discussed in the 2017 *Guideline*, a Tier 2 assessment involves application of more sophisticated, case-specific CTMs in consultation with the appropriate permitting authority and conducted consistent with the recommendations in the most current version of the Single-source Modeling Guidance. Where it is necessary to estimate O_3 and/or secondary $PM_{2.5}$ impacts with case-specific air quality modeling, a candidate model should be selected for estimating single-source impacts on O_3 and/or secondarily formed $PM_{2.5}$ that meets the general criteria for an "alternative model" where there is no preferred model as outlined in section 3.2.2.e of the 2017 *Guideline*. The general criteria include:

i. The model has received a scientific peer review;

ii. The model can be demonstrated to be applicable to the problem on a theoretical basis;

iii. The databases that are necessary to perform the analysis are available and adequate;

iv. Appropriate performance evaluations of the model have shown that the model is not biased toward underestimates; and

iv. A protocol on methods and procedures to be followed has been established.

Section 3.2.2 further provides that the appropriate EPA Regional Office, in consultation with the EPA Model Clearinghouse, is authorized to approve a particular model and approach as an alternative model application.

Both Lagrangian puff models and photochemical grid models may be appropriate for this purpose where those models satisfy alternative model criteria in section 3.2.2 of the 2017 *Guideline*. That said, the EPA believes photochemical grid models are generally most

appropriate for addressing O_3 and secondary $PM_{2.5}$ impacts because they provide a spatially and temporally dynamic realistic chemical and physical environment for plume growth and chemical transformation. Publicly available and documented Eulerian photochemical grid models such as the Comprehensive Air Quality Model with Extensions (CAMx) (Ramboll Environ, 2018) and the Community Multiscale Air Quality (CMAQ) (Byun and Schere, 2006) model 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 O_3 and $PM_{2.5}$ (Chen et al., 2014; Civerolo et al., 2010; Russell, 2008; Tesche et al., 2006). In addition, these models have been used extensively to support O_3 and $PM_{2.5}$ SIPs and to explore relationships between inputs and air quality impacts in the United States and elsewhere (Cai et al., 2011; Civerolo et al., 2010; Hogrefe et al., 2011).

On August 4, 2017, the EPA released a memorandum (U.S. EPA, 2017b) providing information specific to how the CAMx and the CMAQ model systems were relevant for each of these elements. This memorandum provides an alternative model demonstration for the CAMx and CMAQ photochemical transports models establishing their fit for purpose in PSD compliance demonstrations for O_3 and $PM_{2.5}$ and in NAAQS attainment demonstrations for O_3, $PM_{2.5}$ and Regional Haze. The memorandum also provides for their general applicability for use in PSD compliance demonstrations; however, it does not replace the need for such demonstrations to provide model protocols describing model application choices or the evaluation of model inputs and baseline predictions against measurements relevant for their specific use by permit applicants and state, local, and tribal air agencies.

For those situations where a refined Tier 2 demonstration is necessary, the EPA has also provided the Single-source Modeling Guidance that provides recommended, credible procedures

to estimate single-source secondary impacts from sources for permit related assessments. Extensive peer-reviewed literature demonstrates/documents that photochemical grid models have been applied for single-source impacts and that the models adequately represent secondary pollutant impacts from a specific facility, in comparison to near-source downwind in-plume measurements. The literature shows that these models can clearly differentiate impacts of a specific facility from those of other sources (Baker and Kelly, 2014; Zhou et al., 2012). Other peer-reviewed research has clearly shown that photochemical grid models are able to simulate impacts from single sources on secondarily-formed pollutants (Baker et al., 2015; Bergin et al., 2008; Kelly et al., 2015). Further, single-source secondary impacts have been provided in technical reports that further support the utility of these tools for single-source scientific and regulatory assessments (ENVIRON 2012a; ENVIRON 2012b; Yarwood et al., 2011). The EPA firmly believes that the peer-reviewed science clearly demonstrates that photochemical grid models can adequately assess single-source impacts. The EPA recognizes that ongoing evaluations in this area will lead to continual improvements in science and associated predictive capabilities of these models.

For the purposes of conducting a Tier 2 assessment, the application of a CTM will involve case-specific factors that should be part of the consultation process with the appropriate permitting authority and reflected in the agreed-upon modeling protocol. Consistent with the Single-source Modeling Guidance and section 9.2.1 of the 2017 *Guideline*, EPA recommends that the modeling protocols for this purpose should include the following elements:

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 appropriate permitting authority

2. Model and Modeling Inputs

- Rationale for the selection of air quality, meteorological, and emissions models
- Modeling domain
- Horizontal and vertical resolution
- Specification of initial and boundary conditions
- Episode selection and rationale for episode selection
- Rationale for and description of meteorological model setup
- Basis for and development of emissions inputs
- Methods used to quality assure emissions, meteorological, and other model inputs

3. Model Performance Evaluation

- Describe ambient database(s)
- Describe evaluation procedures and performance metrics

As stated previously, we expect that the EPA Regional Offices, with assistance from the OAQPS, may assist reviewing authorities, as necessary, to structure appropriate technical demonstrations leading to the development of appropriate chemical transport modeling applications for the purposes of estimating potential O_3 and/or secondary $PM_{2.5}$ impacts.

III.5 Comparison to the SIL

This section provides recommendations for source impact analyses where a permit applicant compares the proposed source's ambient O_3 or $PM_{2.5}$ impacts to an appropriate SIL as part of the required demonstration that a proposed source or modification will not cause or contribute to a violation of the O_3 or $PM_{2.5}$ NAAQS. These recommendations are also generally applicable for demonstrations that a proposed source or modification will not cause or contribute to a violation of the $PM_{2.5}$ PSD increments, see Section V.4. The EPA's recommended SIL values for O_3 and $PM_{2.5}$ NAAQS and $PM_{2.5}$ PSD increments are listed in Table II-1 and Table II-2. (U.S. EPA 2018a).

III.5.1 SIL Comparison for O_3

For Assessment Case 2, an analysis of secondary O_3 impacts would be conducted where the proposed source's precursor emissions of NO_X and/or VOC are equal to or greater than the respective SERs. The EPA recommends that the assessment of the precursor emission impacts on O_3 formation should be conducted based on the two-tiered demonstration approach as provided for specific to O_3 in section 5.3 of the 2017 *Guideline*. Under the Tier 1 approach, for source impact analyses, the highest of the multi-season (or episode) averages of the maximum modeled daily 8-hour O_3 concentrations predicted each season (or episode) should be compared to the appropriate O_3 SIL, since this metric represents the maximum potential daily 8-hour O_3 impact from the proposed source or modification. Under the Tier 2 approach, where a CTM is directly applied to estimate the source impacts, the comparison should be done at each receptor, *i.e.*, each modeled grid cell. If the source impact is less than the SIL, then the analysis is generally sufficient to support a finding that the source will not cause or contribute to a NAAQS violation.

However, if the source impact is equal to or greater than the SIL, then the analysis is insufficient to show that a source will not cause or contribute to a violation of the NAAQS and a cumulative impact assessment would be necessary.

III.5.2 SIL Comparison for $PM_{2.5}$

For Assessment Case 2, an analysis of primary $PM_{2.5}$ impacts would be conducted where the proposed source's direct $PM_{2.5}$ emissions are equal to or greater than the applicable SER (10 tpy). In such situations, the modeled estimates of ambient primary $PM_{2.5}$ concentrations due to direct emissions using the EPA preferred AERMOD dispersion model (or other acceptable preferred or approved alternative model) should be compared to an appropriate $PM_{2.5}$ SIL in the source impact analysis. The dispersion modeling methods here are similar to the methods used for other primary pollutants, including the use of maximum allowable emissions, following Table 8-2 of the 2017 *Guideline*. However, due to the form of the $PM_{2.5}$ NAAQS, we recommend that one of the following be compared to the SIL, depending on the meteorological data used in the analysis:

- The highest of the 5-year averages of the maximum modeled annual 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or highest of the 5-year averages of the annual average $PM_{2.5}$ concentrations (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 5 years of representative National Weather Service (NWS) data;

- The highest modeled 24-hour $PM_{2.5}$ concentration (for the 24-hour $PM_{2.5}$ NAAQS) or the highest modeled average $PM_{2.5}$ concentration (for the annual $PM_{2.5}$ NAAQS) predicted at each receptor based on 1 year of site-specific meteorological data; or the

highest of the multi-year averages of the maximum modeled annual 24-hour $PM_{2.5}$ concentration (for the 24-hour $PM_{2.5}$ NAAQS) or the highest of the multi-year averages of the maximum modeled annual average $PM_{2.5}$ concentrations (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 2 or more years, up to 5 complete years, of available site-specific meteorological data; or

- The highest of the 3-year averages of the maximum modeled annual 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or highest of the 3-year averages of the annual average $PM_{2.5}$ concentrations (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 3 years of prognostic meteorological data.

These metrics represent the maximum potential 24-hour or annual $PM_{2.5}$ impacts from the proposed source or modification at any receptor, given the form of the NAAQS, and, therefore, provide an appropriate part of the basis for determining whether a cumulative modeling analysis would be needed. If the source impact is less than the SIL, then the analysis is generally sufficient to support a finding that the source will not cause or contribute to a NAAQS violation. However, if the source impact is equal to or greater than the SIL, then the analysis is insufficient to show that a source will not cause or contribute to a violation of the NAAQS and a cumulative impact assessment would be necessary to make the NAAQS compliance demonstration.

For Assessment Case 3, analyses of both primary and secondary $PM_{2.5}$ impacts are necessary because the proposed source's direct $PM_{2.5}$ emissions and emissions of at least one $PM_{2.5}$ precursor are equal to or greater than the respective SERs. In this case, both the primary and secondary $PM_{2.5}$ impacts from the proposed source or modification would be included in the comparison to the appropriate $PM_{2.5}$ SIL in the source impact analysis. As with Case 2, the ambient impacts due to direct $PM_{2.5}$ emissions would be estimated using the EPA preferred

AERMOD dispersion model (or other acceptable preferred or approved alternative model). For the assessment of the precursor emission impacts on $PM_{2.5}$ formation, the EPA recommends that this part of the assessment should be conducted based on the two-tiered demonstration approach as provided for specific to $PM_{2.5}$ in section 5.4 of the 2017 *Guideline*. However, the comparison to the SIL will depend on the type of assessment conducted for the secondary $PM_{2.5}$ impacts from the source.

In the SIL comparison for Case 3, the primary and secondary $PM_{2.5}$ impacts may be combined in various ways that may entail greater or lesser degrees of conservatism. For example, combining the peak estimated primary $PM_{2.5}$ impact with the peak estimated secondary $PM_{2.5}$ impact, unpaired in time and space, would tend to be a conservative estimate of combined impacts since, as noted above, peak impacts associated with a source's direct $PM_{2.5}$ and precursor emissions are not likely well-correlated in time or space. The conservatism associated with combining peak estimated primary and secondary impacts for comparison to a SIL makes this an appropriate initial approach to combining estimated primary and secondary $PM_{2.5}$ impacts.

Other approaches for combining primary and secondary $PM_{2.5}$ impacts for comparison to a SIL for Case 3 will vary based on the degree of temporal and spatial pairing of estimated primary and secondary $PM_{2.5}$ impacts. Full temporal and spatial pairing may not be feasible in many cases, given that the dispersion modeling and chemical transport modeling may be based on different data periods. Furthermore, full temporal and spatial pairing of primary and secondary $PM_{2.5}$ impacts may not be appropriate in many cases because photochemical grid modeling represents gridded concentration estimates whereas dispersion modeling produces estimates at discrete receptor locations and because of the limitations in the skill of both the

dispersion model and the photochemical grid model to accurately predict impacts on a paired in time and space basis. As a result, consideration of some degree of temporal pairing of primary and secondary $PM_{2.5}$ impacts is most appropriate on a seasonal or monthly basis with considerations of spatial pairing that reflects the general lack of correlation between primary and secondary impacts, *i.e.*, primary impacts being higher near the source while secondary impacts being higher at some distance away from the source.

The permitting authority and the permit applicant should thoroughly discuss the details regarding combining modeled primary and secondary $PM_{2.5}$ impacts for Case 3 situations and should reach agreement during the initial review of the modeling protocol. The permitting authority should ensure that any approach for combining estimated primary and secondary $PM_{2.5}$ impacts for comparison to a SIL for Case 3 conforms to the recommendations described above for Case 2 regarding the form of the modeled estimate. Accordingly, the approach should be based on the highest of the multi-year averages of the maximum modeled 24-hour or annual $PM_{2.5}$ concentrations predicted each year at each receptor, which represents the maximum potential impact from the proposed source or modification.

For Assessment Case 4, an analysis of secondary $PM_{2.5}$ impacts would be conducted for the proposed source's precursor emissions that are equal to or greater than the respective SERs. For this source impact analysis, under the Tier 1 approach, the highest of the multi-year averages of the maximum predicted modeled 24-hour or annual $PM_{2.5}$ concentrations should be compared to the appropriate $PM_{2.5}$ SIL since these metrics represent the maximum potential impact from the proposed source or modification. Under the Tier 2 approach, where a CTM is directly applied to estimate the source impacts, the comparison should be done at each receptor, *i.e.*, each modeled grid cell.

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IV. PSD Compliance Demonstrations for the O_3 and $PM_{2.5}$ NAAQS: Cumulative Impact Analysis

Where the source impact analysis described in Section III is insufficient to show that a source will not cause or contribute to a violation of the O_3 or $PM_{2.5}$ NAAQS, a cumulative impact assessment will then be necessary to determine whether the source complies with the NAAQS. A cumulative assessment accounts for the combined impacts of the proposed new or modifying source's emissions, emissions from other nearby sources, and representative background levels of O_3 or $PM_{2.5}$ within the modeling domain. The cumulative impacts are then compared to the O_3 or $PM_{2.5}$ NAAQS to determine whether there is a modeled NAAQS violation. If not, then the NAAQS compliance demonstration is sufficient. If there are modeled violations, then the source impact at the location of these violations is compared to the appropriate SIL to determine if the proposed new or modifying source emissions will cause or contribute to a violation of the NAAQS. This section provides details on conducting an appropriate cumulative impact assessment for the O_3 and $PM_{2.5}$ NAAQS.

O_3

The cumulative impact assessment should include the following components of O_3 impacts, as appropriate, for comparison to the NAAQS:

- Proposed new or modifying source
    - Impacts on O_3 from each precursor (NO_X and/or VOC) that is proposed to be emitted in a significant amount, *i.e.*, equal to or greater than the respective SER (40 tpy)
- Nearby sources
    - Impacts on O_3 from precursors (NO_X and/or VOC) are typically accounted for through representative monitored background

- Monitored background level of O_3 that accounts for O_3 impacts from regional transport and from nearby sources[16]

$PM_{2.5}$

The cumulative impact assessment should include the following components of $PM_{2.5}$ impacts, as appropriate, for comparison to the NAAQS:

- Proposed new or modifying source
    - Primary impacts on $PM_{2.5}$, *i.e.*, from direct $PM_{2.5}$ emissions that are proposed to be emitted in a significant amount, *i.e.*, equal to or greater than the SER (10 tpy)
    - Secondary impacts on $PM_{2.5}$ from each precursor (NO_X and/or SO_2) that is proposed to be emitted in a significant amount, *i.e.*, equal to or greater than the respective SER (40 tpy)
- Nearby sources
    - Primary impacts on $PM_{2.5}$
    - Impacts on $PM_{2.5}$ from precursors (NO_X and/or SO_2) are typically accounted for through representative monitored background
- Monitored background level of $PM_{2.5}$ that accounts for secondary $PM_{2.5}$ impacts from regional transport and from nearby sources, and primary $PM_{2.5}$ impacts from background sources not included in the modeled inventory, *e.g.*, minor sources[17]

[16] The emissions impact of any nearby source that has received a permit but is not yet operational should be included in the air quality assessment. In such cases, consultation with the appropriate permitting authority on the appropriate assessment approach is recommended.

[17] The emissions impact of any nearby source that has received a permit but is not yet operational should be included in the air quality assessment. In such cases, consultation with the appropriate permitting authority on the appropriate assessment approach is recommended

As with the source impact analysis, the primary impacts of direct $PM_{2.5}$ emissions from the proposed new or modifying source and nearby sources in a cumulative impact analysis should be estimated based on the AERMOD dispersion model (or other acceptable preferred or approved alternative model). In addition, EPA recommends that the estimate of secondary $PM_{2.5}$ impacts from the proposed new or modifying source should be conducted based on the two-tiered demonstration approach described in section 5.2 of the 2017 *Guideline*. As noted above, secondary impacts on $PM_{2.5}$ from regional transport, precursor emissions from nearby sources, and primary $PM_{2.5}$ impacts from background sources not included in the modeled inventory should be accounted for through representative monitored background concentrations.

IV.1 Modeling Inventory

Section 8 of the 2017 *Guideline* provides the current required and recommended approaches for characterizing source emissions and developing the O_3 and/or $PM_{2.5}$ modeling inventory for purposes of NAAQS compliance modeling in PSD air quality demonstrations. Section 8.2 and Table 8-2 of the 2017 *Guideline* address the appropriate emissions limit, operating level, and operating factor to be modeled, which is the maximum allowable emissions rate for the proposed new or modifying source in most cases and an allowable emissions rate adjusted for actual operations for any nearby sources. For applications that require the assessment of secondarily formed O_3 or $PM_{2.5}$ through case-specific chemical transport modeling, information regarding the development of the appropriate modeling inventory can be found in the Single-source Modeling Guidance.

Section 8.3.3 of the 2017 *Guideline* emphasizes the importance of professional judgment in the identification of nearby and other sources "that are not adequately represented by ambient

monitoring data" that should be included in the modeled emission inventory and identifies "a significant concentration gradient in the vicinity of the [proposed] source" as a primary criterion for this selection. Additionally, the 2017 *Guideline* suggests that "the number of nearby sources to be explicitly modeled in the air quality analysis is expected to be few except in unusual situations" and that "[i]n most cases, the few nearby sources will be located within the first 10 to 20 km from the [proposed] source." The EPA also provided modeling guidance in March 2011 (U.S. EPA, 2011c) that includes a detailed discussion of the significant concentration gradient criterion. However, several application-specific factors should be considered when determining the appropriate inventory of nearby sources to include in the cumulative modeling analysis, including the potential influence of terrain characteristics on concentration gradients and the availability and adequacy of ambient monitoring data to account for impacts from nearby sources as well as other background sources.

Consistent with the 2017 revisions to the *Guideline*, the EPA cautions against the application of very prescriptive procedures for identifying which nearby sources should be included in the modeled emission inventory for NAAQS compliance demonstrations, such as the procedures described in Chapter C, Section IV.C.1 of the draft "New Source Review Workshop Manual" (U.S. EPA, 1990). Our main concern is that following such procedures in a literal and uncritical manner may, in many cases, increase the likelihood of double-counting modeled and monitored concentrations, resulting in cumulative impact assessments that are overly conservative and would unnecessarily complicate the permitting process. The identification of which sources to include in the modeled emissions inventory should be addressed in the modeling protocol and, as necessary, discussed in advance with the permitting authority.

Since modeling of direct $PM_{2.5}$ emissions has been limited and infrequent, the availability

of an adequate direct $PM_{2.5}$ emission inventory for nearby sources may not exist in all cases. Recommendations for developing $PM_{2.5}$ emission inventories for use in PSD applications will be addressed separately, but existing SIP inventories for $PM_{2.5}$ or statewide PSD inventories of sources for refined modeling are expected to provide a useful starting point for this effort.

IV.2 Monitored Background

Section 8.3 of the 2017 *Guideline* provides recommendations for determination of monitored background concentrations to include in cumulative impact assessments for NAAQS compliance, which should account for impacts from existing sources that are not explicitly included in the modeled inventory and natural sources. From newly-acquired pre-construction monitoring data and/or existing representative air quality data gathered for purposes of a permitting analysis, permit applicants should assess and document what the background monitoring data represent to the extent possible, including any information that may be available from the state or other agency responsible for siting and maintaining the monitor.[18]

Determining the monitored background concentrations of O_3 and/or $PM_{2.5}$ to include in the cumulative impact assessment may entail different considerations from those for other criteria pollutants lacking secondary formation. An important aspect of the monitored background concentration for O_3 or $PM_{2.5}$ is that the ambient monitoring data should in most cases account for the impact of secondary formation of either pollutant from precursor emissions of existing sources impacting the modeling domain. Additionally, for $PM_{2.5}$, ambient monitoring

[18] Please note in the case of an existing source seeking a permit for a modification, there is potential overlap across secondary impacts from monitored background and from precursor emission from the existing source. In such cases, recommendations for excluding monitored values when the source in question is impacting the monitor in section 8.3.2.b of the 2017 *Guideline* may need to be modified to avoid overcompensating in cases where the monitored concentrations are also intended to account for the existing source's impacts on secondary $PM_{2.5}$.

data should account for the component of the background levels of primary $PM_{2.5}$ from emissions of nearby sources that are not included in the modeled inventory. As with other criteria pollutants, consideration should also be given to the potential for some double-counting of the impacts from modeled emissions that may be also included in the background monitored concentrations. This should generally be of less importance than the representativeness of the monitor for secondary formation of O_3 and $PM_{2.5}$., unless the monitor is located relatively close to nearby sources of primary $PM_{2.5}$ that could be impacting the monitor. Also, due to the nature of O_3 and secondary $PM_{2.5}$, monitored background concentrations of O_3 and $PM_{2.5}$ are more likely to be homogeneous across the modeling domain in most cases compared to most other pollutants.

Depending on the nature of local $PM_{2.5}$ levels within the modeling domain, it may be appropriate to account for seasonal variations in monitored background $PM_{2.5}$ levels, which may not be correlated with seasonal patterns of the modeled primary $PM_{2.5}$ levels. For example, maximum modeled primary $PM_{2.5}$ impacts associated with low-level emission sources are likely to occur during winter months due to longer periods of stable atmospheric conditions, whereas maximum ambient levels of secondary $PM_{2.5}$ typically occur during spring and summer months due to high levels of sulfates (particularly in the eastern United States). The use of temporally-varying monitored background concentrations in a cumulative impact analysis is discussed in more detail in Section IV.3.

IV.3 Comparison to the NAAQS

As indicated in Figure II-1, the first step of a cumulative impact analysis consists of a comparison of the combined modeled and monitored concentrations, as discussed above, with

the applicable NAAQS to determine if there are any projected violations of the O_3 and/or $PM_{2.5}$ NAAQS.

O_3

Ozone differs from other criteria pollutants because it is secondarily formed by NOx and VOC precursor emissions and there are not direct O_3 emissions to be considered in the NAAQS compliance demonstration. The O_3 design value that is representative for the area, rather than the overall maximum monitored background concentration, should generally be used as the monitored component of the cumulative analysis. The O_3 design value is based on the 3-year average of the annual fourth-highest daily maximum 8-hour average O_3 concentrations (80 FR 65292).

The EPA recommends that the modeled O_3 impacts should be added to the monitor-based design value for comparison to the NAAQS, as appropriate. The monitoring data should be representative in that it accounts for O_3 formation associated with existing sources both within and outside of the modeling domain. The EPA recommends that modeled O_3 impacts should be based on a Tier 1 or 2 assessment that accounts for the source's precursor emissions of NOx and/or VOC that are proposed to be emitted in a significant amount. The resulting cumulative O_3 concentrations would then be compared to the O_3 NAAQS (0.070 ppm).

$PM_{2.5}$

Combining the modeled and monitored concentrations of $PM_{2.5}$ for comparison to the 24-hour or annual $PM_{2.5}$ NAAQS entails considerations that differ from those for other criteria pollutants due to the issues identified at the end of Section IV.2. Based on assessment cases shown in Table III-2, the discussion below addresses comparisons to the NAAQS in the context of dispersion modeling of direct $PM_{2.5}$ emissions only (*i.e.*, Case 2) and for applications

involving assessments of secondary $PM_{2.5}$ impacts (*i.e.*, Cases 3 and 4).

Given the importance of secondary formation of $PM_{2.5}$ and the potentially high background levels relative to the $PM_{2.5}$ NAAQS, greater emphasis is generally placed on the monitored background levels relative to the modeled inventory for $PM_{2.5}$ than for other pollutants. This is true for both $PM_{2.5}$ NAAQS and PSD increments assessments. Also, given the probabilistic form of the $PM_{2.5}$ NAAQS, careful consideration should be given to how the monitored and modeled concentrations are combined to estimate the cumulative impact levels.

The $PM_{2.5}$ design value that is representative for the area, rather than the overall maximum monitored background concentration, should generally be used as the monitored component of the cumulative analysis. The $PM_{2.5}$ design value for the annual averaging period is based on the 3-year average of the annual average $PM_{2.5}$ concentrations, while the $PM_{2.5}$ design value for the 24-hour averaging period is based on the 3-year average of the annual 98^{th} percentile 24-hour average $PM_{2.5}$ concentrations (78 FR 3086). Details regarding the determination of the annual 98^{th} percentile monitored 24-hour value based on the number of days sampled during the year are provided in the data interpretation procedures for the $PM_{2.5}$ NAAQS in Appendix N to 40 CFR part 50.

It should be noted here that although the monitored design values for the $PM_{2.5}$ standards are defined in terms of 3-year averages, this definition does not preempt or alter the 2017 *Guideline's* requirement for use of 5 years of representative NWS meteorological data, at least 1 year of site-specific data, or at least 3 years of prognostic meteorological data for purposes of modeling primary emissions of $PM_{2.5}$.[19] The 5-year average based on use of representative NWS meteorological data, the average across one or more (up to 5) complete years of available site-

[19] See 40 CFR part 51, Appendix W, section 8.4.2.e.

specific data, or the average across 3 years of prognostic meteorological data serves as an unbiased estimate of the 3-year average for purposes of modeling demonstrations of compliance with the NAAQS. Modeling of "rolling 3-year averages," using years 1 through 3, years 2 through 4, and years 3 through 5 as recommended in the EPA's SIP Modeling Guidance, is not required.

For each case, the EPA recommends that the modeled design concentrations of primary $PM_{2.5}$ and/or the modeled secondary $PM_{2.5}$ impacts should be added to the monitor-based design value for comparison to the NAAQS, as appropriate. The primary $PM_{2.5}$ modeled design concentration should be based on:

- The 5-year average of the modeled annual 98th percentile 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or 5-year average of the modeled annual average $PM_{2.5}$ concentration (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 5 years of representative NWS data;
- The modeled 98th percentile 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or modeled average $PM_{2.5}$ concentration (for the annual $PM_{2.5}$ NAAQS) predicted at each receptor based on 1 year of site-specific meteorological data, or the multi-year average of the modeled annual 98th percentile 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or modeled annual average $PM_{2.5}$ concentration (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 2 or more years, up to 5 complete years, of available site-specific meteorological data; or
- The 3-year average of the modeled annual 98th percentile 24-hour $PM_{2.5}$ concentrations (for the 24-hour $PM_{2.5}$ NAAQS) or 3-year average of the modeled

annual average $PM_{2.5}$ concentration (for the annual $PM_{2.5}$ NAAQS) predicted each year at each receptor, based on 3 years of prognostic meteorological data.

The EPA recommends that secondary $PM_{2.5}$ modeled impacts should be based on either a Tier 1 or 2 assessment accounting for the source's $PM_{2.5}$ precursor emissions of NOx and/or SO_2 that are proposed to be emitted in a significant amount. The resulting cumulative $PM_{2.5}$ concentrations would then be compared to the 24-hour $PM_{2.5}$ NAAQS (35 $\mu g/m^3$) and/or the annual $PM_{2.5}$ NAAQS (12 $\mu g/m^3$).

Specifically, for Case 2, where the source's direct $PM_{2.5}$ emissions are equal to or greater than the SER, the modeled design concentration should be based on AERMOD (or other acceptable preferred or approved alternative model) estimates of the proposed source's and other nearby sources' direct $PM_{2.5}$ emissions combined with the monitor-based design value. The monitor should be representative in that it accounts for secondary $PM_{2.5}$ formation associated with existing sources both within and outside of the modeling domain, in addition to the background levels of primary $PM_{2.5}$ associated with nearby and background sources that are not included in the modeled inventory.

For Case 3, where the source's direct $PM_{2.5}$ emissions and NO_X and/or SO_2 precursor emissions are proposed to be emitted in amounts equal to or greater than the respective SERs, the cumulative impact for comparison to the NAAQS should be based on the sum of the modeled design concentration for primary $PM_{2.5}$ impacts (from dispersion model estimates based on the proposed source's and other nearby source's direct $PM_{2.5}$ emissions), the modeled secondary $PM_{2.5}$ impacts (based on a Tier 1 or 2 assessment accounting for the proposed source's $PM_{2.5}$ precursor emissions), and the monitored design value (see Case 2 discussion above on monitor representativeness).

For Case 4, where the source's NO_X and/or SO_2 precursor emissions are proposed to be emitted in amounts equal to or greater than the respective SERs, the cumulative impact for comparison to the NAAQS should be based on the sum of the modeled secondary $PM_{2.5}$ impacts (based on a Tier 1 or 2 assessment accounting for the proposed source's $PM_{2.5}$ precursor emissions) and the monitor-based design value (see Case 2 discussion above on monitor representativeness).

The recommendations provided above constitute a First Level analysis for $PM_{2.5}$ NAAQS compliance demonstrations. For applications where impacts from primary $PM_{2.5}$ emissions are not temporally correlated with background $PM_{2.5}$ levels, combining the modeled and monitored levels as described above may be overly conservative in some situations. For example, there are areas of the country where background $PM_{2.5}$ levels are substantially higher on average during the summer months as compared to the winter months; however, the projected modeled impacts from the new or modified source may be substantially greater in the winter rather than in the summer. In such cases, a Second Level modeling analysis may be advisable to account for these temporal relationships. Such an analysis would involve combining the monitored and modeled $PM_{2.5}$ concentrations on a seasonal (or quarterly) basis, as appropriate. The use of a seasonally-varying monitored background component is likely to be a more important factor for the 24-hour $PM_{2.5}$ NAAQS analysis than for the annual $PM_{2.5}$ NAAQS. Careful evaluation of when model projections of $PM_{2.5}$ impacts and background $PM_{2.5}$ levels peak throughout the year is recommended before embarking on a Second Level modeling analysis. This is because the First Level approach may already adequately capture the temporal correlation. As a part of this process to determine the appropriate level of analysis, the permit applicant should consult with the appropriate permitting authority and then reflect the appropriate approach in their modeling

protocol.

The AERMOD model provides several options for specifying the monitored background concentration for inclusion in the cumulative impact assessment. The options that are most relevant to $PM_{2.5}$ analyses include:

- For First Level 24-hour or annual $PM_{2.5}$ NAAQS analyses, an option to specify a single annual background concentration that is applied to each hour of the year, and
- For Second Level 24-hour $PM_{2.5}$ NAAQS analyses, an option to specify four seasonal background values that are combined with modeled concentrations on a seasonal basis.

The AERMOD model also allows the user to track the effect of background concentrations on the cumulative modeled design concentration.

For Second Level 24-hour $PM_{2.5}$ NAAQS modeling analyses, EPA recommends that the distribution of monitored data equal to and less than the annual 98th percentile be appropriately divided into seasons (or quarters) for each of the three years that are used to develop the monitored design value. This will result in data for each year of the multi-year data, which contains one season (or quarter) with the 98th percentile value and three seasons (quarters) with maximum values which are less than or equal to the 98th percentile value. The maximum concentration from each of the seasonal (or quarterly) subsets should then be averaged across these three years of monitoring data. The resulting average of seasonal (or quarterly) maximums should then be included as the four seasonal background values within the AERMOD model. Therefore, the monitored concentrations greater than the 98th percentile in each of the three years would not be included in the seasonal (or quarterly) subsets. These excluded monitored

concentrations are the same values that are excluded when determining the monitored design value. An example of the calculations for a Second Level 24-hour $PM_{2.5}$ NAAQS modeling analysis is provided in Appendix D.

For a monitor with a daily (1-in-1 day monitor) sampling frequency and 100% data completeness, the highest seven monitored concentrations for each year would be excluded from the seasonal (or quarterly) subdivided datasets. Similarly, for a monitor with every third day (1-in-3 day monitor) sampling frequency and 100% data completeness, the highest two monitored concentrations for each year would be excluded from the seasonal (or quarterly) subdivided datasets. The monitored concentrations excluded from the subdivided datasets could primarily come from one or two seasons (or quarters) each year or could be evenly distributed across all four seasons (or quarters) each year. Additionally, the monitored concentrations not included in the subdivided datasets could shift seasonally (or quarterly) from one year to the next. Given the reason for considering a Second Level 24-hour analysis (*i.e.*, lack of temporal correlation between modeled and monitored concentrations), it is likely that the monitored data greater than the 98^{th} percentile would be concentrated in one or two seasons as opposed to evenly distributed throughout the year. As mentioned earlier, see Appendix N of 40 CFR part 50 in determining the appropriate 98^{th} percentile rank of the monitored data based on the monitor sampling frequency and valid number of days sampled during each year.

The EPA does not recommend a "paired sums" approach on an hour-by-hour basis because of the spatial and temporal variability throughout a typical modeling domain on an hourly basis and the complexities and limitations of hourly observations from the current $PM_{2.5}$ ambient monitoring network. The implicit assumption underlying this “paired sums’ approach is that the background monitored levels for each hour are spatially uniform and that the monitored

values are fully representative of background levels at each receptor for each hour. Such an assumption does not account for the many factors that contribute to the temporal and spatial variability of ambient $PM_{2.5}$ concentrations across a typical modeling domain on an hourly basis.[20] Furthermore, the pairing of daily monitored background and 24-hour average modeled concentrations is not recommended except in rare cases of relatively isolated sources where the available 1-in-1 day monitor can be shown to be representative of the ambient concentration levels in the areas of maximum impact from the proposed new source. In most cases, the seasonal (or quarterly) pairing of monitored and modeled concentrations previously described in the Second Level approach should sufficiently address situations in which the impacts from primary $PM_{2.5}$ emissions are not temporally correlated with background $PM_{2.5}$ levels. Any monitor-model pairing approach aside from the First or Second Level methods should be justified on a case-by-case basis in consultation with the appropriate permitting authority and the appropriate EPA Regional Office.

IV.4 Determining Whether Proposed Source Causes or Contributes to Modeled Violations

If the cumulative impact assessment following these recommendations results in predicted modeled violations of the O_3 and/or $PM_{2.5}$ NAAQS, then the permit applicant will need

[20] The complexity of the $PM_{2.5}$ ambient monitoring network presents special challenges with a "paired sum" approach that are not present with other NAAQS pollutants. The Federal Reference Method (FRM) $PM_{2.5}$ monitoring network is based on 24-hour samples that are taken on average every third day at the 1-in-3 day monitors. The frequency of daily or 1-in-1 day $PM_{2.5}$ monitors is steadily increasing but is relatively limited to the largest cities and metropolitan regions of the U.S. Various methods to "data fill" the 1-in-3 day monitoring database to create a pseudo-daily dataset have been explored in a few situations, but none of these data filling methods have been demonstrated to create a representative daily $PM_{2.5}$ dataset that the EPA would consider acceptable for inclusion in a $PM_{2.5}$ NAAQS compliance demonstration. The use of continuous $PM_{2.5}$ monitors, which are more limited in number compared to the FRM monitors and may require careful quality assurance of individual hourly measurements, may be an option but should be discussed in advance with the appropriate permitting authority.

to demonstrate that the proposed source's emissions do not cause or contribute to the modeled NAAQS violations. In the SILs Guidance, the EPA explained that the permitting authority may further evaluate whether the proposed source or modification will cause or contribute to predicted violations by comparing the proposed source's modeled impacts, paired in time and space with the predicted violations, to an appropriate SIL. The proposed source or modification would not be considered to cause or contribute to predicted violations of the O_3 or $PM_{2.5}$ NAAQS where the modeled impacts of the proposed source or modification at those particular times and locations are less than the appropriate O_3 or $PM_{2.5}$ NAAQS SIL. As explained in the SILs Guidance, a permitting authority that chooses to use an O_3 or $PM_{2.5}$ SIL value to support a PSD permitting decision should justify the value and its use in the administrative record for the permitting action.

A demonstration that a proposed source or modification does not cause or contribute to a predicted violation should be based on a comparison of the modeled concentrations (primary and secondary impacts) at the receptor location(s) showing the violation(s) of the O_3 or $PM_{2.5}$ NAAQS to the appropriate O_3 or $PM_{2.5}$ NAAQS SIL, *i.e.*,

- For a predicted violation of the O_3 NAAQS, the average of the predicted annual (or episodic) 98^{th} percentile daily maximum 8-hour averaged O_3 concentrations at the affected receptor(s) should be compared to an appropriate O_3 NAAQS SIL, *e.g.*, SIL values recommended by EPA in the SILs Guidance (Table II-1).
- For a predicted violation of the annual $PM_{2.5}$ NAAQS, the average of the predicted annual concentrations at the affected receptor(s) should be compared to an appropriate $PM_{2.5}$ annual NAAQS SIL, *e.g.*, SIL values recommended by EPA in the SILs Guidance (Table II.1).

- For a predicted violation of the 24-hour $PM_{2.5}$ NAAQS, the average of the predicted annual 98th percentile 24-hour average concentrations at the affected receptor(s) should be compared to an appropriate $PM_{2.5}$ 24-hour NAAQS SIL, *e.g.*, SIL values recommended by EPA in the SILs Guidance (Table II-1).

V. PSD Compliance Demonstration for the $PM_{2.5}$ Increments

As summarized in Section II of this guidance, CAA section 165(a)(3) requires that proposed new and modified major stationary sources seeking a PSD permit must demonstrate that their proposed emissions increases will not cause or contribute to a violation of any NAAQS or PSD increments. Based on the flow diagram presented in Figure II-2, this section describes the EPA's recommendations for completing the required compliance demonstration for the PSD increments for $PM_{2.5}$.

V.1 Overview of the PSD Increment System

This section provides an overview of the PSD increment system by defining basic terms, such as increment, baseline concentration, baseline area, trigger date, minor source baseline date, and major source baseline date. This section also introduces and discusses the concepts of increment consumption and expansion.

V.1.1 PSD Increments and Baseline Concentration

The term "increment" generally refers to what the CAA calls the "maximum allowable increase over baseline concentrations" with respect to a criteria pollutant. The CAA section 169(4) defines "baseline concentration," generally, as "the ambient concentration levels which exist at the time of the first application for a [PSD] permit for an area subject to this part…."[21] Accordingly, an increment analysis is generally concerned with the emissions increases affecting

[21] EPA's regulations at 40 CFR 52.21(b)(14)(ii) (and 51.166(b)(14)(ii)) provide that the triggering application is to be a complete PSD application. Hence, the term "complete application" will be used throughout this section with regard to the minor source baseline date and increment consumption.

air quality in a particular PSD area after the date that the first complete PSD application is submitted to the permitting authority.[22] When comparing the ambient impact of such total emissions increases against the increment value for a particular pollutant, a cumulative increase in the ambient concentration of that pollutant that is greater than the increment generally is considered "significant deterioration." When the cumulative impact analysis identifies significant deterioration in this way, the permitting authority should determine whether the emissions increase from the proposed new source or modification will cause or contribute to the projected violation of the PSD increment.

Based on the statutory definition of baseline concentration, as described above, it is conceptually possible to measure whether there will be significant deterioration in at least two separate ways. The first way involves comparing a direct modeled projection of the change in air quality caused by all increment-consuming and expanding emissions to the increment in the area of concern (known as the baseline area, discussed below in Section V.1.2). The second approach is to make a determination of whether the current monitored ambient air quality concentration in the applicable baseline area, supplemented by the modeled impact of the proposed source, will exceed an allowable ambient air quality ceiling. This latter approach requires comparing such monitored concentration(s) to the sum of the increment and the baseline concentration for the baseline area.

Historically, because of the lack of monitoring data to adequately represent the baseline concentration combined with various other limitations associated with the use of ambient air

[22] The EPA also considers emissions decreases occurring after the date of the first PSD application to affect increment consumption to the extent that such decreases cause an improvement of air quality in the area of concern. Thus, the concept of increment "expansion" is also discussed in this section.

quality monitoring data for measuring increment consumption,[23] the EPA has recommended that the required increment analysis be based exclusively on the first approach, which models the increment-related emissions increases or decreases to determine the resulting ambient air quality change and compares this value with the increments for a particular pollutant.

V.1.2 PSD Baseline Area and Key Baseline Dates

In order to determine whether a PSD increment would be violated as part of a PSD permit review, it is necessary to identify (1) the affected geographic area in which the increment will be tracked and (2) the key baseline dates after which emissions changes affect increment in that area. The relevant geographic area for determining the amount of increment consumed is known as the "baseline area." The baseline area is established primarily on the basis of the location of the first major source to submit a complete PSD application after an established "trigger date" (see discussion of key dates below) and may be comprised of one or more areas that are designated as "attainment" or "unclassifiable" pursuant to CAA section 107(d) for a particular pollutant within a state. In accordance with the regulatory definition of baseline area at 40 CFR 52.21(b)(15), the area is an "intrastate area" and does not include any area in another state.[24] At a minimum, the baseline area is the attainment or unclassifiable area in which the first PSD applicant after the trigger date proposes to locate, but additional attainment or unclassifiable areas could be included in a particular baseline area when the proposed source's modeled impact

[23] The EPA described certain limitations associated with the use of ambient air quality monitoring data for measuring increment consumption in the preamble to its proposed PSD regulations in 1979. For example, the CAA provides that certain emissions changes should not be considered increment consuming. These limitations generally continue to apply to the extent that certain emissions changes detected by an ambient monitor are not considered to consume increment. See 44 Fed. Reg. 51924, 51944 (September 5, 1979).

[24] While baseline dates are established on an intrastate basis, once a baseline area is established, emissions changes from other states may contribute to the amount of increment consumed.

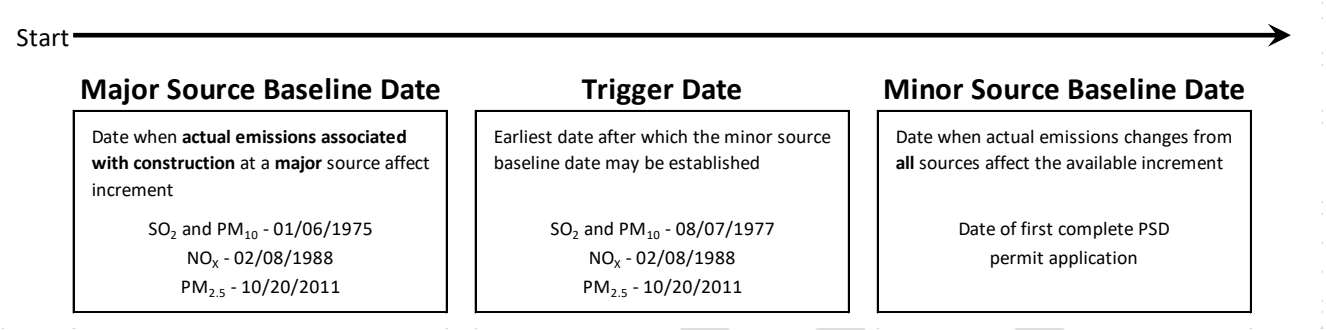
in any such additional areas exceeds certain concentrations specified in the regulatory definition of baseline area. Once a baseline area has been established, subsequent PSD applicants proposing to locate, or which could have a significant impact, in that area should rely on the associated baseline dates, discussed below, to determine whether the new or modified source's proposed emissions would cause or contribute to an increment violation.

Within any baseline area, three key dates will apply in order to conduct the required increment analysis: (1) trigger date; (2) minor source baseline date; and (3) major source baseline date. The trigger date is a date fixed by regulation for each pollutant at 40 C.F.R. 52.21(b)(14)(ii), which is the earliest date after which proposed new or modified major sources submitting a complete PSD application establishes the "minor source baseline date" in a newly established baseline area. Accordingly, the minor source baseline date is the date on which PSD permit applicants must actually begin tracking increment tracking. Depending upon the number of separate attainment and unclassifiable areas that exist for a particular pollutant in a state and the timing of major source construction within the state, there may be a number of minor source baseline dates that apply to different baseline areas established in that state. Beginning with the PSD source whose complete application has established the minor source baseline date in a particular area, any increase or decrease in actual emissions occurring after the minor source baseline date at any source that will affect air quality in the baseline area will affect the amount of PSD increment consumed in that baseline area (in the case of an emissions decrease, see discussion on increment expansion in Section V.1.3 of this guidance, below).

Finally, the "major source baseline date" is a date fixed by regulation for each pollutant at 52.21(b)(14)(i) and *precedes* the trigger date. As further explained below, changes in emissions resulting from construction at major stationary sources only that occur after the major source

baseline date but before the minor source baseline date will also affect increment. The relationship of these three key dates with each other is further illustrated in Figure V-1.

Figure V-1. Determining Baseline Date(s) and When Increment Consumption Starts



Emissions changes occurring before the minor source baseline date generally do not affect increment in an area (*i.e.*, are not increment-consuming) but are considered to affect the baseline concentration, which, as explained above, represents the ambient pollutant concentration levels that exist at the time of the minor source baseline date, or the date of the first complete application for a PSD permit in a an area after the trigger date. However, as noted above, the CAA provides an exception for certain emissions changes that occur specifically at major stationary sources as a result of construction[25] that commences after the major source baseline date. Specifically, for projects at major stationary sources on which construction commenced on a date prior to the major source baseline date, the changes in emissions from such projects affect the baseline concentration (not the amount of increment consumed) even if the emissions change may not actually occur until after the major or minor source baseline dates. Alternately, for projects at major stationary sources on which construction commenced after the

[25] The CAA section 169(2)(C) indicates that the term "construction," when used in connection with any source or facility, includes modifications defined in CAA section 111(a)(4). "Modification" is defined at section 111(a)(4) to mean any physical change or change in the method of operation at a stationary source which increases the amount of any air pollutant emitted by the source or which results in the emission of any air pollutant not previously emitted.

major source baseline date, the project emissions will be considered to affect increment, even if the new or modified source actually begins operation before the minor source baseline date.

V.1.3 PSD Increment Expansion

The "increment consumption" analysis allows permit applicants and permitting authorities to take into account emissions reductions that occur in the baseline area of concern. Such emissions reductions are generally said to result in the *expansion* of increment in the area; however, not all emissions reductions truly result in an expansion of the increment. Some emissions reductions, instead, result in a *freeing up* of increment that had previously been consumed.

In the case of true "increment expansion," emissions in the area are allowed to increase by the amount allowed by the original increment plus the amount of air quality improvement (relative to the baseline concentration) achieved by the reduction of emissions that were not considered to consume increment because of their relationship to the established baseline dates for the area.[26] In such cases, it is appropriate to model the emissions decrease as a negative amount to account for the resulting lowering of the baseline concentration and simulate the expansion of the increment.

On the other hand, in cases where a source's emissions contribute to the amount of increment consumed, a reduction in such increment-consuming emissions at some later date

[26] The concept of increment expansion is derived from CAA section 163(a), which provides that a PSD applicant must assure "that maximum allowable increases *over baseline concentrations* … shall not be exceeded." [Emphasis added.] The target for determining significant deterioration thus becomes the ambient concentration resulting from the sum of the increment and the baseline concentration. When a decrease in emissions that contribute to the baseline concentration occurs, an emissions increase that simply "restores" the air quality to the original baseline concentration in a particular baseline area can be allowed, regardless of the amount of increment otherwise being consumed.

results in some amount of the consumed increment being freed up. That is, the resulting air quality improvement is now available for a source to increase its emissions within the limits of the original increment level. A subsequent reduction in increment-consuming emissions should not be modeled as a negative value to determine the amount of increment that has been freed up; instead, such emissions reductions are simply no longer counted in the increment consumption equation.

V.2 PSD $PM_{2.5}$ Increments

In 2010, the EPA established the $PM_{2.5}$ increments at the levels shown in Table V-1 through the "Prevention of Significant Deterioration (PSD) for Particulate Matter Less Than 2.5 Micrometers ($PM_{2.5}$) – Increments, Significant Impact Levels (SILs) and Significant Monitoring Concentration (SMC)" final rule.[27] This 2010 rule established October 20, 2011, as the trigger date and October 20, 2010, as the major source baseline date for $PM_{2.5}$ increments. The EPA developed the increment system for $PM_{2.5}$ generally following the same concepts that were previously applied for development of the increments for PM_{10}, SO_2, and nitrogen dioxide (NO_2). As explained above, the framework reflects the statutory concepts set forth in the statutory definition of baseline concentration that was explained in Section V.1 of this guidance.

Table V-1. $PM_{2.5}$ Increments

	Class I	Class II	Class III
Increments, $\mu g/m^3$			
Annual arithmetic mean	1	4	8
24-hour maximum	2	9	18

Source: Prevention of Significant Deterioration (PSD) for Particulate Matter Less Than 2.5 Micrometers (PM2.5) - Increments, Significant Impact Levels (SILs) and Significant Monitoring Concentration (SMC) final rule (75 FR 64864)

[27] See 75 FR 64864.

The obvious difference between an increment analysis and the NAAQS analysis for $PM_{2.5}$ is that the increment analysis is concerned with the degree of change in air quality caused by a new or modified PSD source rather than the impact of that source on overall air quality (as defined by the applicable NAAQS) in the area of concern (baseline area). With this in mind, it should be noted here that an increment analysis is relevant only to the extent that NAAQS compliance has been ensured. That is, an adequate air quality analysis demonstrating compliance with the statutory requirements must ensure that the proposed PSD source's emissions will not cause or contribute to either the NAAQS or PSD increments.[28]

Another key difference involves the modeling inventory from which the necessary emissions data is derived. That is, only sources that have $PM_{2.5}$ emissions (direct and precursor) that affect the amount of increment consumed in the area of concern should be included in the modeling inventory for the increment analysis. Moreover, from such sources only those specific emissions changes that affect increment should be included in the actual modeling analysis.

The cumulative impact analysis for $PM_{2.5}$ increments is also different and based on the actual emission changes occurring at existing sources in the baseline area after the pertinent baseline dates (*i.e.*, major and minor source baseline dates), whereas NAAQS analyses are generally based on the cumulative impact associated with the maximum allowable emissions from the new or modifying source and other nearby sources (with specific provisions for operating levels of nearby sources). Furthermore, ambient monitoring data, while useful for establishing background concentration for the NAAQS analysis, may not be particularly useful for the typical increment analysis. The limitations associated with using monitoring data for an

[28] The CAA section 163(b)(4) provides that the maximum allowable concentration of any air pollutant allowed in an area shall not exceed the concentration allowed by the primary or secondary NAAQS.

increment analysis are discussed in greater detail in Sections V.1 and V.3 of this guidance.

It is also important to note that the $PM_{2.5}$ NAAQS and increments for the 24-hour averaging period are defined in different forms and therefore must be analyzed differently.[29] The 24-hour $PM_{2.5}$ NAAQS is defined based on the 3-year average of the annual 98th percentile of the 24-hour average concentrations, while the 24-hour $PM_{2.5}$ increments are based on the second highest maximum 24-hour concentration.

V.3 PSD Compliance Demonstration for the $PM_{2.5}$ Increments

The initial steps for the $PM_{2.5}$ increment analysis, which include the determination of the significant emissions increases to include in the source impact analysis and comparison of the modeled impacts against the $PM_{2.5}$ SILs will rely upon the results derived from the $PM_{2.5}$ NAAQS analysis described in Sections III and IV of this guidance. Moreover, the technical approach involving the options and alternatives agreed upon for estimating secondary $PM_{2.5}$ impacts and combining primary and secondary $PM_{2;5}$ impacts for the NAAQS analysis will also be relevant for completing the $PM_{2.5}$ increment analysis to determine whether the emissions increase from the proposed source or modification will cause or contribute to any $PM_{2.5}$ increment violation.

V.3.1 $PM_{2.5}$ Increments: Source Impact Analysis

The EPA's recommendations on completing the required compliance demonstration for the $PM_{2.5}$ PSD increments is based upon the same four assessment cases detailed in Section II.4 for $PM_{2.5}$ NAAQS. As shown in Table V-2, a modeled compliance demonstration is not required

[29] The annual NAAQS and increments for $PM_{2.5}$ are both measured as annual arithmetic mean values.

for Case 1 since neither direct $PM_{2.5}$ emissions nor $PM_{2.5}$ precursor (NO_X and/or SO_2) emissions are equal to or greater than the respective SERs. Case 1 is the only assessment case that does not require a modeled compliance demonstration for $PM_{2.5}$, whereas each of the remaining three assessment cases would necessitate a source impact analysis that should be conducted following the detailed recommendations provided in previous sections for a NAAQS analysis.

Table V-2. EPA Recommended Approaches for Assessing Primary and Secondary $PM_{2.5}$ Impacts by Assessment Case

Assessment Case	Description of Assessment Case	Primary Impacts Approach	Secondary Impacts Approach*
Case 1: No Air Quality Analysis	Direct $PM_{2.5}$ emissions < 10 tpy SER NO_X emissions and SO_2 emissions < 40 tpy SER	N/A	N/A
Case 2: Primary Air Quality Impacts Only	Direct $PM_{2.5}$ emissions ≥ 10 tpy SER NO_X emissions and SO_2 emissions < 40 tpy SER	**Appendix W preferred or approved alternative dispersion model**	N/A
Case 3: Primary and Secondary Air Quality Impacts	Direct $PM_{2.5}$ emissions ≥ 10 tpy SER NO_X emissions and/or SO_2 emissions ≥ 40 tpy SER	**Appendix W preferred or approved alternative dispersion model**	Include each precursor of $PM_{2.5}$ emitted in a significant amount, see Section II.2. • **Tier 1 Approach** (*e.g.*, MERPs) • **Tier 2 Approach** (*e.g.*, Chemical Transport Modeling)
Case 4: Secondary Air Quality Impacts Only	Direct $PM_{2.5}$ emissions < 10 tpy SER NO_X emissions and/or SO_2 emissions ≥ 40 tpy SER	N/A	Include each precursor of $PM_{2.5}$ emitted in a significant amounts, see Section II.2. • **Tier 1 Approach** (*e.g.*, MERPs) • **Tier 2 Approach** (*e.g.*, Chemical Transport Modeling)

***** In unique situations (*e.g.*, in parts of Alaska where photochemistry is not possible for portions of the year), it may be acceptable for the applicant to rely upon a qualitative approach to assess the secondary impacts. Any qualitative assessments should be justified on a case-by-case basis in consultation with the appropriate EPA Regional Office or other applicable permitting authority.

A modeling analysis based solely on the PSD applicant's proposed emissions increase (*i.e.*, source impact analysis) that does not predict *anywhere* an ambient impact equal to or greater than the applicable $PM_{2.5}$ SIL generally will satisfy the requirement for a demonstration that the source will not cause or contribute to a violation of the $PM_{2.5}$ increments. When the PSD

applicant relies on such analysis to make the required compliance demonstration, the EPA recommends that the applicant should include: (1) a comparison of the predicted impacts of the proposed new or modified source and the allowable increment values, (2) information on the extent, if any, to which increment has already been consumed since the major source baseline date (by major source construction occurring prior to the minor source baseline date) or since the minor source baseline date by nearby emissions changes occurring prior to the proposed source, and (3) information on increment consumption or expansion by more distant emissions changes.

In light of the relatively recent establishment of the fixed dates (*i.e.*, major source baseline date and trigger date) associated with the $PM_{2.5}$ increments (compared to comparable fixed dates for other PSD increments), and the possibility that the minor source baseline date for a particular area has not yet been set, a proposed new or modified source being evaluated for compliance with the $PM_{2.5}$ increments in a particular area may be the first source in the area with increment-consuming emissions. As indicated in Figure II-2, under this situation, a permitting authority may have a sufficient basis to conclude that the $PM_{2.5}$ impacts of the new or modified PSD source, although greater than the applicable $PM_{2.5}$ SILs, may be compared directly to the allowable $PM_{2.5}$ increments without the need for a cumulative analysis (described in Section V.3.2 of this guidance below). Reliance on this initial source impact analysis (rather than a source or cumulative impact analysis that is compared to the applicable $PM_{2.5}$ SILs) likely would be appropriate to assess the amount of increment consumed when the proposed new or modified source represents the first complete PSD application since the trigger date, thus establishing the baseline concentration in the area, and there has been no other major source construction since the major source baseline date.

V.3.2 $PM_{2.5}$ Increments: Cumulative Analysis

Where the source impact analysis described above is insufficient to show that a proposed PSD source will not cause or contribute to a violation of the $PM_{2.5}$ PSD increments, a cumulative impact assessment would be necessary to complete the required increment analysis. A cumulative assessment of increment consumption accounts for the combined impacts of the following:

1. Direct and/or precursor *allowable* emissions that the proposed new or modifying source would emit in significant amounts;
2. Direct and/or precursor *actual* emissions changes that have occurred at existing sources (including the existing source at which a major modification is being proposed, where applicable) since the minor source baseline date for the proposed source's baseline area;
3. Direct and/or precursor *actual* emissions from any major stationary source on which construction commenced after October 20, 2010 (major source baseline date for $PM_{2.5}$); and
4. Direct and/or precursor *allowable* emissions of permitted sources that are not yet fully operative.[30]

Unlike the guidance provided for the cumulative NAAQS analysis for $PM_{2.5}$, it is not typically practical to utilize ambient monitoring data to represent any portion of the impacts that affect the $PM_{2.5}$ increments. Therefore, it is usually necessary to model the applicable emissions from any existing source that will be considered to consume a portion of the $PM_{2.5}$ increments in

[30] Regarding the use of allowable emissions, see 40 CFR 52.21(b)(21)(iv).

the baseline area of concern. It is highly recommended that the PSD applicant work closely with the permitting authority to determine the existing sources (including newly permitted sources) of direct $PM_{2.5}$ and precursor emissions that should be included in the modeling inventory for the increment analysis. Sources whose emissions have not changed substantially since the applicable baseline date may not need to be included for purposes of increment consumption. If there is reason to believe that an existing source's actual emissions have decreased since the applicable baseline date, the PSD applicant may want to check with the permitting authority to ascertain whether the authority allows for increment expansion to be considered.

Once the modeling inventory for the increment analysis has been developed and approved, and the increment-consuming emissions have been determined, the modeled cumulative impacts resulting from the increases and decreases in emissions are then compared to the $PM_{2.5}$ increments to determine whether any increment violations will result. This section provides recommendations on conducting an appropriate cumulative impact assessment for $PM_{2.5}$ increments.

V.3.2.1 Assessing Primary $PM_{2.5}$ Impacts

As explained in Section III.3 of this guidance, the assessment of primary $PM_{2.5}$ impacts from the proposed new or modifying PSD source is essentially the same for the $PM_{2.5}$ NAAQS and increments. In both cases, the permit applicant must account for the impacts from the proposed new or modifying source's *allowable* emissions increase of direct $PM_{2.5}$.

To assess the impact of direct $PM_{2.5}$ emissions from existing increment-consuming sources, *actual* emissions increases that have occurred since the applicable minor source baseline date should generally be modeled. Alternatively, existing source impacts from direct $PM_{2.5}$

emissions may be conservatively modeled using an existing source's *allowable* emissions where the PSD applicant determines that such emissions are more readily available and especially when such allowable emissions are not expected to contribute substantially to the amount of increment consumed. In the event that an applicant chooses to conduct the cumulative analysis using *allowable* emissions and identifies potential problems concerning increment consumption, the PSD applicant may then rely on more refined data that better represent a particular source's *actual* emissions.

The $PM_{2.5}$ increments analysis would follow the traditional approach involving modeling only direct $PM_{2.5}$ emissions changes that affect the increment and should be based on application of AERMOD (or other acceptable preferred or approved alternative model), using actual emission changes associated with any increment-consuming or increment-expanding sources. The AERMOD model allows for inclusion of these emissions (represented as negative emissions for the sources expanding increment)[31] in the same model run that includes the allowable increase in emissions from the proposed source and will, therefore, output the net cumulative concentrations at each receptor established for the modeling domain.[32]

V.3.2.2 Assessing Secondary $PM_{2.5}$ Impacts

To assess the impacts from changes in secondary $PM_{2.5}$ precursor emissions from the new or modified source, as well as from other increment-consuming sources, the EPA recommends the analysis for each applicable precursor of $PM_{2.5}$ be conducted collectively based on the two-tiered demonstration approach outlined in EPA's 2017 *Guideline*.

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[31] See discussion about increment expansion in Section V.1.3 of this guidance.

[32] The "maximum" cumulative impacts will be output as zero if the cumulative impacts computed in the model are less than zero).

In recent years, several rules promulgated by the EPA have resulted in control requirements that have significantly reduced NO_X and SO_2 precursor emissions affecting ambient $PM_{2.5}$ concentrations in many areas.[33] This is particularly true in the eastern U.S. As a result, in some cases, the impacts of secondary $PM_{2.5}$ emissions may be addressed by a demonstration that provides ambient monitoring data that generally confirms a downward trend in contributions of precursor emissions occurring after the applicable $PM_{2.5}$ minor source baseline date (or the major source baseline date). If it can be confirmed that such secondary emissions reductions have occurred in a particular baseline area, it may be possible to complete the $PM_{2.5}$ increments modeling analysis simply by focusing on potential increment consumption associated with direct $PM_{2.5}$ emissions. For areas where $PM_{2.5}$ precursor emission increases from other increment-consuming sources have occurred since the major or minor source baseline dates, and are, thus, likely to have added to $PM_{2.5}$ concentration increases within the baseline area (and, thus, consume $PM_{2.5}$ increment), the chemical transport modeling methods (using the emissions input data applicable to increment analyses) discussed in Section III of this guidance may be appropriate for estimating the portion of $PM_{2.5}$ increment consumed due to secondary $PM_{2.5}$ impacts associated with those increases in precursor emissions.

V.4. Determining Whether a Proposed Source Will Cause or Contribute to an Increment Violation

When a proposed PSD source predicts, through a cumulative impact analysis, that a

[33] Such rules include the Finding of Significant Contribution and Rulemaking for Certain States in the Ozone Transport Assessment Group Region for Purposes of Reducing Regional Transport of Ozone (also known as the NOx SIP Call), 63 FR 57356 (October 27, 1998); the Clean Air Interstate Rule (CAIR) Final Rule, 70 FR 25162 (May 12, 2005); CSAPR Final Rule, 76 FR 48208 (August 8, 2011); CSAPR Update for the 2008 Ozone NAAQS (CSAPR Update) Final Rule, 81 FR 74504 (October 26, 2016); and the Mercury and Air Toxics Standards Rule (MATS), 77 FR 9304 (February 16, 2012).

modeled violation of any $PM_{2.5}$ increment will occur within the baseline area of concern, a closer examination of the proposed source's individual impact(s) at the violating receptor(s) and the time(s) of violation become important considerations. The EPA's longstanding policy is that a proposed PSD source will be considered to cause or contribute to an increment violation if its impact (primary and secondary) is significant (equal to or greater than the applicable $PM_{2.5}$ SIL) at the location and time of the modeled violation.[34] Accordingly, a proposed source or modification generally will not be considered to cause or contribute to an increment violation, even if it's modeled impacts equal or exceed the applicable $PM_{2.5}$ SILs, if it can demonstrate to the satisfaction of the permitting authority that such significant impacts do *not* occur at the location and time of any modeled violation.[35] In cases where a proposed PSD source models impacts that equal or exceed the applicable $PM_{2.5}$ SIL *and* would cause a new violation of any $PM_{2.5}$ increment, it is the EPA's longstanding policy to allow the PSD applicant to obtain sufficient offsets, in the form of emissions reductions internally or from another existing source, to avoid causing the violation at each affected receptor where (and when) a violation is modeled. In an area where a proposed PSD source would cause or contribute to an existing increment violation(s), the PSD source cannot be approved for construction unless such existing violation(s) is entirely corrected at each affected receptor prior to the operation of the proposed

[34] *See*, *e.g.*, 43 FR 26380 at 26401, June 19, 1978; EPA memo titled "Interpretation of 'Significant Contribution,'" December 16, 1980; EPA memo titled "Air Quality Analysis for Prevention of Significant Deterioration," July 5, 1988; and more recently, EPA memo titled "Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program," April 17, 2018, Attachment at page 18 ("If the modeled impact is below the recommended SIL value *at the violating receptor during the violation*, the EPA believes this will be sufficient…to conclude that the source does not cause or contribute to…the predicted violation.")(Emphasis added).

[35] The difficulties associated with combining primary and secondary impacts spatially and temporally were described in Sections III and IV of this guidance. In the case of a $PM_{2.5}$ increment analysis, as with the $PM_{2.5}$ NAAQS analysis, the applicant and permitting authority will need to agree upon an approach that best satisfies the required compliance demonstration.

source.[36]

[36] *See*, *e.g.*, 43 FR 26380 at 26401, June 19, 1978; 45 FR 52676 at 52678, August 7, 1980; and EPA memo titled "Air Quality Analysis for Prevention of Significant Deterioration," July 5, 1988. ("…for any increment violation (new or existing) for which the proposed source has a significant impact, the permit should not be approved unless the increment violation is corrected prior to operation of the proposed source.) Note that this policy for the PSD increments differs from the policy for sources that contribute to an existing NAAQS violation, for which the proposed sources needs only compensate for its own adverse impact on the NAAQS violation in accordance with 40 CFR 51.165(b)(3).

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Appendix A: Draft Conceptual Description of O_3 and $PM_{2.5}$ Concentrations in the U.S.

This appendix provides a brief summary of the current O_3 and $PM_{2.5}$ monitoring networks. It also characterizes O_3 and PM air quality in terms of their precursor emissions and chemical composition, concentration levels, and spatial and temporal patterns across the nation based on the ambient data and analyses contained in the EPA's "Integrated Science Assessment for Ozone and Related Photochemical Oxidants,"[37] "The Particle Pollution Report,"[38] and "Particulate Matter Staff Paper."[39] Such information may be useful for permit applicants in preparing conceptual descriptions, as discussed in this guidance. Permit applicants also encouraged to reference the EPA's "Air Quality Trends" website at https://www.epa.gov/air-trends for the current O_3 and $PM_{2.5}$ trends and design values.

Conceptual Descriptions of O_3

1. O_3 Monitoring Networks

To monitor compliance with the NAAQS, state, local, and tribal environmental agencies operate O_3 monitoring sites at various locations, depending on the population of the area and typical peak O_3 concentrations. In 2015, there were over 1,300 O_3 monitors reporting O_3 concentration data to EPA. All monitors that currently report O_3 concentration data to the EPA use ultraviolet Federal Equivalent Methods (FEMs). Since the highest O_3 concentrations tend to be associated with particular seasons for various locations, EPA requires O_3 monitoring during specific monitoring seasons which vary by state. The O_3 monitoring seasons for each state are listed in Appendix D to 40 CFR part 58.

Figure A-1 shows the locations of all U.S. ambient O_3 monitoring sites reporting data to EPA during the 2013-2015 period. The gray dots represent State and Local Ambient Monitoring Stations (SLAMS) which are operated by state and local governments to meet regulatory requirements and provide air quality information to public health agencies. SLAMS monitors make up about 80 percent of the ambient O_3 monitoring network in the U.S. The minimum monitoring requirements to meet the SLAMS O_3 network design criteria are specified in Appendix D to 40 CFR part 58. The requirements are based on both population and ambient concentration levels for each Metropolitan Statistical Area (MSA). At least one site for each MSA must be designed to record the maximum concentration for that particular area. The blue dots highlight two important subsets of monitoring sites within the SLAMS network: the "National Core" (NCore) network, which consists of about 80 monitoring sites that collect multi-pollutant measurements on a year-round basis, and the "Photochemical Assessment Monitoring

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[37] U.S. Environmental Protection Agency (2013). Integrated Science Assessment for Ozone and Related Photochemical Oxidants. U.S. Environmental Protection Agency, Research Triangle Park, NC. EPA/600/R-10/076 (2013 ISA), section 3.2.2 found at https://cfpub.epa.gov/ncea/isa/recordisplay.cfm?deid=247492.

[38] The Particle Pollution Report: Current Understanding of Air Quality and Emissions through 2003. http://www.epa.gov/airtrends/aqtrnd04/pmreport03/pmcover_2405.pdf#page=1.

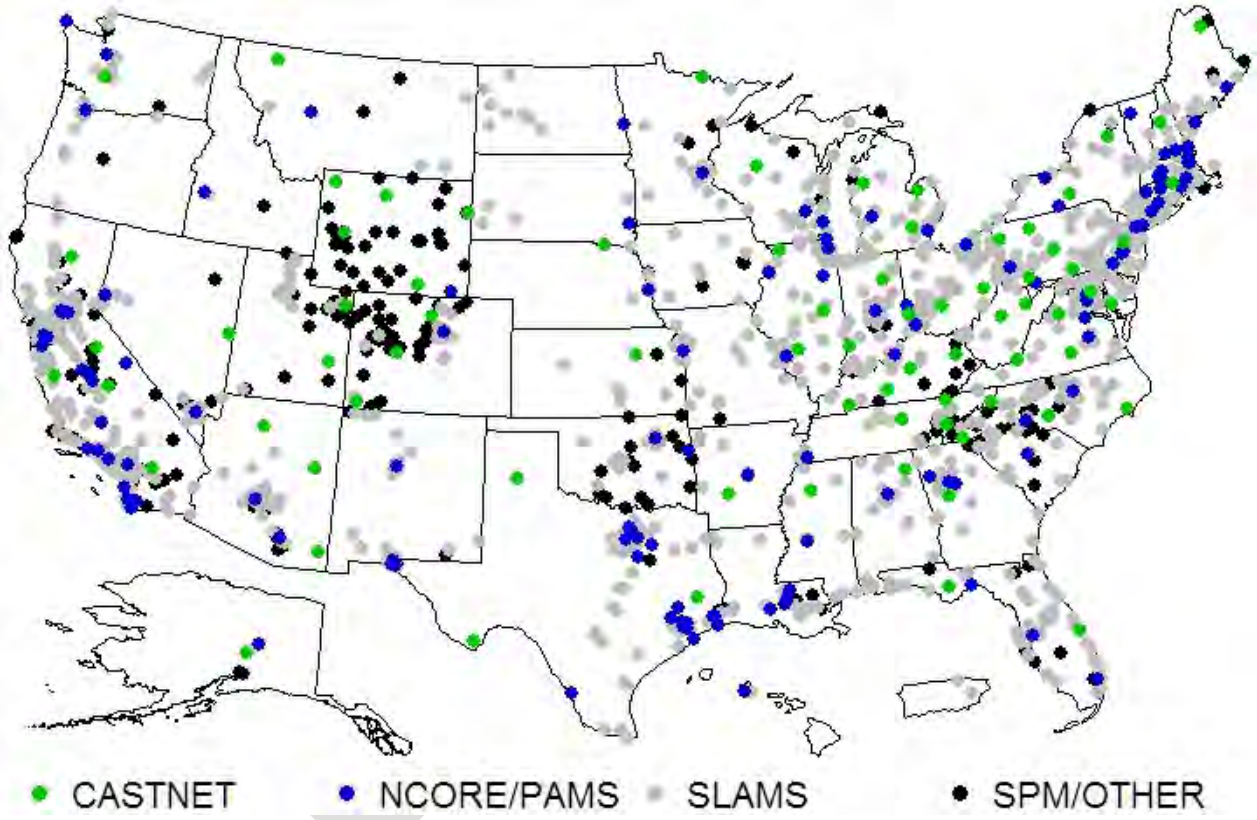
[39] Particulate Matter Staff Paper: Review completed in 2012. http://www.epa.gov/ttn/naaqs/standards/pm/s_pm_cr_sp.html.

Stations" (PAMS) network, which consists of about 75 monitoring sites that collect summertime measurements of various precursor gases involved O_3 formation.

The green dots in Figure A-1 represent O_3 monitoring sites in the Clean Air Status and Trends Network (CASTNet) which are mostly located in rural areas. There were about 80 CASTNet sites reporting data to EPA in 2015, with sites in the eastern U.S. generally being operated by the EPA, and sites in the western U.S. generally being operated by the National Park Service (NPS).

Finally, the black dots in Figure A-1 represent "Special Purpose" (SPM) monitoring sites, which generally collect data for research studies, public health reporting, or other non-regulatory purposes, and all other O_3 monitoring sites which includes monitors operated by tribes, industry, and other federal agencies such as the U.S. Forest Service (USFS).

Figure A-1. Locations of U.S. Ambient O_3 Monitoring Sites in 2013-2015



2. O_3 Precursor Emissions and Atmospheric Chemistry

O_3 is formed by photochemical reactions of precursor gases and is not directly emitted from specific sources. In the stratosphere, O_3 occurs naturally and provides protection against harmful solar ultraviolet radiation. In the troposphere, near ground level, O_3 forms through atmospheric reactions involving two main classes of precursor pollutants: volatile organic

compounds (VOCs) and nitrogen oxides (NO_X). Carbon monoxide (CO) and methane (CH4) are also important for O_3 formation over longer time periods.[40]

Emissions of O_3 precursor compounds can be divided into anthropogenic and natural source categories, with natural sources further divided into biogenic emissions (from vegetation, microbes, and animals) and abiotic emissions (from biomass burning, lightning, and geogenic sources). Anthropogenic sources, including mobile sources and power plants, account for the majority of NO_X and CO emissions. Anthropogenic sources are also important for VOC emissions, though in some locations and at certain times of the year (*e.g.*, southern states during summer), the majority of VOC emissions come from vegetation.[41] In practice, the distinction between natural and anthropogenic sources is often unclear, as human activities directly or indirectly affect emissions from what would have been considered natural sources during the preindustrial era. Thus, emissions from plants, animals, and wildfires could be considered either natural or anthropogenic, depending on whether emissions result from agricultural practices, forest management practices, lightning strikes, or other types of events.[42]

Rather than varying directly with emissions of its precursors, O_3 changes in a nonlinear fashion with the concentrations of its precursors. NO_X emissions lead to both the formation and destruction of O_3, depending on the local quantities of NO_X, VOC, radicals, and sunlight. In areas dominated by fresh emissions of NO_X, radicals are removed, which lowers the O_3 formation rate. In addition, the scavenging of O_3 by reaction with NO is called "titration" and is often found in downtown metropolitan areas, especially near busy streets and roads, as well as in power plant plumes. This short-lived titration results in localized areas in which O_3 concentrations are suppressed compared to surrounding areas, but which contain NO_2 that adds to subsequent O_3 formation further downwind. Consequently, O_3 response to reductions in NO_X emissions is complex and may include O_3 decreases at some times and locations and increases of O_3 at other times and locations. In areas with relatively low NO_X concentrations, such as those found in remote continental areas and rural and suburban areas downwind of urban centers, O_3 production typically varies directly with NO_X concentrations (*e.g.*, decreases with decreasing NO_X emissions). The NOx titration effect is most pronounced in urban core areas which have higher volume of mobile source NOx emissions from vehicles than do the surrounding areas. It should be noted that such locations, which are heavily NO_X saturated (or radical limited), tend to have much lower observed O_3 concentrations than downwind areas. As a general rule, as NOx emissions reductions occur, one can expect lower O_3 values to increase while the higher O_3 values would be expected to decrease. NOx reductions are expected to result in a compressed O_3 distribution, relative to current conditions.

The formation of O_3 from precursor emissions is also affected by meteorological parameters such as the intensity of sunlight and atmospheric mixing. Major episodes of high ground-level O_3 concentrations in the eastern United States are associated with slow-moving high pressure systems. High pressure systems during the warmer seasons are associated with the sinking of air, resulting in warm, generally cloudless skies, with light winds. The sinking of air

[40] 2013 ISA, section 3.2.2.

[41] 2013 ISA, section 3.2.1.

[42] 2013 ISA, sections 3.2 and 3.7.1.

results in the development of stable conditions near the surface which inhibit or reduce the vertical mixing of O_3 precursors. The combination of inhibited vertical mixing and light winds minimizes the dispersal of pollutants, allowing their concentrations to build up. In addition, in some parts of the United States (*e.g.*, in Los Angeles), mountain barriers limit mixing and result in a higher frequency and duration of days with elevated O_3 concentrations. Photochemical activity involving precursors is enhanced during warmer seasons because of the greater availability of sunlight and higher temperatures.[43]

3. Spatial and Temporal Patterns in Ambient O_3 Concentrations

3.1. Diurnal and Seasonal Patterns

Since O_3 formation is a photochemical process, it is not surprising that concentration levels have strong diurnal and seasonal patterns. Concentration levels tend to be highest at times when sunlight reaches its highest intensity, namely during the afternoon hours of the late spring and summer months. However, there are other factors at work, such as the influence of biogenic VOC emissions and stratospheric intrusions during the spring months, long-range transport, and traffic patterns which often cause peak NO_X emissions to occur during the morning and evening rush hours.

Figure A-2 shows the diurnal pattern in the hourly O_3 concentrations based on ambient monitoring data from 2000 to 2015. For each monitoring site, the median (top panel) and 95th percentile (bottom panel) values for each hour of the day were calculated, and each boxplot shows the range of those values for that particular hour across all monitoring sites. The whiskers of each boxplot extend to the 5th and 95th percentiles, the box represents the inter-quartile range, and the centerline represents the median value. The median and 95th percentile values show a consistent pattern in that O_3 levels tend to be lowest during the early AM hours, increasing rapidly after sunrise. Concentrations typically reach their peak during the afternoon hours, then decrease at a fairly constant rate throughout the evening and nighttime hours.

Figure A-3 shows the seasonal pattern in the daily maximum 8-hour O_3 concentrations based on ambient monitoring data from 2000 to 2015. For each monitoring site, the median (top panel) and 95th percentile (bottom panel) values for each month of the year were calculated, and each boxplot shows the range of those values for that particular month across all monitoring sites. The whiskers of each boxplot extend to the 5th and 95th percentiles, the box represents the inter-quartile range, and the centerline represents the median value. Again, the median and 95th percentile values show a consistent pattern in that O_3 levels tend to be highest during the spring and summer months (April to September), and lower during the fall and winter months (October to March).

[43] 2013 ISA, section 3.2.

Figure A-2. Distribution of Median and 95th Percentile Hourly O_3 Concentrations by Hour of the Day based on 2000-2015 Monitoring Data

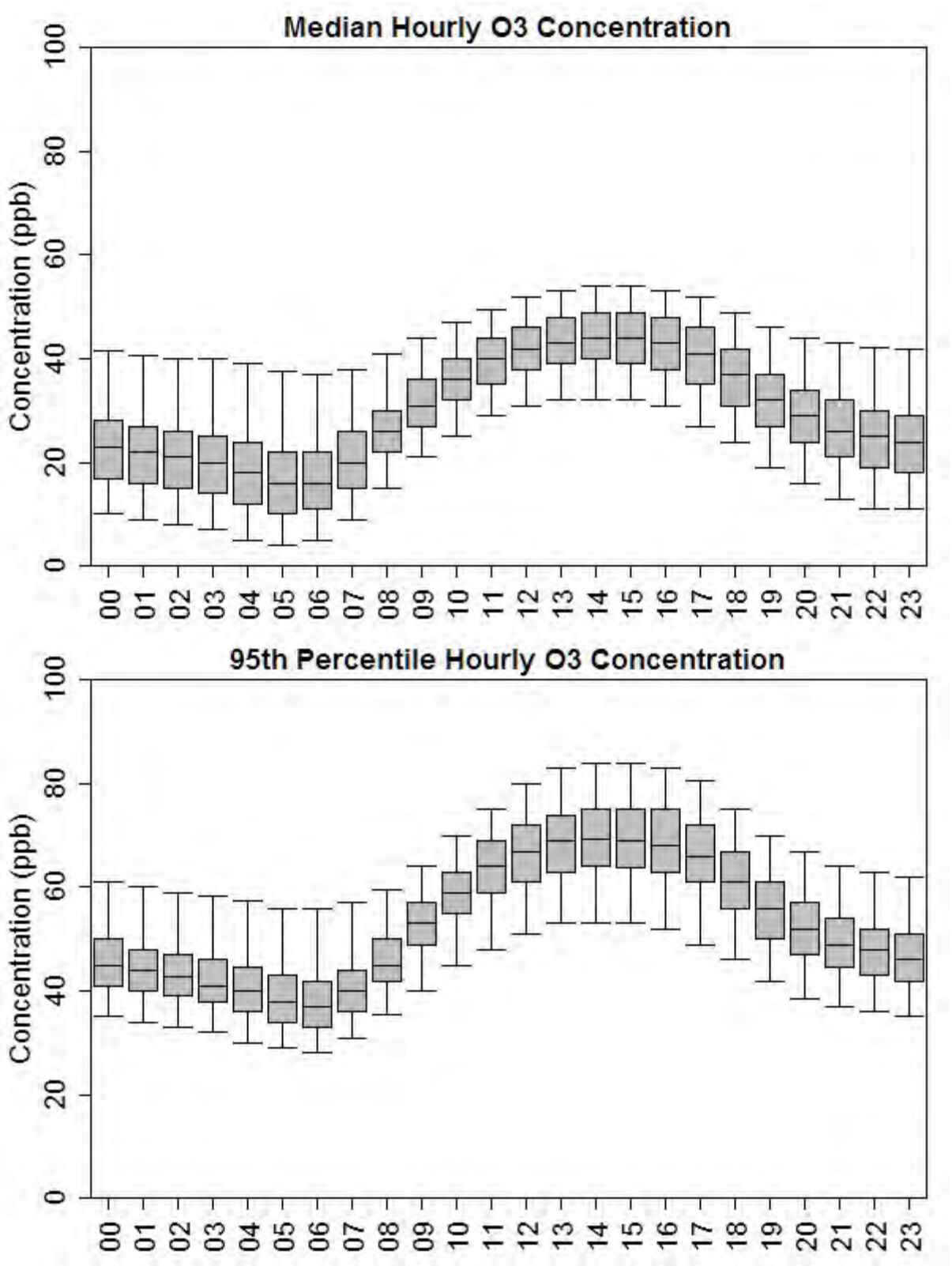
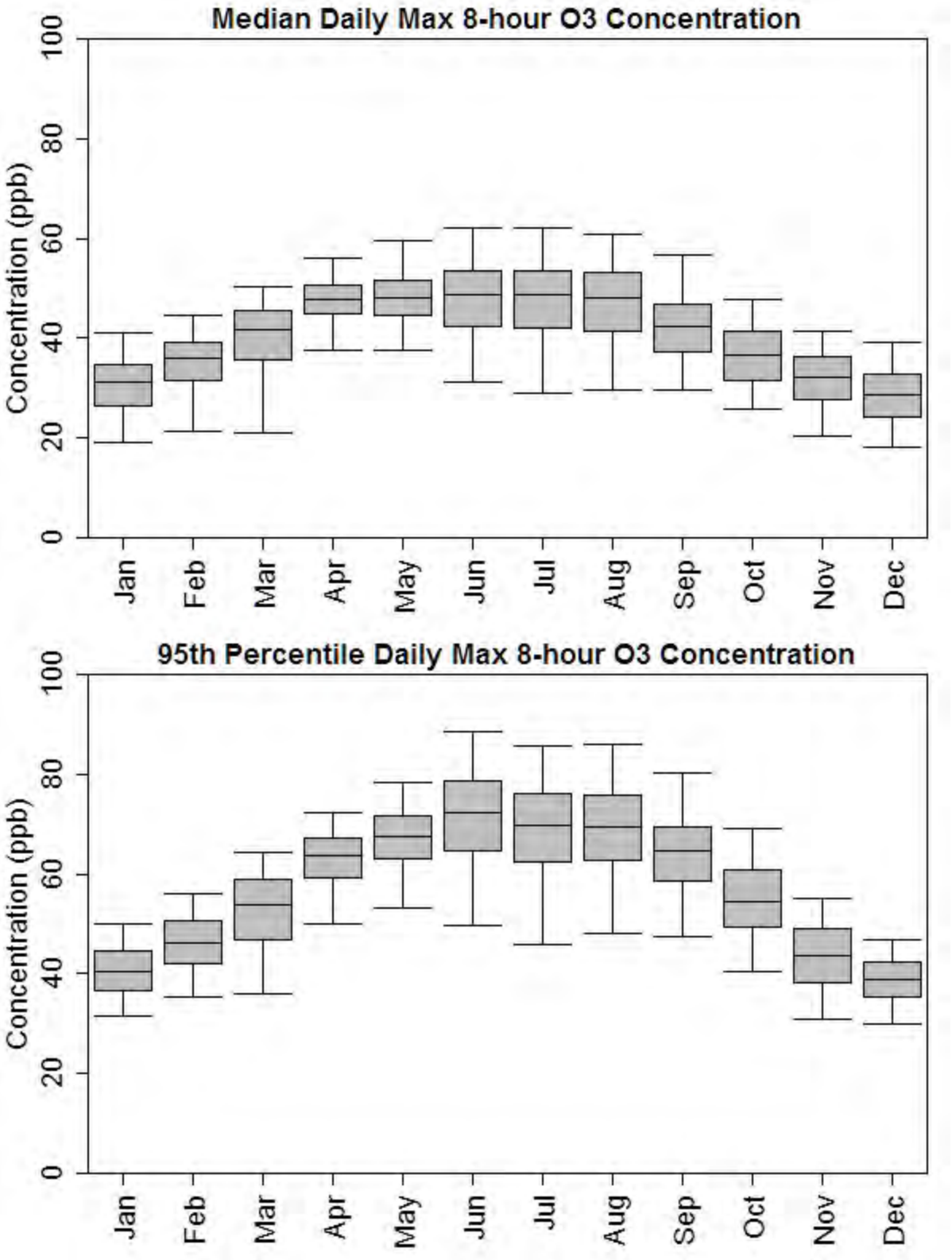


Figure A-3. Distribution of Median and 95th Percentile Daily Maximum 8-hour O_3 Concentrations by Month of the Year based on 2000-2015 Monitoring Data

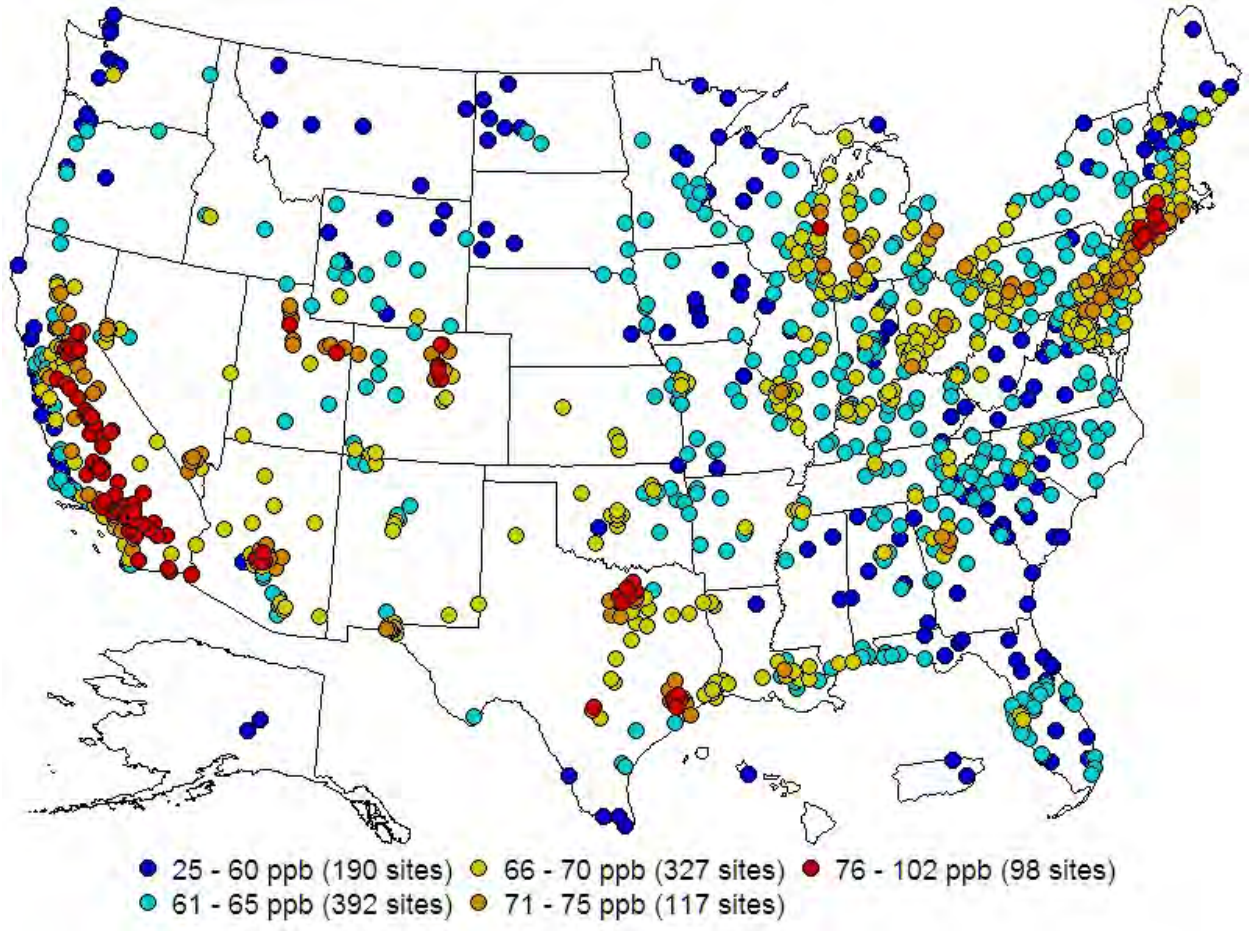


3.2. Spatial Patterns

To determine whether or not the O_3 NAAQS has been met at an ambient monitoring site, a statistic commonly referred to as a "design value" must be calculated based on three consecutive years of data collected from that site. The form of the O_3 NAAQS design value statistic is the 3-year average of the annual 4th highest daily maximum 8-hour O_3 concentration in parts per million (ppm). The O_3 NAAQS is met at an ambient monitoring site when the design value is less than or equal to 0.070 ppm. In counties or other geographic areas with multiple monitors, the area-wide design value is defined as the design value at the highest individual monitoring site, and the area is said to have met the NAAQS if all monitors in the area are meeting the NAAQS.

Figure A-4 shows a map of the O_3 design values in the U.S. based on data collected during the 2013-2015 period. The highest design values occur in California and near large metropolitan areas such as Dallas, Denver, Houston, New York City, and Phoenix. The lowest design values occur in the Pacific Northwest, the Northern Rockies, the Upper Midwest, and parts of New England and the Southeast. In general, sparsely populated areas tend to have lower design values than more urbanized areas.

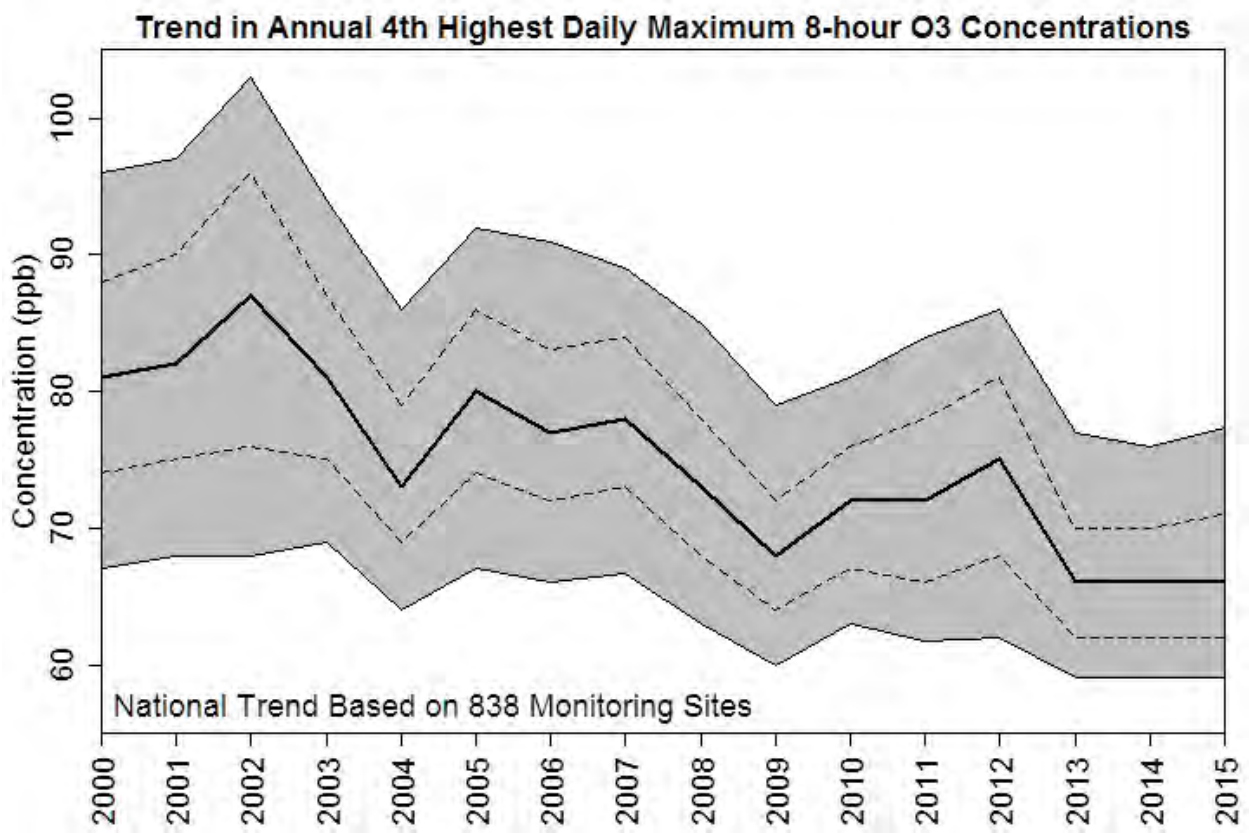
Figure A-4. Map of 2013-2015 O_3 Design Values in parts per billion (ppb)



3.3. Interannual Variability and Trends

Figure A-5 shows the national trend in the annual 4th highest daily maximum 8-hour O_3 concentration from 2000 to 2015. The solid black line represents the median value for each year based on 838 "trends" sites with complete monitoring records, the dashed lines represent the 25th and 75th percentile values for each year, and the shaded gray area covers the 10th percentile value up to the 90th percentile value for each year. While there is considerable year-to-year variability, overall the trend shows an improvement in O_3 air quality over the 15-year period. In fact, the median annual 4th highest value has decreased by 18% since the beginning of the century, and by 24% since 2002.

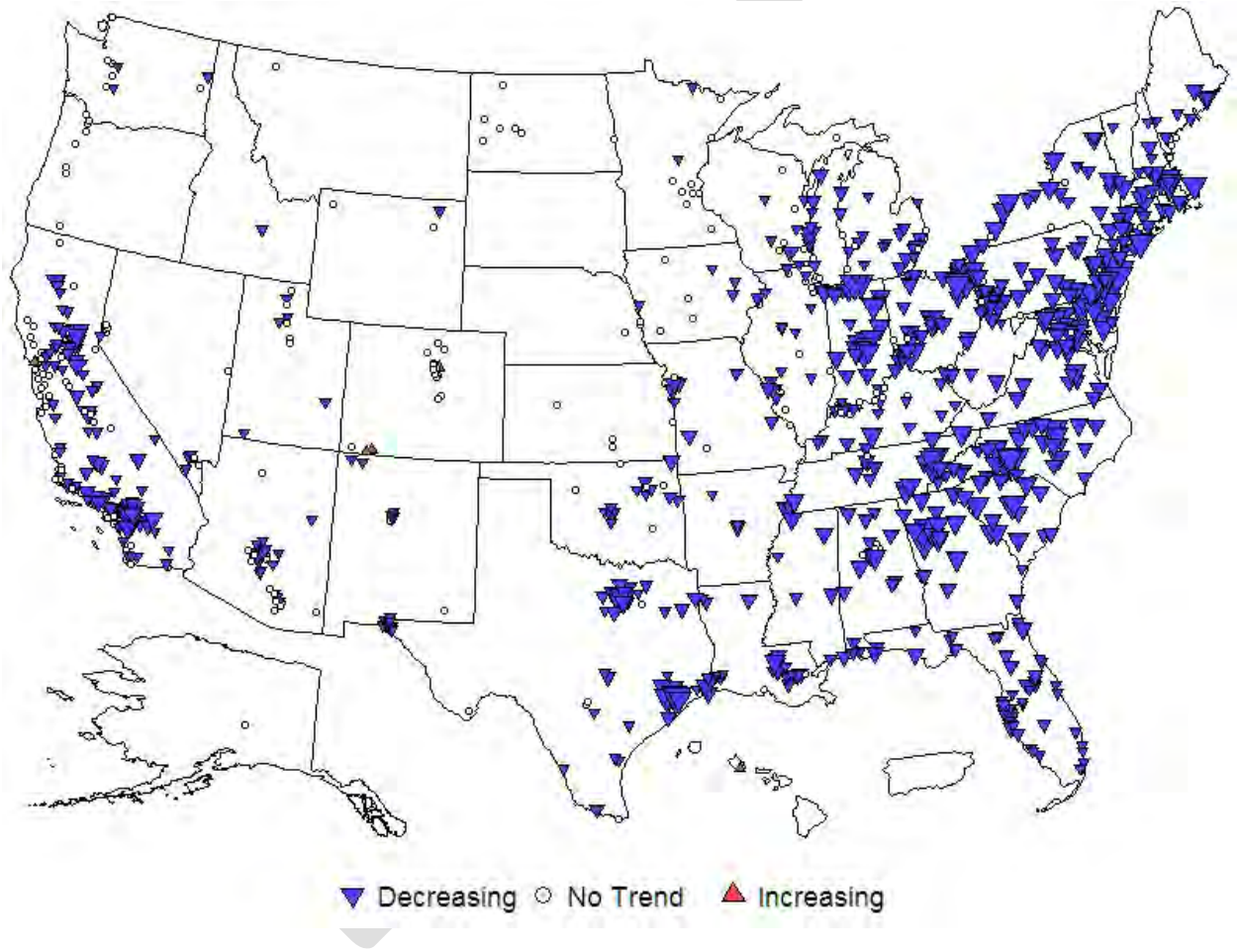
Figure A-5. National Trend in the Annual 4th Highest Daily Maximum 8-hour O_3 Concentration



Since the national trend is a simple aggregate of the site-level trends, it is also important to look at how these trends vary spatially. Figure A-6 shows a map of the trends at each monitoring site with at least 12 complete years of data from 2000-2015. The magnitude of the trend at each site is computed using the Theil-Sen slope estimator, and the Mann-Kendall statistic is calculated in order to test for statistical significance using a threshold of 0.05. The trend at each monitoring site is classified as Decreasing (p-value < 0.05, slope < 0; blue triangles), No Trend (p-value >= 0.05, white circles), or Increasing (p-value < 0.05, slope > 0; red triangles). The size of each triangle is proportional to the magnitude of the trend at each monitoring site.

Figure A-6 shows that O_3 levels have decreased across much of the eastern U.S. as a result of regional control programs such as the NOx SIP Call and the Clean Air Interstate Rule (CAIR). Large reductions have occurred near many urban areas where local control programs have been implemented in addition to the regional controls. In the western U.S., where control programs have been more localized, the reductions have occurred mostly in California and near large urban areas. In other areas most sites have not shown a significant trend, and there are only a handful of sites have shown an increasing trend.

Figure A-6. Map of site-level O_3 trends across the U.S. from 2000 to 2015



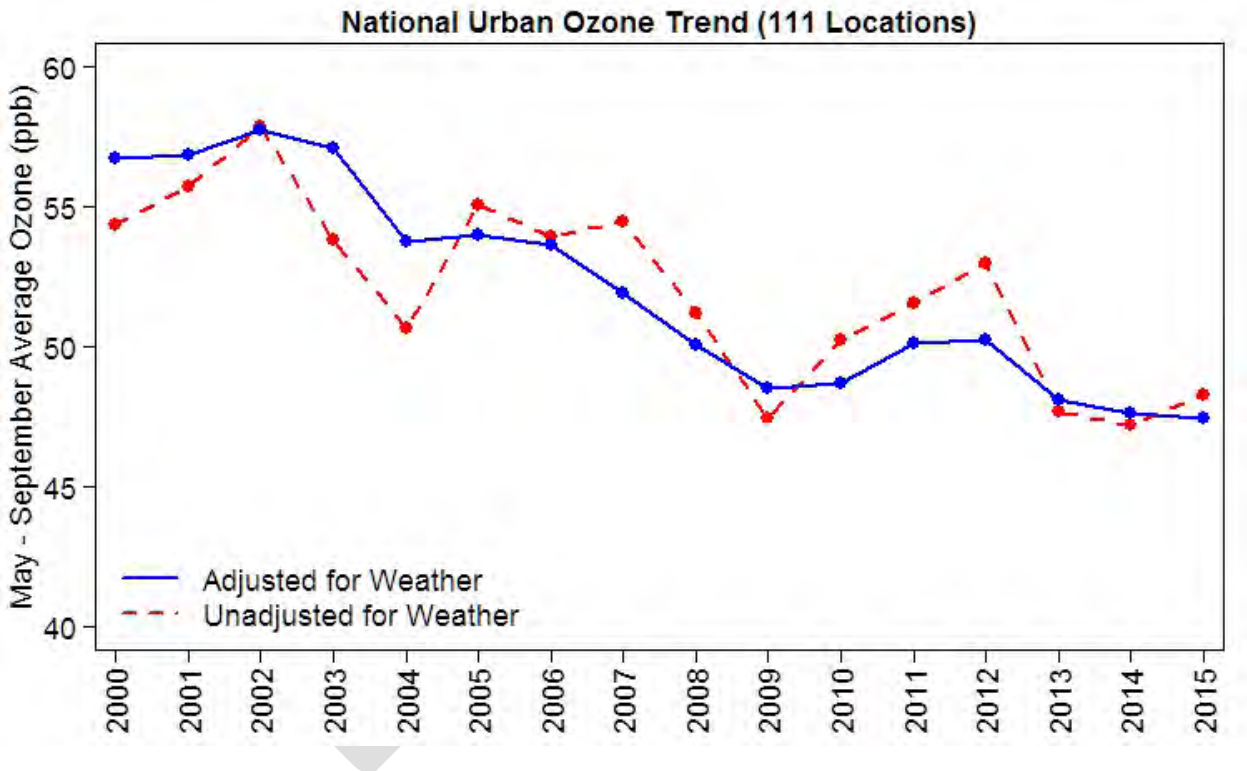
Variations in meteorological conditions play an important role in determining O_3 concentrations. Ozone is more readily formed on warm, sunny days when the air is stagnant. Conversely, O_3 generation is more limited when it is cool, rainy, cloudy, or windy. EPA uses a statistical model to adjust for the variability in seasonal average O_3 concentrations due to weather conditions to provide a more accurate assessment of the underlying trend in O_3 caused by emissions.[44] Figure A-7 shows the national trend in the May to September mean of the daily

[44] Louise Camalier, William Cox, and Pat Dolwick (2007). The Effects of Meteorology on Ozone in Urban Areas and their use in Assessing Ozone Trends. Atmospheric Environment, Volume 41, Issue 33, October 2007, pages 7127-7137.

maximum 8-hour O_3 concentrations from 2000 to 2015 in 111 urban locations. The dotted red line shows the trend in observed O_3 concentrations at selected monitoring sites, while the solid blue line shows the underlying O_3 trend at those sites after removing the effects of weather. The solid blue lines represent O_3 levels anticipated under "typical" weather conditions and serve as a more accurate assessment of the trend in O_3 due to changes in precursor emissions.

Figure A-7 shows that after adjusting for the year-to-year variability in meteorology, the overall trend in seasonal average O_3 concentrations is much smoother. The adjusted trend clearly shows that the NOx SIP Call program resulted in a sharp decrease in summertime O_3 concentrations starting in 2004. The adjusted trend also indicates that O_3 levels decreased between 2004 and 2009, followed by a small increase from 2009 to 2012, then continued to decrease after 2012.

Figure A-7. Trend in the May to September mean of the daily maximum 8-hour O_3 concentration before (dotted red line) and after (solid blue line) adjusting for year-to-year variability in meteorology.



Conceptual Description of $PM_{2.5}$

1. $PM_{2.5}$ Monitoring Networks

1.1. PM Mass Networks

The 1997 promulgation of a fine particulate NAAQS led to deployment of over 1,500 $PM_{2.5}$ sites (about 1,000 currently in operation) used to determine whether an area complies with the standard. These sites use a Federal Reference Method (FRM) or Federal Equivalent Method (FEM), daily sampling over 24-hours, or every third or sixth day. Nearly 200 additional measurements not meeting FRM or FEM specifications are provided by the chemical speciation sites (Figure A-1). Approximately 450 stations provide indirect measurements of continuous FEM (hourly resolution) $PM_{2.5}$ mass.

1.2. Interagency Monitoring of Protected Visual Environments (IMPROVE) Program

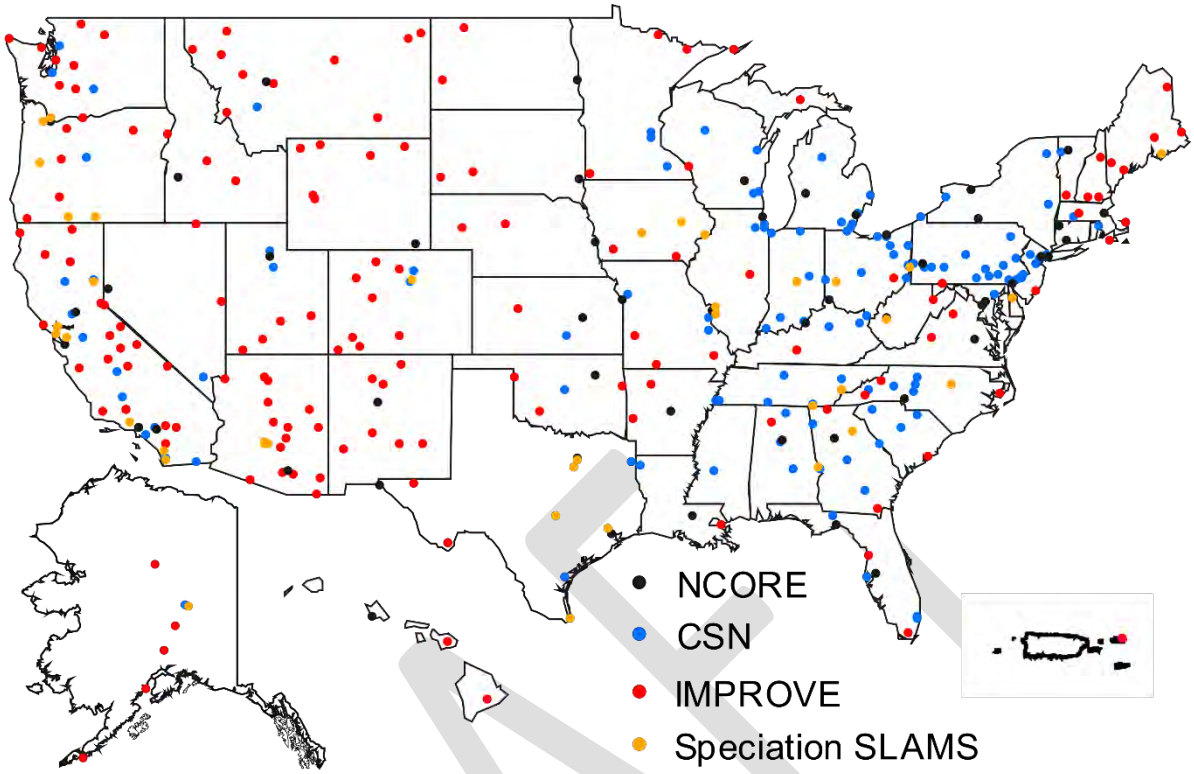
The IMPROVE network, with over 150 sites, has provided nearly a 20+ year record of major components of $PM_{2.5}$ (sulfate, nitrate, organic and elemental carbon fractions, and trace metals) in pristine areas of the United States (Figure A-8). IMPROVE is led by the National Park Service; various federal and state agencies support its operations. The primary focus of the network is to track visibility and trends in visibility.

1.3. $PM_{2.5}$ Chemical Speciation Monitoring

In addition to the IMPROVE network, approximately 200 EPA speciation sites operate in urban areas of the United States to assist $PM_{2.5}$ assessment efforts. No FRM exists for particulate speciation, which is not directly required to determine attainment, and there are slight differences between monitors and methods used in the Chemical Speciation Network (CSN). However, the network's coverage (Figure A-8) across urban and rural areas has proved essential for a wide range of research and analysis. The speciation networks typically collect a 24-hour sample every three, and sometimes six, days.

Only a handful of sites provide near continuous speciation data, usually limited to some combination of sulfate, carbon (organic and elemental splits) and nitrate. This enables insight to diurnal patterns for diagnosing various cause-effect phenomena related to emissions characterization, source attribution analysis and model evaluation.

Figure A-8. Locations of chemical speciation sites delineated by program type



2. Composition of $PM_{2.5}$

Particulate matter (PM) is a highly complex mixture of solid particles and liquid droplets distributed among numerous atmospheric gases which interact with solid and liquid phases. Particles range in size from those smaller than 1 nanometer (10^{-9} meter) to over 100 microns (1 micron is 10^{-6} meter) in diameter (for reference, a typical strand of human hair is 70 microns and particles less than about 20 microns generally are not detectable by the human eye). Particles are classified as $PM_{2.5}$ and $PM_{10\text{-}2.5}$, corresponding to their size (diameter) range in microns and referring to total particle mass under 2.5 and between 2.5 and 10 microns, respectively.

Particles span many sizes and shapes and consist of hundreds of different chemicals. Particles are emitted directly from sources and also are formed through atmospheric chemical reactions and often are referred to as primary and secondary particles, respectively. Particle pollution also varies by time of year and location and is affected by several aspects of weather such as temperature, clouds, humidity, and wind. Further complicating particles is the shifting between solid/liquid and gaseous phases influenced by concentration and meteorology, especially temperature.

Particles are made up of different chemical components. The major components, or species, are carbon, sulfate and nitrate compounds, and crustal materials such as soil and ash (Figure A-9). The different components that make up particle pollution come from specific sources and are often formed in the atmosphere. Particulate matter includes both "primary" PM, which is directly emitted into the air, and "secondary" PM, which forms indirectly from fuel

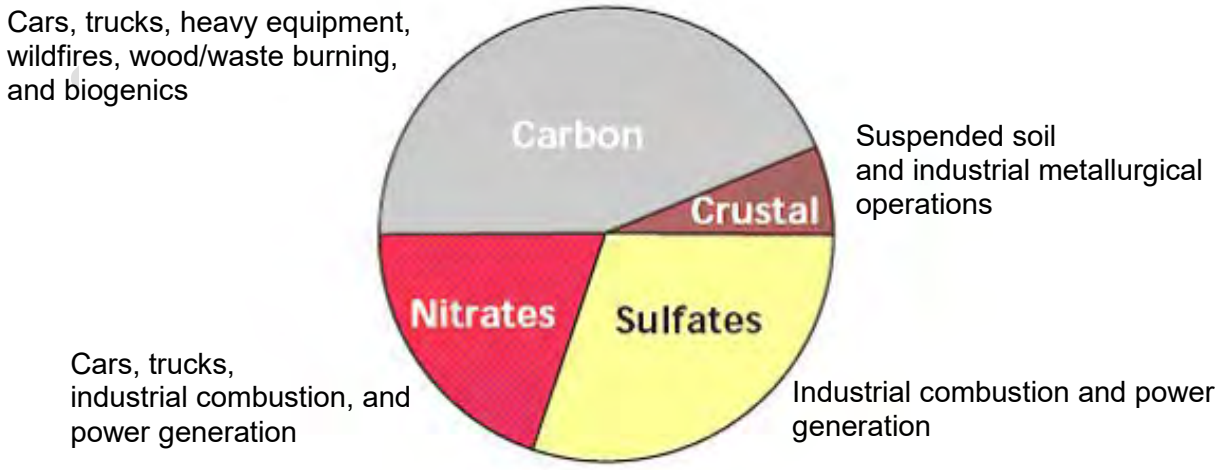
combustion and other sources. Primary PM consists of carbon (soot) emitted from cars, trucks, heavy equipment, forest fires, and burning waste and crustal material from unpaved roads, stone crushing, construction sites, and metallurgical operations. Secondary PM forms in the atmosphere from gases. Some of these reactions require sunlight and/or water vapor. Secondary PM includes:

- Sulfates formed from sulfur dioxide emissions from power plants and industrial facilities;
- Nitrates formed from nitrogen oxide emissions from cars, trucks, industrial facilities, and power plants; and
- Carbon formed from reactive organic gas emissions from cars, trucks, industrial facilities, forest fires, and biogenic sources such as trees.

In addition, ammonia from sources such as fertilizer and animal feed operations is part of the formation of sulfates and nitrates that exist in the atmosphere as ammonium sulfate and ammonium nitrate. Note that fine particles can be transported long distances by wind and weather and can be found in the air thousands of miles from where they were formed.

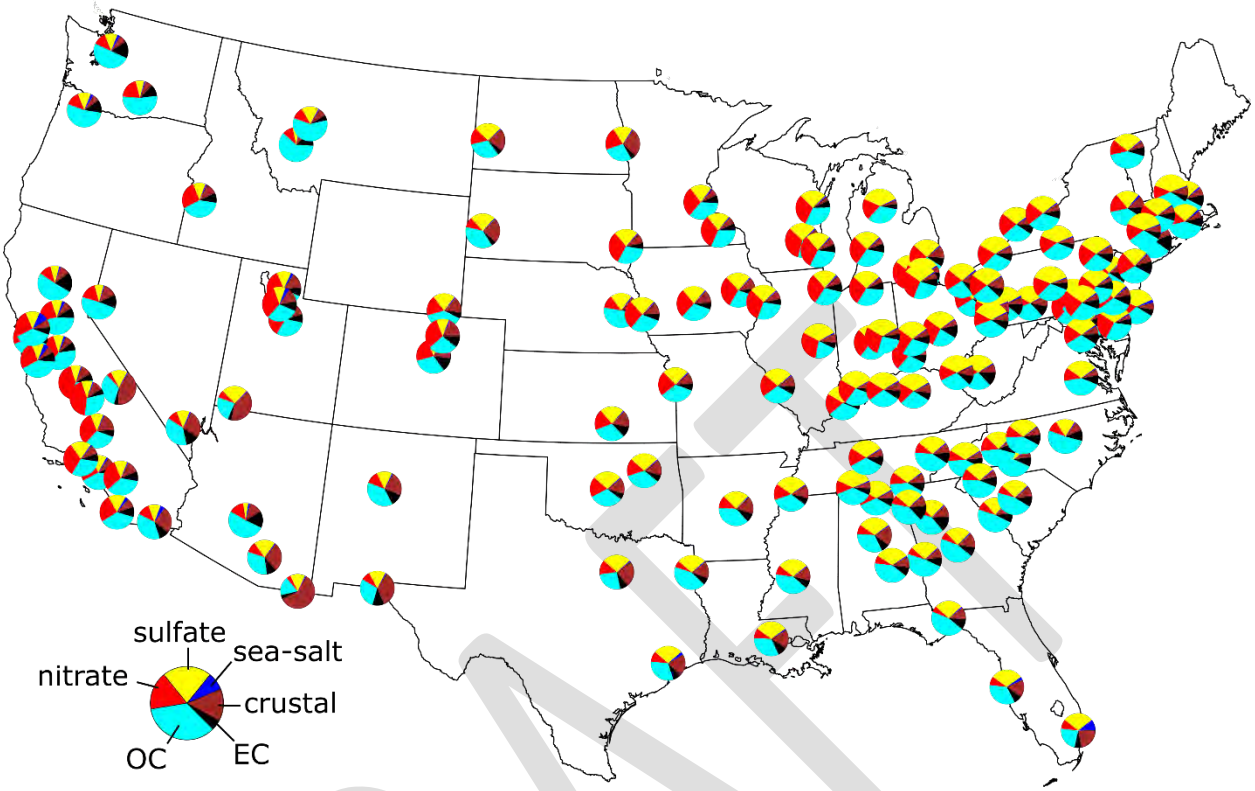
The chemical makeup of particles varies across the United States (as shown in Figure A-10). For example, fine particles in the eastern half of the United States contain more sulfates than those in the West, while fine particles in southern California contain more nitrates than other areas of the country. Organic carbon is a substantial component of fine particle mass everywhere.

Figure A-9. National Average of Source Impacts on Fine Particle Levels



Source: The Particulate Matter Report, EPA-454-R-04-002, Fall 2004. Carbon reflects both organic carbon and elemental carbon. Organic carbon accounts for automobiles, biogenics, gas-powered off-road, and wildfires. Elemental carbon is mainly from diesel powered sources.

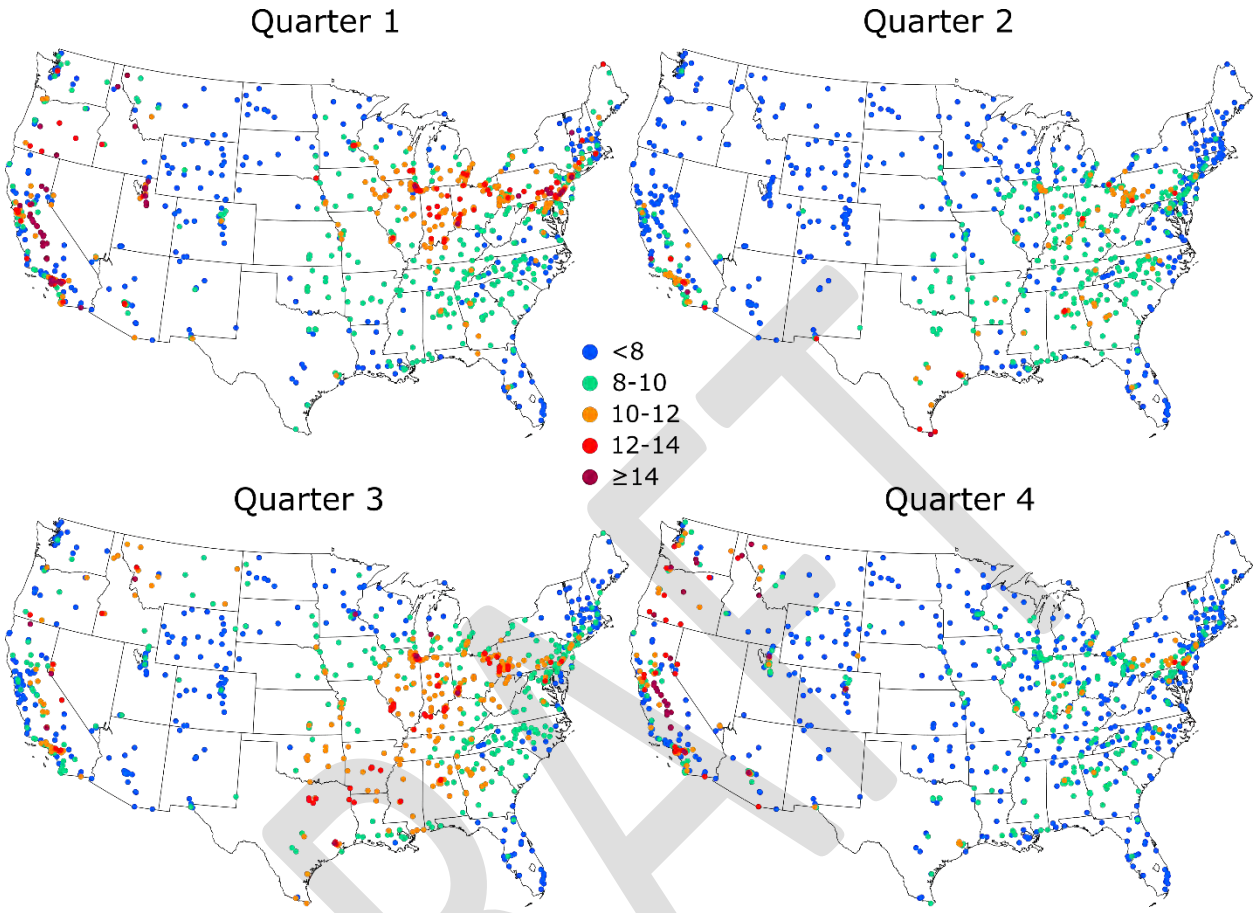
Figure A-10. Annual Average $PM_{2.5}$ Composition grouped by CBSA: 2013-2015



3. Seasonal and Daily Patterns of $PM_{2.5}$

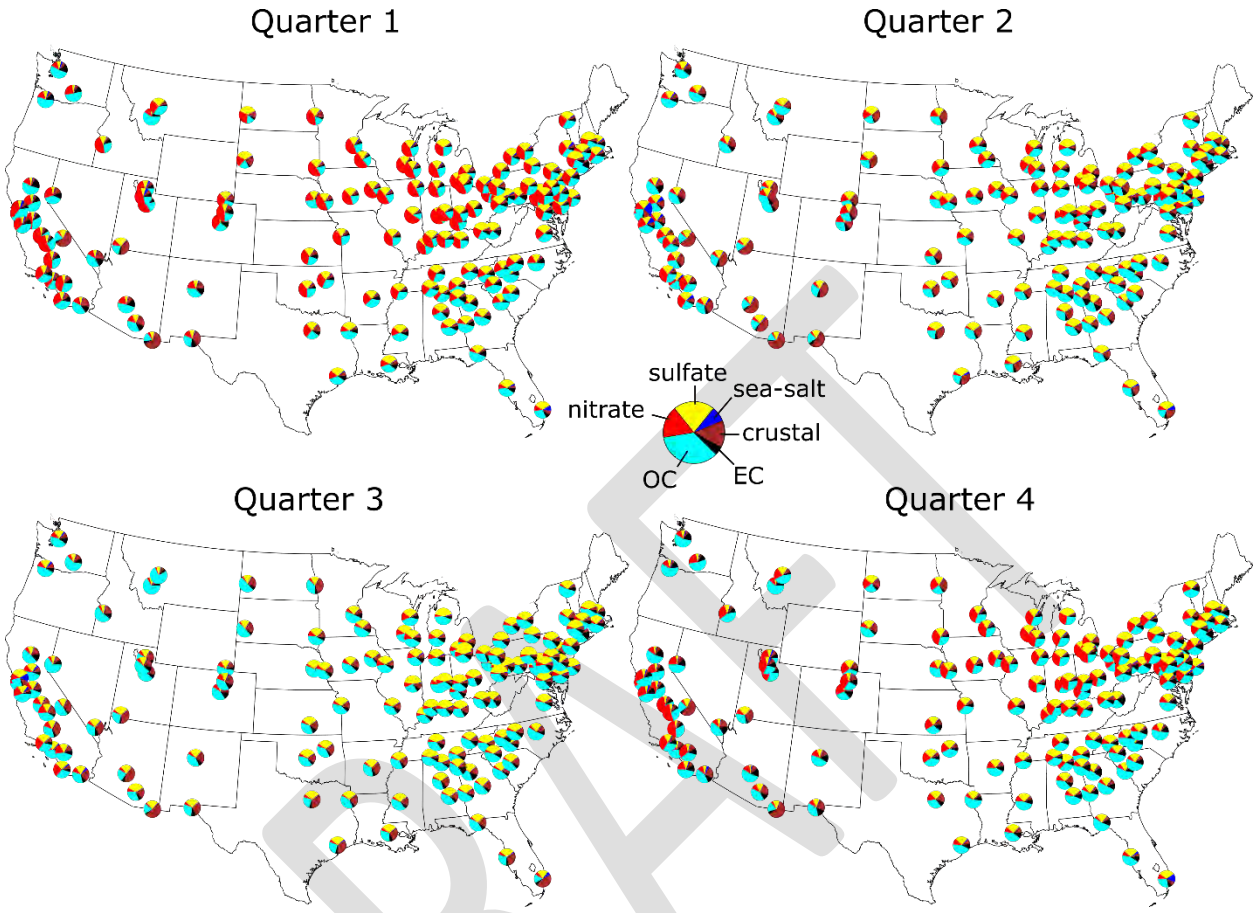
Fine particles often have a seasonal pattern. Both daily values and quarterly average of $PM_{2.5}$ also reveal patterns based on the time of year. Unlike daily O_3 levels, which are usually elevated in the summer, daily $PM_{2.5}$ values at some locations can be high at any time of the year. As shown in Figure A-11, $PM_{2.5}$ values in the eastern half of the United States are typically higher in the third calendar quarter (July-September) when sulfates are more readily formed from sulfur dioxide (SO_2) emissions from power plants in that region and when secondary organic aerosol is more readily formed in the atmosphere. Fine particle concentrations tend to be higher in the first calendar quarter (January through March) in the Midwest in part because fine particle nitrates are more readily formed in cooler weather. $PM_{2.5}$ values are high during the first (January through March) and fourth calendar quarter (October through December) in many areas of the West, in part because of fine particle nitrates and also due to carbonaceous particles which are directly emitted from wood stove and fireplace use. Average concentration from all locations reporting $PM_{2.5}$ with valid design values is shown.

Figure A-11. Quarterly Averages of $PM_{2.5}$ Concentration (µg m^{-3}): 2013-2015



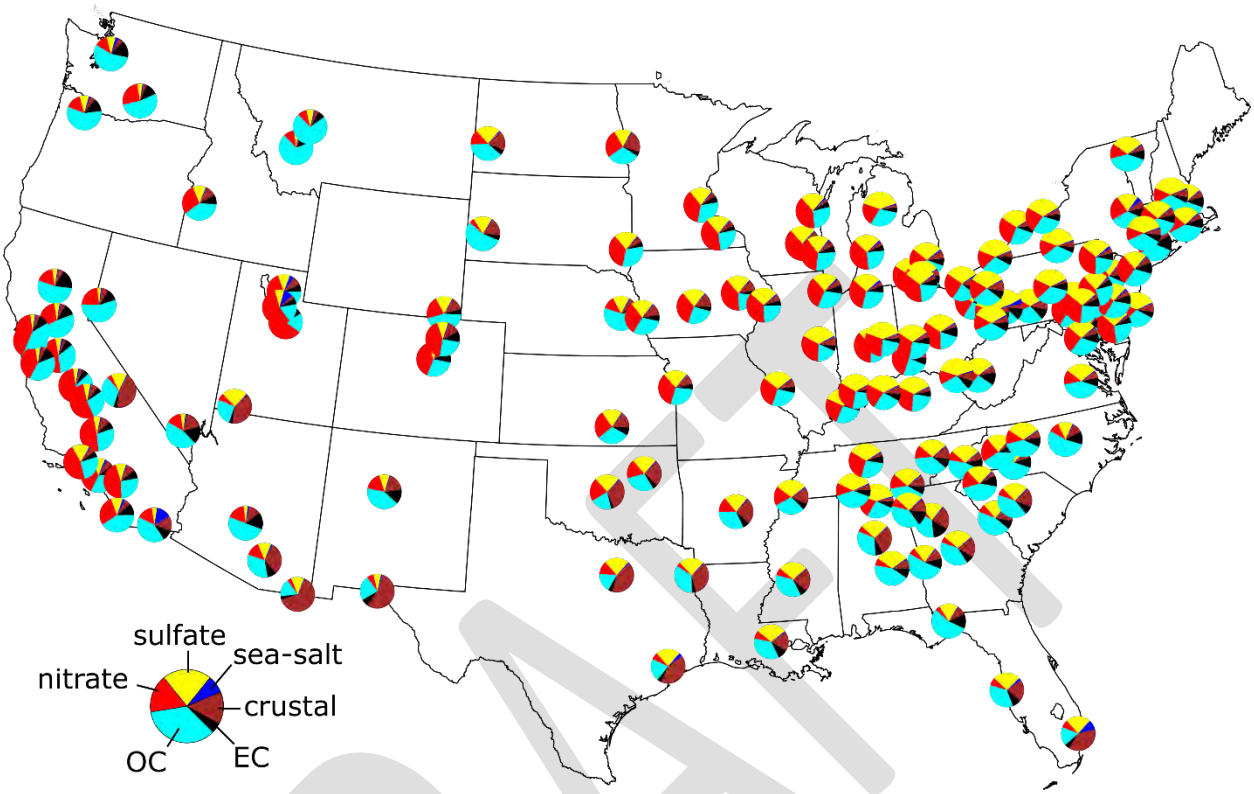
The composition of $PM_{2.5}$ also varies by season and helps explain why mass varies by season. Figure A-12 shows the average composition by season (spring, summer, fall and winter) for $PM_{2.5}$ data collected during 2013-2015. In the eastern United States, sulfate are high in the spring (March-May) and summer (July-September). Nitrates are most evident in the midwest and western cities where its percentage is moderately high in the winter and fall. Organic carbon (OC) is high throughout the year.

Figure A-12. Quarterly Average $PM_{2.5}$ Composition grouped by CBSA: 2013-2015



The composition of the highest daily $PM_{2.5}$ values may be different than that for the annual average. Figure A-13 provides 2013-2015 data $PM_{2.5}$ composition on high mass days across the United States. Mass is proportioned into six components: sulfates, nitrates, OC, elemental carbon (EC), crustal material, and sea-salt. Except for the southeast (where there is little nitrate in $PM_{2.5}$), nitrates are slightly higher in the top 10 percent of the $PM_{2.5}$ days. For the 2013-2015 measurements, the percent of sulfates is currently similar or slightly less on the top 10 percent of the days as compared to the annual averages. The portion of OC appears to be similar on the high days compared to the annual averages, except for the Northern Rockies and Upper Midwest where the high days are influenced by OC from wood stoves/fireplaces and wildfires.

Figure A-13. $PM_{2.5}$ Composition on 10% highest mass concentration days grouped by CBSA: 2013-2015



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Appendix B: General Guidance on Use of Dispersion Models for Estimating Primary $PM_{2.5}$ Concentrations

This appendix provides general guidance on the application of dispersion models for estimating ambient concentrations of $PM_{2.5}$ associated with direct emissions of primary $PM_{2.5}$. This guidance is based on and is consistent with the EPA's *Guideline on Air Quality Models*, published as Appendix W of 40 CFR part 51, and focuses primarily on the application of AERMOD, the EPA's preferred dispersion model for most situations. Appendix W is the primary source of information on the regulatory application of air quality models for State Implementation Plan (SIP) revisions for existing sources and for New Source Review (NSR) and Prevention of Significant Deterioration (PSD) programs. There will be applications of dispersion models unique to specific areas, (*i.e.*, there may be areas of the country where it is necessary to model unique specific sources or types of sources). In such cases, there should be consultation with the state or appropriate permitting authority with the appropriate EPA Regional Office modeling contact to discuss how best to model a particular source.

Recently issued EPA guidance of relevance for consideration in modeling for $PM_{2.5}$ includes:

- "Model Clearinghouse Review of Modeling Procedures for Demonstrating Compliance with $PM_{2.5}$ NAAQS" February 26, 2010 (U.S. EPA, 2010a);
- "Modeling Procedures for Demonstrating Compliance with $PM_{2.5}$ NAAQS" March 23, 2010 (U.S. EPA, 2010b); and
- "Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas" November 2013 (U.S.EPA, 2013a).

The guidance listed above, in addition to other relevant support documents can be found on the SCRAM website at: https://www.epa.gov/scram.

The following sections will refer to the relevant sections of Appendix W and other existing guidance with summaries as necessary. Please refer to those original guidance documents for full discussion and consult with the appropriate EPA Regional Office modeling contact if questions arise about interpretation on modeling techniques and procedures.[45]

1. Model selection

Preferred air quality models for use in regulatory applications are addressed in Appendix A of the EPA's *Guideline on Air Quality Models*. If a model is to be used for a particular application, the user should follow the guidance on the preferred model for that application. These models may be used without an area specific formal demonstration of applicability as long as they are used as indicated in each model summary of Appendix A. Further recommendations for the application of these models to specific source problems are found in Appendix W. In

[45] A list of EPA Regional Office modeling contacts is available on the SCRAM website at: https://www.epa.gov/scram/air-modeling-regional-contacts.

2005, the EPA promulgated the American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) as the Agency's preferred near-field dispersion model for a wide range of regulatory applications in all types of terrain based on extensive developmental and performance evaluation. For PSD/NSR modeling under the $PM_{2.5}$ NAAQS, AERMOD should be used to model primary $PM_{2.5}$ emissions unless use of an alternative model can be justified (section 3.2, Appendix W).

The AERMOD modeling system includes the following components:

- AERMOD: the dispersion model (U.S. EPA, 2019a);
- AERMAP: the terrain processor for AERMOD (U.S. EPA, 2018,); and
- AERMET: the meteorological data processor for AERMOD (U.S. EPA, 2019b;).

Other components that may be used, depending on the application, are:

- BPIPPRIME: the building input processor (U.S. EPA, 2004);
- AERSURFACE: the surface characteristics processor for AERMET (U.S. EPA, 2008);
- AERSCREEN: a screening version of AERMOD (U.S. EPA, 2016a; U.S. EPA, 2011); and
- AERMINUTE: a pre-processor to calculate hourly average winds from ASOS 2-minute observations (U.S. EPA, 2015).

Before running AERMOD, the user should become familiar with the user's guides associated with the modeling components listed above and the AERMOD Implementation Guide (AIG) (U.S. EPA, 2019c). The AIG lists several recommendations for applications of AERMOD that would be applicable for SIP and PSD permit modeling.

1.2. Receptor grid

The model receptor grid is unique to the particular situation and depends on the size of the modeling domain, the number of modeled sources, and complexity of the terrain. Receptors should be placed in areas that are considered ambient air (*i.e.*, outside of buildings and where the public generally has access) and placed out to a distance such that areas of violation can be detected from the model output to help determine the size of nonattainment areas. Receptor placement should be of sufficient density to provide resolution needed to detect significant gradients in the concentrations with receptors placed closer together near the source to detect local gradients and placed farther apart away from the source. In addition, the user may want to place receptors at key locations such as around facility "fence lines"[46] (which define the ambient air boundary for a particular source) or monitor locations (for comparison to monitored

[46] It should be noted that the term "fence line" for modeling purposes generally makes reference to a source's property boundary and may not refer literally to the existence of a fence at such boundary. The EPA's "ambient air" policy does not mandate that public access to a source's property be precluded by a fence; other measures that effectively preclude public access may be approved for establishing an ambient air exclusion for PSD modeling purposes.

concentrations for model evaluation purposes). The receptor network should cover the modeling domain. States may already have existing receptor placement strategies in place for regulatory dispersion modeling under NSR/PSD permit programs.

If modeling indicates elevated levels of $PM_{2.5}$ (near the standard) near the edge of the receptor grid, consideration should be given to expanding the grid or conducting an additional modeling run centered on the area of concern. As noted above, terrain complexity should also be considered when setting up the receptor grid. If complex terrain is included in the model calculations, AERMOD requires that receptor elevations be included in the model inputs. In those cases, the AERMAP terrain processor (U.S. EPA, 2018) should be used to generate the receptor elevations and hill heights. The latest version of AERMAP (version 09040 or later) can process either Digitized Elevation Model (DEM) or National Elevation Data (NED) data files. The AIG recommends the use of NED data since it is more up to date than DEM data, which is no longer updated (Section 4.3 of the AIG).

2. Source inputs

This section provides guidance on source characterization to develop appropriate inputs for dispersion modeling with the AERMOD modeling system. Section 2.1 provides guidance on use of emission, Section 2.2 covers guidance on Good Engineering Practice (GEP) stack heights, Section 2.3 provides details on source configuration and source types, Section 2.4 provides details on urban/rural determination of the sources, and Section 2.5 provides general guidance on source grouping, which may be important for design value calculations.

2.1. Emissions

Consistent with Appendix W, dispersion modeling for the purposes of PSD permitting should be based on the use of continuous operation at maximum allowable emissions or federally enforceable permit limits (see Table 8-2 of Appendix W) for the project source for all applicable averaging periods. Also consistent with past and current guidance, in the absence of maximum allowable emissions or federally enforceable permit limits, potential to emit emissions (*i.e.*, design capacity) should be used. Maximum allowable emissions and continuous operation should also be assumed for nearby sources included in the modeled inventory for the 24-hr $PM_{2.5}$ NAAQS, while maximum allowable emissions and the actual operating factor averaged over the most recent 2 years should be used for modeled nearby sources for the annual $PM_{2.5}$ NAAQS.

2.2. Good Engineering Practice (GEP) stack height

Consistent with previous modeling guidance and section 7.2.2.1 of Appendix W, for stacks with heights that are within the limits of Good Engineering Practice (GEP), actual heights should be used in modeling. Under the EPA's regulations at 40 CFR 51.100, GEP height, H_g, is determined to be the greater of:

- 65 m, measured from the ground-level elevation at the base of the stack;
- for stacks in existence on January 12, 1979, and for which the owner or operator had obtained all applicable permits or approvals required under 40 CFR parts 51 and 52

H_g=2.5H

provided the owner or operator produces evidence that this equation was actually relied on in designing the stack or establishing an emission limitation to ensure protection against downwash;

- for all other stacks,

  H_g=H + 1.5L,

  where H is the height of the nearby structure(s) measured from the ground-level elevation at the base of the stack and L is the lesser dimension of height or projected width of nearby structure(s); or

- the height demonstrated by a fluid model or a field study approved by the EPA or the state/local permitting agency which ensures that the emissions from a stack do not result in excessive concentrations of any air pollutant as a result of atmospheric downwash, wakes, eddy effects created by the source itself, nearby structures or nearby terrain features.

For more details about GEP, see the Guideline for Determination of Good Engineering Practice Stack Height Technical Support Document (U.S. EPA, 1985).

If stack heights exceed GEP, then GEP heights should be used with the individual stack's other parameters (temperature, diameter, exit velocity). For stacks modeled with actual heights below GEP that may be subject to building downwash influences, building downwash should be considered as this can impact concentrations near the source (section 7.2.2.1(b), Appendix W). If building downwash is being considered, the BPIPPRIME program (U.S. EPA, 2004) should be used to input building parameters for AERMOD.

2.3. Source configurations and source types

An accurate characterization of the modeled facilities is critical for refined dispersion modeling, including accurate stack parameters and physical plant layout. Accurate stack parameters should be determined for the emissions being modeled. Since modeling would be done with maximum allowable or potential emissions levels at each stack, the stack's parameters such as exit temperature, diameter, and exit velocity should reflect those emissions levels. Accurate locations (*i.e.*, latitude and longitude or Universal Transverse Mercator (UTM) coordinates and datum)[47] of the modeled emission sources are also important, as this can affect the impact of an emission source on receptors, determination of stack base elevation, and relative location to any nearby building structures. Not only are accurate stack locations needed, but accurate information for any nearby buildings is important. This information would include

[47] Latitudes and longitudes to four decimal places position a stack within 30 feet of its actual location and five decimal places position a stack within three feet of its actual location. Users should use the greatest precision available.

location and orientation relative to stacks and building size parameters (height, and corner coordinates of tiers) as these parameters are input into BPIPPRIME to calculate building parameters for AERMOD. If stack locations and or building information are not accurate, downwash will not be accurately accounted for in AERMOD.

Emission source type characterization within the modeling environment is also important. As stated in the AERMOD User's Guide (U.S. EPA, 2019a), emissions sources can be characterized as several different source types: POINT sources, capped stacks (POINTCAP), horizontal stacks (POINTHOR), VOLUME sources, OPENPIT sources, LINE sources, buoyant lines sources (BUOYLINE), rectangular AREA sources, circular area sources (AREACIRC), and irregularly shaped area sources (AREAPOLY). While most sources can be characterized as POINT sources, some sources, such as fugitive releases or nonpoint sources (emissions from ports/ships, airports, or smaller point sources with no accurate locations), may be best characterized as VOLUME or AREA type sources. Sources such as flares can be modeled in AERMOD using the parameter input methodology described in Section 2.1.2 of the AERSCREEN User's Guide (U. S. EPA, 2016a). If questions arise about proper source characterization or typing, users should consult the appropriate EPA Regional Office modeling contact.

2.4. Urban/rural determination

For any dispersion modeling exercise, the urban or rural determination of a source is important in determining the boundary layer characteristics that affect the model's prediction of downwind concentrations. Figure B-1 gives example maximum 24-hour concentration profiles for a 10 meter stack (Figure B-1a) and a 100 m stack (Figure B-1b) based on urban vs. rural designation. The urban population used for the examples is 100,000. In Figure B-1a, the urban concentration is much higher than the rural concentration for distances less than 750 m from the stack but then drops below the rural concentration beyond 750 m. For the taller stack in Figure B-1b, the urban concentration is much higher than the rural concentration even as distances increase from the source. These profiles show that the urban or rural designation of a source can be quite important.

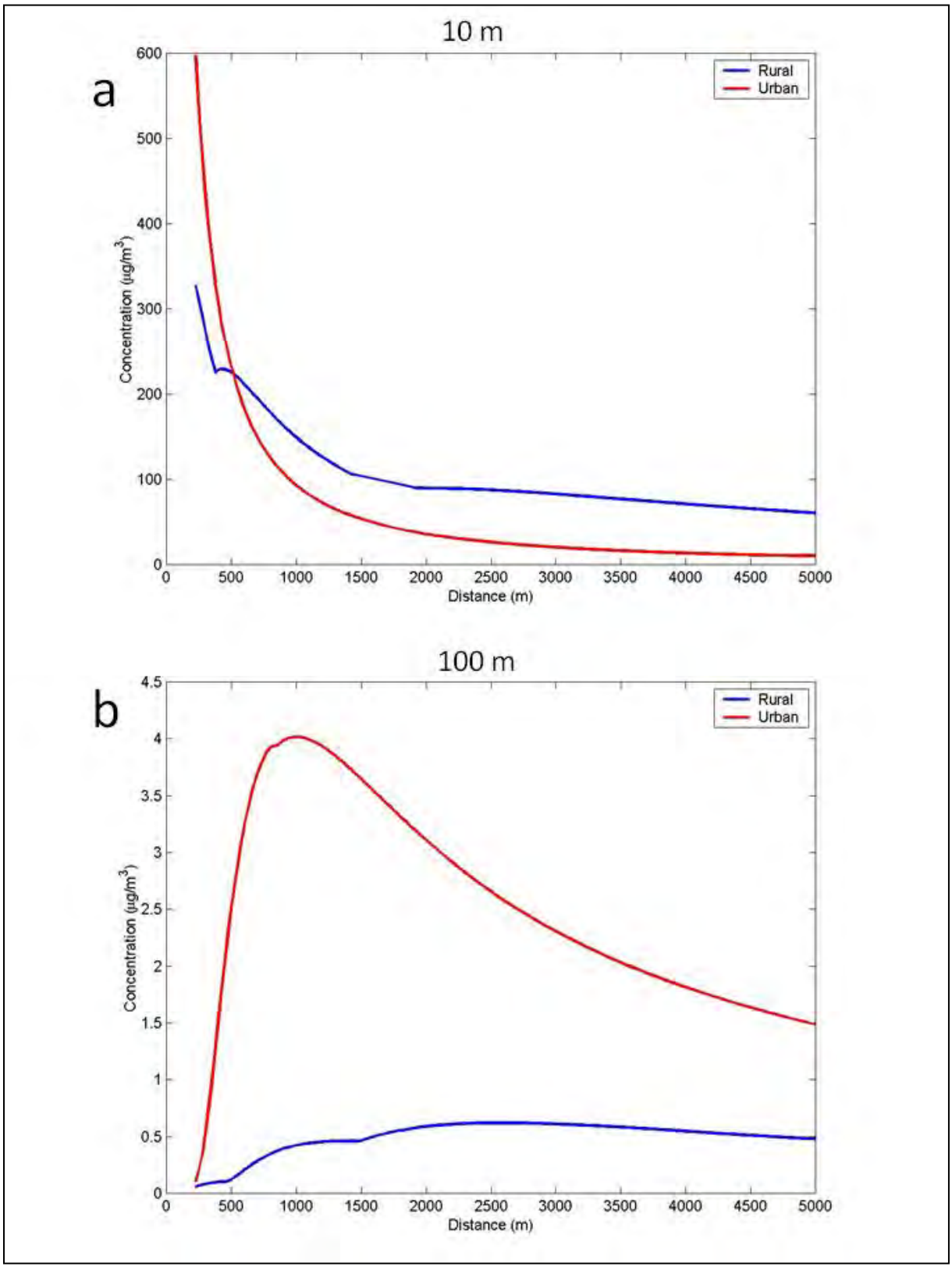
Determining whether a source is urban or rural can be done using the methodology outlined in section 7.2.1.1 of Appendix W and recommendations outlined in Sections 5.1 through 5.3 in the AIG (U.S. EPA, 2019c). In summary, there are two methods of urban/rural classification described in section 7.2.3 of Appendix W.

The first method of urban determination is a land use method (Appendix W, section 7.2.2.1.1(b)(i)). In the land use method, the user analyzes the land use within a 3 km radius of the source using the meteorological land use scheme described by Auer (1978). Using this methodology, a source is considered urban if the land use types I1 (heavy industrial), I2 (light-moderate industrial), C1 (commercial), R2 (common residential), and R3 (compact residential) are 50 percent or more of the area within the 3 km radius circle. Otherwise, the source is considered a rural source. The second method uses population density and is described in section 7.2.2.1.1(b)(ii) of Appendix W. As with the land use method, a circle of 3 km radius is used. If the population density within the circle is greater than 750 people/km^2, then the source is

considered urban. Otherwise, the source is modeled as a rural source. Of the two methods, the land use method is considered more definitive (section 7.2.1.1.b, Appendix W).

Caution should be exercised with either classification method. As stated in Section 5.1 of the AIG (U.S. EPA, 2009), when using the land use method, a source may be in an urban area but located close enough to a body of water or other non-urban land use category to result in an erroneous rural classification for the source. The AIG in Section 5.1 cautions users against using the land use scheme on a source by source basis, but advises considering the potential for urban heat island influences across the full modeling domain. When using the population density method, section 7.2.2.1.1(b)(ii)of Appendix W states, "Population density should be used with caution and should not be applied to highly industrialized areas where the population density may be low and thus a rural classification would be indicated, but the area is sufficiently built-up so that the urban land use criteria would be satisfied..." With either method, section 7.2.1.1(f) of Appendix W recommends modeling all sources within an urban complex as urban, even if some sources within the complex would be considered rural using either the land use or population density method.

Figure B-1. Urban (red) and rural (blue) concentration profiles for (a) 10 m buoyant stack release, and (b) 100 m buoyant stack release



Another consideration that may need attention by the user, and is discussed in Section 5.1 of the AIG, relates to tall stacks located within or adjacent to small to moderate size urban areas. In such cases, the stack height or effective plume height for very buoyant sources may extend above the urban boundary layer height. The application of the urban option in AERMOD for these types of sources may artificially limit the plume height. The use of the urban option may not be appropriate for these sources, since the actual plume is likely to be transported over the urban boundary layer. Section 5.1 of the AIG gives details on determining if a tall stack should be modeled as urban or rural based on comparing the stack or effective plume height to the urban boundary layer height. The 100 m stack illustrated in Figure B-1b, may be such an example as the urban boundary layer height for this stack would be 189 m (based on a population of 100,000) and equation 104 of the AERMOD formulation document (Cimorelli, et al., 2004). This equation is:

$$z_{iuc} = z_{iuo}\left(\frac{P}{P_o}\right)^{1/4} \quad \text{(B-1)}$$

where z_{iuo} is a reference height of 400 m corresponding to a reference population P_o of 2,000,000 people.

Given that the stack is a buoyant release, the plume may extend above the urban boundary layer and may be best characterized as a rural source, even if it were near an urban complex. However, beginning with version 15181 of AERMOD, a formulation bug fix was incorporated that modified the treatment of plume rise for urban sources, especially for tall stacks in urban areas. See Section 5.1 of the AIG for more information. Even with the bug fix in AERMOD 15181, exclusion of these elevated sources from application of the urban option would need to be justified on a case-by-case basis in consultation with the appropriate permitting authority.

AERMOD requires the input of urban population when utilizing the urban option. Population can be entered to one or two significant digits (*i.e.*, an urban population of 1,674,365 can be entered as 1,700,000). Users can enter multiple urban areas and populations using the URBANOPT keyword in the runstream file (U.S. EPA, 2019a). If multiple urban areas are entered, AERMOD requires that each urban source be associated with a particular urban area or AERMOD model calculations will abort. Urban populations can be determined by using a method described in Section 5.2 of the AIG (U.S. EPA, 2019c).

2.5. Source groups

In AERMOD, individual emission sources' concentration results can be combined into groups using the SRCGROUP keyword (Section 3.3.11 of the AERMOD User's Guide (U.S, EPA, 2019a). The user can automatically calculate a total concentration (from all sources) using the SRCGROUP ALL keyword. For the purposes of design value calculations, source group ALL should be used, especially if all sources in the modeling domain are modeled in one AERMOD run. Design values should be calculated from the total concentrations (all sources and background). Individual source impacts on the total concentration may be necessary to determine the culpability to any NAAQS violations.

3. Meteorological data

This section gives guidance on the selection of meteorological data for input into AERMOD. Much of the guidance from section 8.4 of Appendix W is applicable to SIP and PSD permit modeling and is summarized here. In Section 3.2.1, the use of the tool, AERMINUTE (U.S. EPA, 2015), is introduced. AERMINUTE is an AERMET pre-processor that calculates hourly averaged winds from ASOS (Automated Surface Observing System) 1-minute winds. Section 3.2.4 discusses the use of prognostic meteorological data.

3.1. Surface characteristics and representativeness

The selection of meteorological data that are input into a dispersion model should be considered carefully. The selection of data should be based on spatial and climatological (temporal) representativeness (Appendix W, section 8.4). The representativeness of the data is based on: 1) the proximity of the meteorological monitoring site to the area under consideration, 2) the complexity of terrain, 3) the exposure of the meteorological site, and 4) the period of time during which data are collected. Sources of meteorological data are: National Weather Service (NWS) stations, site-specific or onsite data, and other sources such as universities, Federal Aviation Administration (FAA), military stations, and others. In specific cases, prognostic meteorological data may be appropriate for use and obtained from similar sources. Appendix W addresses spatial representativeness issues in sections 8.4.1.a and 8.4.2.b.

Spatial representativeness of the meteorological data can be adversely affected by large distances between the source and receptors of interest and the complex topographic characteristics of the area (Appendix W, sections 8.4.1.a and 8.4.2.b). If the modeling domain is large enough such that conditions vary drastically across the domain, then the selection of a single station to represent the domain should be carefully considered. Also, care should be taken when selecting a station if the area has complex terrain. While a source and meteorological station may be in close proximity, there may be complex terrain between them such that conditions at the meteorological station may not be representative of the source. An example would be a source located on the windward side of a mountain chain with a meteorological station a few kilometers away on the leeward side of the mountain. Spatial representativeness for off-site data should also be assessed by comparing the surface characteristics (albedo, Bowen ratio, and surface roughness) of the meteorological monitoring site and the analysis area. When processing meteorological data in AERMET (U.S. EPA, 2016c), the surface characteristics of the meteorological site or the prognostic meteorological model output grid cell should be used (section 8.4.2.b of Appendix W and the AERSURFACE User's Guide (U.S. EPA 2008)). Spatial representativeness should also be addressed for each meteorological variable separately. For example, temperature data from a meteorological station several kilometers from the analysis area may be considered adequately representative, while it may be necessary to collect wind data near the plume height (section 8.4.2.b of Appendix W).

Surface characteristics can be calculated in several ways. For details, see Section 3.1.2 of the AIG (U.S. EPA, 2019c). The EPA has developed a tool, AERSURFACE (U.S. EPA, 2008) to aid in the determination of surface characteristics for observed meteorological data. The current version of AERSURFACE uses the 1992 National Land Cover Data. Note that the use of

AERSURFACE is not a regulatory requirement, but the methodology outlined in Section 3.1.2 of the AIG should be followed unless an alternative method can be justified. For prognostic meteorological output, the surface characteristics of the representative grid cell should be used.

3.2. Meteorological inputs

Appendix W states in section 8.4.2.e that the user should acquire enough meteorological data to ensure that worst-case conditions are adequately represented in the model results. Appendix W states that 5 years of NWS meteorological data, at least 1 year of site-specific data, or at least 3 years of prognostic data should be used and should be adequately representative of the study area. If 1 or more years of site-specific data are available, those data are preferred. While the form of the $PM_{2.5}$ NAAQS contemplates obtaining 3 years of monitoring data, this does not preempt the use of 5 years of NWS data or at least 1 year of site-specific data in the modeling. The 5-year average based on the use of NWS data, an average across 3 or more years of prognostic data, or an average across 1 or more years of available site specific data, serves as an unbiased estimate of the 3-year average for purposes of modeling demonstrations of compliance with the NAAQS.

3.2.1. NWS data

NWS data are available from the National Climatic Data Center (NCDC) in many formats, with the most common one in recent years being the Integrated Surface Hourly data (ISH). Most available formats can be processed by AERMET. As stated in Section 3.1, when using data from an NWS station alone or in conjunction with site-specific data, the data should be spatially and temporally representative of conditions at the modeled sources. Key points regarding the use of NWS data can be found in the EPA's March 8, 2013 clarification memo "Use of ASOS meteorological data in AERMOD dispersion modeling" (U.S. EPA, 2013b). The key points are:

- The EPA has previously analyzed the effects of ASOS implementation on dispersion modeling and found that generally AERMOD was less sensitive than ISCST3 to the implementation of ASOS.
- The implementation of the ASOS system over the conventional observation system should not preclude the consideration of NWS stations in dispersion modeling.
- The EPA has implemented an adjustment factor (0.5 knots) in AERMET to adjust for wind speed truncation in ASOS winds
- The EPA has developed the AERMINUTE processor (U.S. EPA, 2015) to process 2-minute ASOS winds and calculate an hourly average for input into AERMET. The use of hourly averaged winds better reflect actual conditions over the hour as opposed to a single 2-minute observation.

3.2.2. Site-specific data

The use of site-specific meteorological data is the best way to achieve spatial

representativeness. AERMET can process a variety of formats and variables for site-specific data. The use of site-specific data for regulatory applications is discussed in detail in section 8.4.4 of Appendix W. Due to the range of data that can be collected onsite and the range of formats of data input to AERMET, the user should consult Appendix W, the AERMET User's Guide (U.S. EPA, 2016c), and Meteorological Monitoring Guidance for Regulatory Modeling Applications (U.S. EPA, 2000). Also, when processing site-specific data for an urban application, Section 3.3 of the AERMOD Implementation Guide offers recommendations for data processing. In summary, the guide recommends that site-specific turbulence measurements should not be used when applying AERMOD's urban option in order to avoid double counting the effects of enhanced turbulence due to the urban heat island.

3.2.3. Upper air data

AERMET requires full upper air soundings to calculate the convective mixing height. For AERMOD applications in the U.S., the early morning sounding, usually the 1200 UTC (Universal Time Coordinate) sounding, is typically used for this purpose. Upper air soundings can be obtained from the Radiosonde Data of North America CD for the period 1946-1997. Upper air soundings for 1994 through the present are also available for free download from the Radiosonde Database Access website. Users should choose all levels or mandatory and significant pressure levels[48] when selecting upper air data. Selecting mandatory levels only would not be adequate for input into AERMET as the use of just mandatory levels would not provide an adequate characterization of the potential temperature profile.

3.2.3. Prognostic data

In specific situations where it is infeasible or cost prohibitive to collect adequately representative site-specific data or there is not a representative NWS or comparable meteorological station available, it may be appropriate to use prognostic meteorological data, if deemed adequately representative. However, if prognostic data are not representative of the transport and dispersion conditions in the area of concern, the collection of site-specific data is necessary (section 8.4.5.1 of Appendix W). To facilitate the use of prognostic meteorological data, EPA has developed a processor, Mesoscale Model Interface Program, MMIF (Environ, 2015), to process MM5 (Mesoscale Model 5) or WRF (Weather Research Forecast) model data for input to various models including AERMOD. MMIF can process data for input to AERMET or AERMOD for a single grid cell or multiple grid cells. For regulatory applications, MMIF should be run to create inputs for AERMET input as described in section 8.4.5.1.b of Appendix W and MMIF guidance (U.S. EPA, 2016b). Specific guidance on running MMIF for AERMOD applications can be found in U.S. EPA, 2016b.

4. Running AERMOD and implications for design value calculations

Recent enhancements to AERMOD include options to aid in the calculation of design

[48] By international convention, mandatory levels are in millibars: 1,000, 850, 700, 500, 400, 300, 200, 150, 100, 50, 30, 20, 10, 7 5, 3, 2, and 1. Significant levels may vary depending on the meteorological conditions at the upper-air station.

values for comparison with the $PM_{2.5}$ NAAQS and to aid in determining whether emissions from the project source caused or contributed to any modeled violations. These enhancements include:

- The MAXDCONT option, which shows the impact of each user-specified source group to the high ranked values for a specified target source group paired in time and space. The user can specify a range of ranks to analyze or specify an upper bound rank, *i.e.*, 8th highest, corresponding to the 98th percentile for the 24-hour $PM_{2.5}$ NAAQS, and a lower threshold concentration value, such as the NAAQS for the target source group. The model will process each rank within the range specified, but will stop after the first rank (in descending order of concentration) that is below the threshold value if specified by the user. A warning message will be generated if the threshold is not reached within the range of ranks analyzed (based on the range of ranks specified on the RECTABLE keyword). This option may be needed to aid in determining which sources should be considered for controls.

For more details about the enhancements, see the AERMOD User's Guide (U. S. EPA, 2019a).

Ideally, all explicitly modeled sources, receptors, and background should be modeled in one AERMOD run for all modeled years. In this case, one of the above output options can be used in AERMOD to calculate design values for comparison to the NAAQS and determine the area's attainment status and/or inform attainment/nonattainment boundaries. The use of these options in AERMOD allows AERMOD to internally calculate concentration metrics that can be used to calculate design values and, therefore, lessen the need for large output files, *i.e.*, hourly POSTFILES.

However, there may be situations where a single AERMOD run with all explicitly modeled sources is not possible. These situations often arise due to runtime or storage space considerations during the AERMOD modeling. Sometimes separate AERMOD runs are done for each facility or group of facilities, or by year, or the receptor network is divided into separate sub-networks. In some types of these situations, the MAXDCONT output option may not be an option for design value calculations, especially if all sources are not included in a single run. If the user wishes to utilize one of the three output options, then care should be taken in developing the model inputs to ensure accurate design value calculations.

Situations that would effectively preclude the use of the MAXDCONT option to calculate meaningful AERMOD design value calculations include the following examples:

- Separate AERMOD runs for each source or groups of sources.
    - SIP modeling includes 10 facilities for 5 years of NWS data and each facility is modeled for 5 years in a separate AERMOD run, resulting in ten separate AERMOD runs.
- Separate AERMOD runs for each source and each modeled year.
    - 10 facilities are modeled for 5 years of NWS data. Each facility is modeled separately for each year, resulting in fifty individual AERMOD runs.

In the two situations listed above, the MAXDCONT option would not be useful as the

different AERMOD runs do not include a total concentration with impacts from all facilities. In these situations, the use of 24-hour POSTFILES, which can be quite large, and external post-processing would be needed to calculate design values.

Situations in which the MAXDCONT options may be used but may necessitate some external post-processing afterwards to calculate a design value include:

- The receptor network is divided into sections and an AERMOD run, with all sources and years, is made for each sub-network.
    - A receptor network of 1,000 receptors is divided into four 250 receptor sub-networks. 10 facilities are modeled with 5 years of NWS data in one AERMOD run for each receptor network, resulting in four AERMOD runs. After the AERMOD runs are complete, the MAXDCONT results for each network can be re-combined into the larger network.
- All sources and receptors are modeled in an AERMOD run for each year.
- Ten facilities are modeled with 5 years of NWS data. All facilities are modeled with all receptors for each year individually, resulting in five AERMOD runs. MAXDCONT output can be used and post-processed to generate the necessary design value concentrations. The receptor network is divided and each year is modeled separately for each sub-network with all sources.
- Ten facilities are modeled with 5 years of NWS data for 1,000 receptors. The receptor network is divided into four 250 receptor networks. For each sub-network, all ten facilities are modeled for each year separately, resulting in twenty AERMOD runs. MAXDCONT output can be used and post-processed to generate the necessary design value concentrations.

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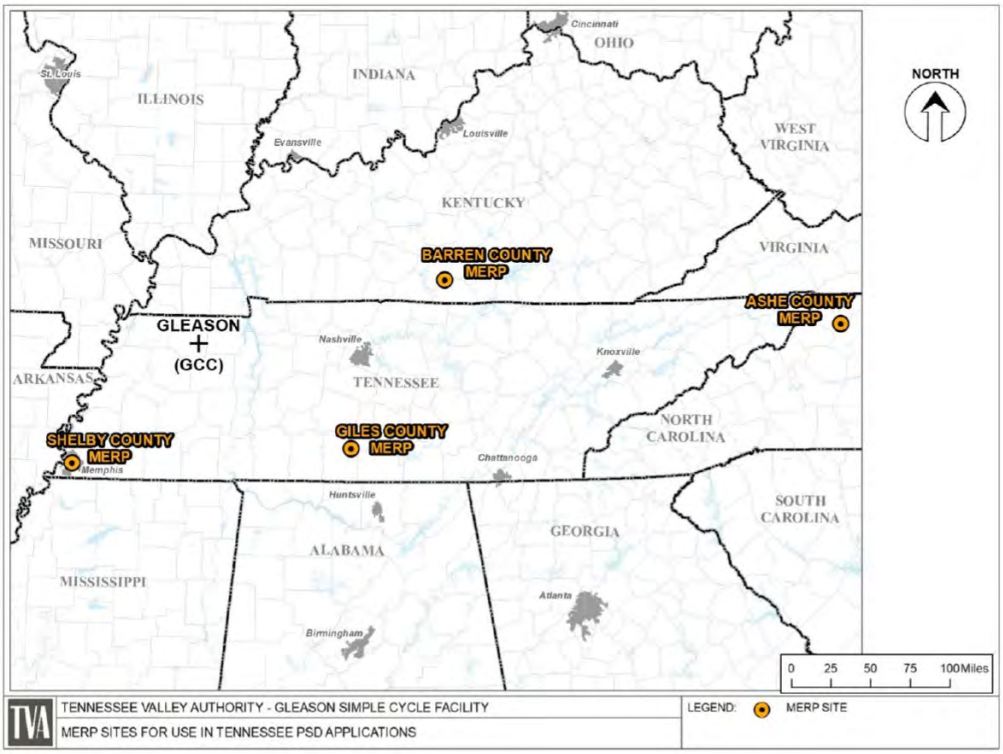
Appendix C: Example of a Tier 1 Demonstration of the Potential for O_3 and Secondary $PM_{2.5}$ Formation

In 2018, a permit applicant, the Tennessee Valley Authority (TVA) Gleason Combustion Turbine Plant, worked closely with the Tennessee Department of Environment and Conservation (TDEC) and EPA Region 4 to develop a compliance demonstration for a major facility modification, including the use of a Tier 1 assessment of O_3 and secondary $PM_{2.5}$ impacts. This Tier 1 assessment was based on the application of Modeled Emission Rates for Precursors (MERPs) and related modeling guidance released by the EPA. In April 2018, the TDEC published state modeling guidance that can be used by PSD applicants in Tennessee that largely restated the technical aspects of the guidance presented in the EPA's 2016 Draft MERPs Guidance.[49] In support of the 2016 Draft MERPs Guidance, the EPA performed photochemical modeling for four hypothetical sources from within Tennessee or in close proximity to Tennessee (Shelby County, TN, Giles County, TN, Barren County, KY and Ashe County, NC), that can be used to represent the O_3 and secondary $PM_{2.5}$ pollutant formation from other large sources in Tennessee (Figure 1).

FIGURE 1



[49] The EPA released a draft version of the "Guidance on the Development of Modeled Emission Rates for Precursors (MERPs) as a Tier 1 Demonstration Tool for Ozone and $PM_{2.5}$ under the PSD Permitting Program" on December 2, 2016, for public review and comment. Based on the feedback gained from this draft, the EPA released a non-draft or final version of the "MERPs Guidance" on April 30, 2019. The information in the 2016 draft MERPs Guidance from which the TDEC based their April 2018 modeling guidance did not substantively change and is representative of information contained in the current 2019 final version of the MERPs Guidance. The 2019 final MERPs Guidance is available at: https://www3.epa.gov/ttn/scram/guidance/guide/EPA-454_R-19-003.pdf.

Assessment of $PM_{2.5}$

Based on information in the EPA's 2016 Draft MERPs Guidance, the lowest, most conservative MERPs from these four hypothetical source locations were established in the TDEC state modeling guidance as the default MERPs that can be used throughout Tennessee without the need for further justification (Table 1). The TVA used these default MERPs to assess secondary $PM_{2.5}$ impacts for the proposed modification at the Gleason facility.

TABLE 1
Default MERPs for Use in TN PSD Applications [1,2]

Precursor	MERPs for 8-hr O_3 (tons/yr)	MERPs for Daily $PM_{2.5}$ (tons/yr)	MERPs for Annual $PM_{2.5}$ (tons/yr)
NO_x	156	4,000	7,407
SO_2	-	667	6,061
VOC	1,339	-	-

Notes:
1. EPA, 2016
2. TDEC, 2018.

The combined primary and secondary impacts of $PM_{2.5}$ for the source impact analysis were assessed using the highest (AERMOD) modeled primary $PM_{2.5}$ concentration (HMC), the Class II SIL, precursor emissions, and the default MERPs. If the sum of the ratios in Equation 4.1 below is less than 1, then the combined $PM_{2.5}$ impacts are below the $PM_{2.5}$ SIL, an adequate compliance demonstration has been performed, and no additional analyses are necessary.

The following equation was used for this assessment:

$$\frac{HMC}{SIL} + \left(\frac{NOx\_Em}{NOx\_MERP}\right) + \left(\frac{SO2\_Em}{SO2\_MERP}\right) < 1 \qquad [4.1]$$

Where:

HMC = Highest modeled primary $PM_{2.5}$ impact using AERMOD and project related $PM_{2.5}$ emissions ($\mu g/m^3$)
SIL = Significant Impact Level ($\mu g/m^3$)
NOx_Em = Project related NOx Emissions (tons per year – tpy)
NOx MERP = From Table 1 (tpy)
SO_2_Em = Project related SO_2 Emissions (tpy)
SO_2_MERP = From Table 1 (tpy)

TVA's 24-hour and annual $PM_{2.5}$ inputs to Equation 4.1 are provided in Table 2 below, and the resulting impacts are calculated in Equation 4-2 and Equation 4-3 below, respectively.

TABLE 2
Secondary $PM_{2.5}$ Inputs for the SILs in Class II Areas [1,2]

Secondary $PM_{2.5}$ Impacts	24-hr Average	Annual Average
Highest Modeled Primary $PM_{2.5}$ Concentration ($\mu g/m^3$) [3]	0.49	0.053
SILs for the NAAQS and PSD Increments in Class II areas ($\mu g/m^3$) [4]	1.2	0.2
GCC NO_x Emissions (tons/yr) [5]	2,270	2,270
Default NO_x MERPs [1]	4,000	7,407
GCC SO_2 Emissions (tons/yr) [5]	14.2	14.2
Default SO_2 MERPs [1]	667	6,061

Notes:

1. EPA, 2016 and TDEC, 2018.
2. Calculations taken from "GCC_SecPM25_O3_calcs_20180912.xlsx" provided on optical disc.
3. $PM_{2.5}$ modeling results (Table 4-9).
4. SILs for the NAAQS in Class I and Class II areas and for PSD increments in Class II areas. Based on the April 17, 2018 EPA memo, *Guidance on Significant Impact Levels for Ozone and Fine Particles in the Prevention of Significant Deterioration Permitting Program*.
5. Emissions taken from Table 3 in "Gleasn PSD Modemssn SA 20180831.xlsx" *(provided by TVA to TDEC on optical disc)*.

Combined Impacts for 24-hour $PM_{2.5}$ for the SIL in Class II Areas:

$$\frac{0.49}{1.2} + \left(\frac{2{,}270}{4{,}000}\right) + \left(\frac{14.2}{667}\right) = 0.997 \qquad [4.2]$$

Combined Impacts for Annual $PM_{2.5}$ for the SIL in Class II Areas:

$$\frac{0.053}{0.2} + \left(\frac{2{,}270}{7{,}407}\right) + \left(\frac{14.2}{6{,}061}\right) = 0.58 \qquad [4.3]$$

Both 24-hour and annual $PM_{2.5}$ impacts were less than 1, which indicated that $PM_{2.5}$ impacts were expected to be below the Class II SILs for the NAAQS and PSD increments. This indicated that emissions from TVA Gleason would not cause or contribute to a violation of the $PM_{2.5}$ NAAQS in Class II areas.

Assessment of O_3

A somewhat more refined analysis was performed to assess the impacts of the proposed project on O_3 concentrations in the area around the facility. Application of the TDEC default NO_X and VOC MERPs for O_3 shown in Table 1 above indicated that O_3 impacts would be greater than the 8-hour O_3 SIL of 1 ppb and that a cumulative O_3 assessment would be necessary to demonstrate whether the facility modification would cause or contribute to a violation of a the O_3 NAAQS.

The O_3 assessment first examined ambient O_3 concentrations in the region surrounding TVA Gleason (GCC). There are no ambient O_3 monitors in the immediate vicinity of GCC, but there are six monitors within 150 km of the facility (Figure 2 and Tables 3 and 4). The Cadiz, KY, monitor was selected as the most representative background site due to its proximity to GCC, its comparable levels of precursor emissions in the county, and it has the largest measurement scale indicating it is representative of regional air quality. The three-year average (2015- 2017) of the fourth-highest 8-hour O_3 concentration was 61 ppb, well below the 70 ppb NAAQS.

FIGURE 2

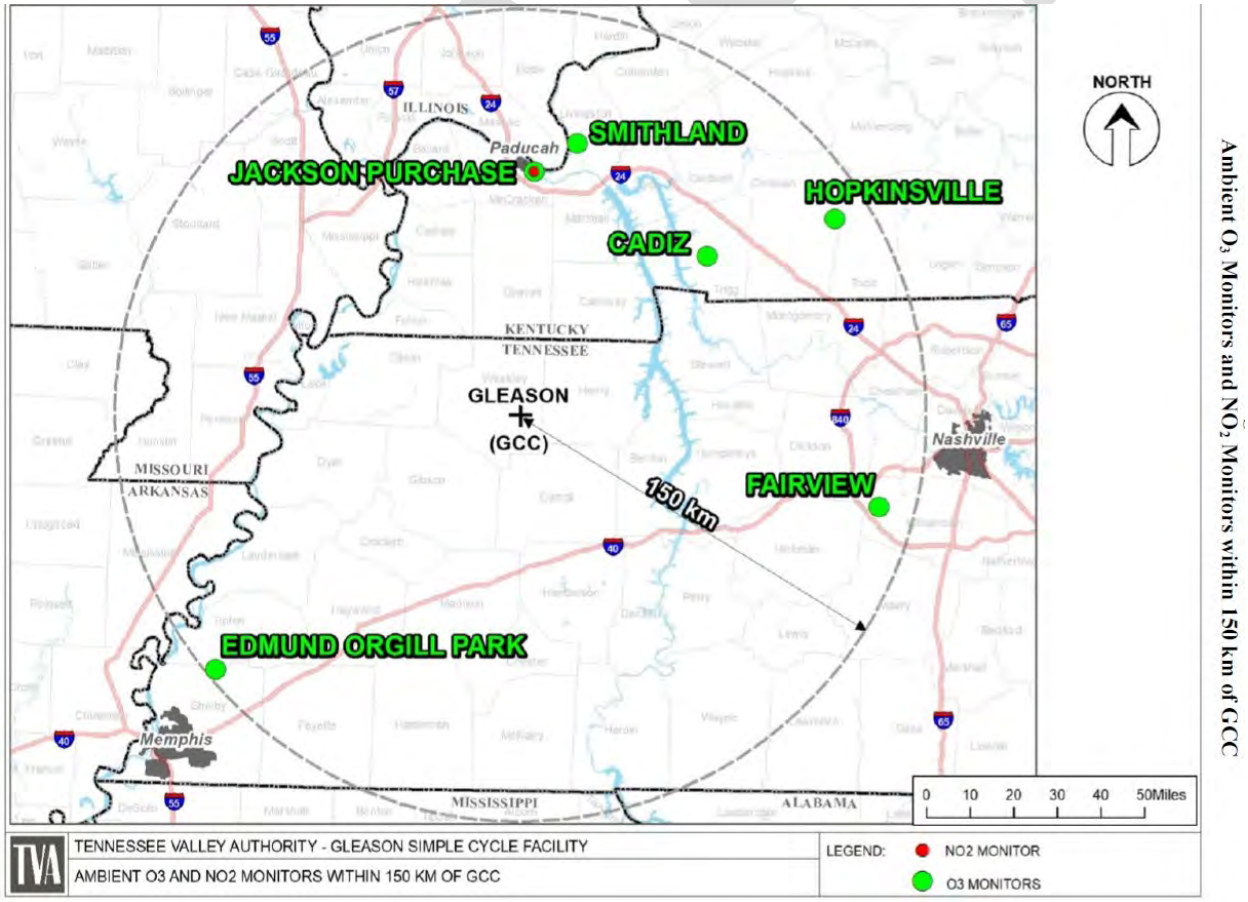


TABLE 3

Ambient O_3 Monitors within 150 km of GCC [1]

Site Name	Site ID	Distance to GCC (km)	Measurement Scale (km)	County NO_x emissions (tons/year) [2]	County VOC Emissions (tons/year) [2]
Weakley County	NA	0	NA	1,216	9,061
Jackson Purchase	21-145-1024	90	0.5 to 4	15,395	6,542
Cadiz	21-221-9991	91	50 to 100	1,424	14,173
Smithland	21-139-0003	103	4 to 50	1,441	5,933
Fairview	47-187-0106	137	4 to 50	5,721	13,557
Hopkinsville	21-047-0006	138	50 to 100	3,589	11,806
Edmund Orgill Park	47-157-1004	147	4 to 50	32,260	38,104

Notes:

1. EPA Air Quality System (AQS) Data Mart: http://www3.epa.gov/airquality/airdata/
2. EPA's National Emission Inventory, 2014 v.2.
3. Data measured during 2015-2017.

TABLE 4

Site Name	Site ID	3 Year Avg. 4th High 8-Hr Ozone Conc. (ppb)
Jackson Purchase	21-145-1024	62
Cadiz	21-221-9991	61
Smithland	21-139-0003	64
Fairview	47-187-0106	60
Hopkinsville	21-047-0006	61
Edmund Orgill Park	47-157-1004	65

As previously discussed, in April 2018, TDEC published modeling guidance on the use of EPA's MERPs in Tennessee (TDEC, 2018) that identified four hypothetical sites, located in Shelby County, TN, Giles County, TN, Barren County, KY and Ashe County, NC, to represent Tennessee sources (Figure 1). Precursor emissions in these four counties were compared to Weakley County, where GCC is located. Weakley County precursor emissions are comparable to emissions in the three rural counties (Giles, Barren and Ashe) and are much lower than Shelby County which is urban (Table 5). Ashe County is much further from GCC and is located in mountainous terrain, unlike the relatively flat terrain around GCC. Both Giles County and Barren County have similar terrain features to Weakley County. NO_X MERPs at these two sites are also lower than in Shelby County and Ashe County, which makes the analysis more conservative as ozone impacts from GCC are dominated by NO_X emissions.

TABLE 5
Comparison of Weakley County to O_3 MERPs Sites for Use in TN [1,2,3]

County	Distance to GCC (km)	Urban / Rural	Elevation (m)	County NO_x Emissions (tons/yr)[1]	County VOC Emissions (tons/yr)[1]	NO_x MERP (tons/yr)[2,3,4]	VOC MERP (tons/yr)[2,3,4]
Weakley, TN	--	Rural	110	1,216	9,061	NA	NA
Shelby, TN	177	Urban	94	32,260	38,104	714	1,339
Giles, TN	188	Rural	240	1,913	11,298	156	4,000
Barren, KY	257	Rural	256	2,122	7,580	169	3,333
Ashe, NC	650	Rural	926	730	6,507	267	8,333

Notes:
1. EPA's National Emissions Inventory, 2014 v.2.
2. EPA, 2016 and TDEC, 2018.
3. Calculations in "GCC_SecPM25_O3_calcs_20180912.xlsx" (provided on optical disc).
4. Lowest, most conservative MERP at each site.

For the two most representative hypothetical sources selected, as part of EPA's MERPs Guidance, the EPA performed photochemical modeling for two hypothetical source heights (low and high stack releases) and three hypothetical emission rates (500, 1000, and 3000 tons per year). As can be seen in Table 6 below, predicted O_3 impacts are nonlinear with respect to precursor emissions. At these hypothetical sources, the amount of O_3 formed from 3,000 tons of NO_X is substantially less than six times the amount formed from 500 tons of NO_X on a per ton basis, so using a MERP based on 500 tons of NO_X would significantly over-estimate the O_3 impacts from GCC. Therefore, this analysis used the most conservative MERPs based on emission rates most similar to emissions from GCC (hypothetical source emissions of 3,000 tons per year for NO_X and 500 tons per year for VOCs) at the two most representative sites (Giles County and Barren County) (Table 7).

TABLE 6

PRECURSOR	POLL	State	County	FIPS	TPY	Stack Ht	CONC	MERP
NO_X	OZONE	Kentucky	Barren	21009	500	10	2.908	172
NO_X	OZONE	Kentucky	Barren	21009	500	90	2.946	170
NO_X	OZONE	Kentucky	Barren	21009	1000	90	5.026	199
NO_X	OZONE	Kentucky	Barren	21009	3000	90	10.687	281
NO_X	OZONE	Tennessee	Giles	47055	500	10	2.616	191
NO_X	OZONE	Tennessee	Giles	47055	500	90	3.208	156
NO_X	OZONE	Tennessee	Giles	47055	1000	90	5.387	186
NO_X	OZONE	Tennessee	Giles	47055	3000	90	10.356	290

GCC Project Emissions are 2,270 for NOx and 158 tpy for VOC.

TABLE 7
O_3 MERPs for Various Emission Rates in Giles County and Barren County [1,2]

County	Stack	NOx Emissions (tons/yr)	NO_x MERP (tons/yr)[1,2]	VOC Emissions (tons/yr)	VOC MERP (tons/yr)[1,2]
Giles, TN	Low	500	163	500	12,500
Giles, TN	High	500	156	500	NA
Giles, TN	Low	1,000	NA	1,000	11,111
Giles, TN	High	1,000	186	1,000	10,000
Giles, TN	High	3,000	290	3,000	4,000
Barren, KY	Low	500	172	500	8,333
Barren, KY	High	500	169	500	8,333
Barren, KY	High	1,000	199	1,000	7,692
Barren, KY	High	3,000	281	3,000	3,333
Most Conservative for Emissions Similar to GCC [3]	-	-	281	-	8,333

Notes:
1. EPA, 2016 and TDEC, 2018.
2. Calculations in "GCC_SecPM25_O3_calcs_20180912.xlsx" (provided on optical disc).
3. Hypothetical sources with NO_x emissions of 3,000 tons per year and VOC emissions of 500 tons per year.

The O_3 impacts for the source impact assessment were calculated as the sum of the ratio of precursor emissions to the MERPs. If the sum of the ratios is less than 1, then O_3 impacts are below the O_3 SIL and no cumulative analysis is necessary.

$$\left(\frac{NOx\_Em}{NOx\_MERP}\right) + \left(\frac{VOC\_Em}{VOC\_MERP}\right) < 1 \qquad [4.4]$$

Where:

NOx_Em = Project related NOx Emissions (tons per year – tpy)
NOx MERP = From Table 7 (tpy)
VOC_Em = Project related VOC Emissions (tpy)
VOC_MERP = From Table 7 (tpy)

GCC's ozone inputs to Equation 4.4 are provided in Table 8, and the resulting impacts are shown in Equation 4.5.

TABLE 8
O_3 Inputs for the SIL in Class II Areas [1,2]

O_3 Precursor	GCC Emissions (tons/yr) [3]	MERP [4,5]
NO_x	2,270	281 [4]
VOC	158	8,333 [5]

Notes:
1. EPA, 2016 and TDEC, 2018.
2. Calculations in "GCC_SecPM25_O3_calcs_20180912.xlsx" (provided on optical disc).
3. Emissions taken from Table 5 in "Gleasn PSD Mod emssn SA 20180831.xlsx" (provided on optical disc).
4. Most conservative MERP for NO_x emissions of 3,000 tons per year at Giles County or Barren County.
5. Most conservative MERP for VOC emissions of 500 tons per year at Giles County or Barren County.

According to Equation 4.5, the sum of the ratios was greater than 1, and O_3 impacts are above the SIL. Therefore, a cumulative O_3 analysis was necessary and performed, which added background O_3 and compared the combined impacts to the NAAQS as shown in Equation 4.6.

$$\left(\frac{2,270}{281}\right) + \left(\frac{158}{8,333}\right) = 8.10 \qquad [4.5]$$

$$Background\ Ozone + \left[\left(\left(\frac{NOx_{Em}}{NOx_{MERP}}\right) + \left(\frac{VOC_{Em}}{VOC_{MERP}}\right)\right) * SIL\right] \leq NAAQS \qquad [4.6]$$

Where:

Background Ozone = 2015-2017 8-hour ozone design value (ppb) for Cadiz monitor
NOx_Em = Project related NOx Emissions (tons per year – tpy)
NOx MERP = From Table 7 (tpy)
VOC_Em = Project related VOC Emissions (tpy)
VOC_MERP = From Table 7 (tpy)
SIL = 1 ppb ozone
NAAQS = 8-hour ozone NAAQS (70 ppb)

Cumulative O_3 impacts from GCC are shown below. Using the 3-year 8-hour ozone design value of 61 ppb from Cadiz, KY, the ratios defined in Equation 4.5, and the O_3 SIL of 1 ppb, the cumulative O_3 impacts did not exceed the NAAQS. This indicated that emissions from GCC would not cause or contribute to a violation of the O_3 NAAQS.

61 + [(2,270 ÷ 281) + (158 ÷ 8,333)] * 1 ppb = 69.1 ppb

61 + [8.08 + .02] * 1 = 69.1 ppb

61 + 8.1 = 69.1 ppb

Appendix D: Example of the background monitoring data calculations for a Second Level 24-hour modeling analysis

This appendix provides an illustrative example of the calculations and data sorting recommendations for the background monitoring data to be used in a Second Level 24-hour $PM_{2.5}$ modeling analysis. In this example, it was determined through discussion and coordination with the appropriate permitting authority that the impacts from the project source's primary $PM_{2.5}$ emissions were most prominent during the cool season and were not temporally correlated with background $PM_{2.5}$ levels that were typical highest during the warm season. So, combining the modeled and monitored levels through a First Level 24-hour $PM_{2.5}$ modeling analysis was determined to be potentially overly conservative. Extending the compliance demonstration to a Second Level analysis allows for a more refined and appropriate assessment of the cumulative impacts on the primary $PM_{2.5}$ emissions in this particular situation.

The example provided is from an idealized Federal Reference Method (FRM) $PM_{2.5}$ monitoring site that operates on a daily (1-in-1 day) frequency with 100% data completeness. In this case, the annual 98th percentile concentration is the 8th highest concentration of the year. In most cases, the FRM monitoring site will likely operate on a 1-and-3 day frequency and will also likely have missing data due to monitor maintenance or collected data not meeting all of the quality assurance criteria. Please reference Appendix N to 40 CFR part 50 to determine the appropriate 98th percentile rank of the monitored data based on the monitor sampling frequency and valid number of days sampled during each year.

The appropriate seasonal (or quarterly) background concentrations to be included as inputs to the AERMOD model per a Second Level 24-hour $PM_{2.5}$ modeling analysis are as follows:

- Step 1 – Start with the most recent 3-years of representative background $PM_{2.5}$ ambient monitoring data that are being used to develop the monitored background $PM_{2.5}$ design value. In this example, the 3-years of 2008 to 2010 are being used to determine the monitored design value.

- Step 2 – For each year, determine the appropriate rank for the daily 98th percentile $PM_{2.5}$ concentration. Again, this idealized example is from a 1-in-1 day monitor with 100% data completeness. So, the 8th highest concentration of each year is the 98th percentile $PM_{2.5}$ concentration. The 98th percentile $PM_{2.5}$ concentration for 2008 is highlighted in Table E-1. The full concentration data from 2009 and 2010 are not shown across the steps in this Appendix for simplicity but would be similar to that of 2008.

- Step 3 – Remove from further consideration in this analysis the $PM_{2.5}$ concentrations from each year that are greater than the 98th percentile $PM_{2.5}$ concentration. In the case presented for a 1-in-1 day monitor, the top 7 concentrations are removed. If the monitor were a 1-in-3 day monitor, only the top 2 concentrations would be removed. The resultant dataset after the top 7 concentrations have been removed from further consideration in this analysis for 2008 is presented in Table E-2.

- Step 4 – For each year, divide the resultant annual dataset of the monitored data equal to or less than the 98th percentile $PM_{2.5}$ concentration into each season (or quarter). For 2008, the seasonal subsets are presented in Table E-3.

- Step 5 – Determine the maximum $PM_{2.5}$ concentration from each of the seasonal (or quarterly) subsets created in Step 4 for each year. The maximum $PM_{2.5}$ concentration from each season for 2008 is highlighted in Table E-3.

- Step 6 – Average the seasonal (or quarterly) maximums from Step 5 across the three years of monitoring data to create the four seasonal background PM2.5 concentrations to be included as inputs to the AERMOD model. These averages for the 2008 to 2010 dataset used in this example are presented in Table E-4. As noted above, the full concentration data from 2009 and 2010 are not shown across the steps in this Appendix for simplicity, but the seasonal maximums from 2009 and 2010 presented in Table E-4 were determined by following the previous five steps similar to that of 2008.

Table E-1. 2008 Daily $PM_{2.5}$ Concentrations

Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.
1-Jan	10.4	16-Feb	15.1	2-Apr	10.5	18-May	11.1	3-Jul	17.1	18-Aug	18.7	3-Oct	12.3	18-Nov	4.4
2-Jan	5.4	17-Feb	11.8	3-Apr	8.2	19-May	7.7	4-Jul	19.8	19-Aug	21.5	4-Oct	19.5	19-Nov	8.2
3-Jan	10.0	18-Feb	3.4	4-Apr	9.7	20-May	13.6	5-Jul	14.3	20-Aug	20.1	5-Oct	23.7	20-Nov	11.1
4-Jan	16.4	19-Feb	4.5	5-Apr	6.9	21-May	12.1	6-Jul	11.5	21-Aug	18.4	6-Oct	19.8	21-Nov	5.3
5-Jan	11.2	20-Feb	4.8	6-Apr	6.3	22-May	10.0	7-Jul	14.3	22-Aug	16.7	7-Oct	21.7	22-Nov	8.9
6-Jan	11.1	21-Feb	11.9	7-Apr	7.9	23-May	13.3	8-Jul	12.2	23-Aug	13.8	8-Oct	12.2	23-Nov	14.0
7-Jan	10.2	22-Feb	20.1	8-Apr	9.8	24-May	11.2	9-Jul	11.1	24-Aug	19.0	9-Oct	5.1	24-Nov	12.7
8-Jan	11.4	23-Feb	11.4	9-Apr	16.5	25-May	17.7	10-Jul	9.7	25-Aug	17.6	10-Oct	10.2	25-Nov	9.7
9-Jan	8.1	24-Feb	19.3	10-Apr	13.3	26-May	14.2	11-Jul	16.4	26-Aug	15.4	11-Oct	10.7	26-Nov	12.8
10-Jan	9.4	25-Feb	18.2	11-Apr	11.0	27-May	15.4	12-Jul	21.5	27-Aug	12.6	12-Oct	5.6	27-Nov	16.6
11-Jan	5.7	26-Feb	12.8	12-Apr	8.8	28-May	13.9	13-Jul	25.1	28-Aug	12.1	13-Oct	5.9	28-Nov	17.2
12-Jan	8.9	27-Feb	5.5	13-Apr	6.3	29-May	9.3	14-Jul	11.7	29-Aug	10.1	14-Oct	9.7	29-Nov	16.6
13-Jan	18.1	28-Feb	9.7	14-Apr	5.1	30-May	14.5	15-Jul	18.9	30-Aug	17.2	15-Oct	12.8	30-Nov	4.5
14-Jan	11.0	29-Feb	12.1	15-Apr	7.9	31-May	20.5	16-Jul	28.9	31-Aug	19.9	16-Oct	16.4	1-Dec	7.5
15-Jan	11.8	1-Mar	9.6	16-Apr	8.2	1-Jun	15.3	17-Jul	27.6	1-Sep	19.4	17-Oct	12.0	2-Dec	10.6
16-Jan	10.7	2-Mar	5.6	17-Apr	14.7	2-Jun	11.5	18-Jul	12.8	2-Sep	18.2	18-Oct	7.9	3-Dec	16.7
17-Jan	10.0	3-Mar	12.5	18-Apr	22.5	3-Jun	17.9	19-Jul	6.2	3-Sep	24.0	19-Oct	6.6	4-Dec	12.5
18-Jan	15.6	4-Mar	7.1	19-Apr	12.8	4-Jun	21.1	20-Jul	20.1	4-Sep	15.4	20-Oct	8.1	5-Dec	7.3
19-Jan	18.0	5-Mar	4.9	20-Apr	6.9	5-Jun	17.9	21-Jul	26.5	5-Sep	12.4	21-Oct	12.2	6-Dec	10.4
20-Jan	6.6	6-Mar	9.9	21-Apr	7.5	6-Jun	17.6	22-Jul	16.9	6-Sep	12.5	22-Oct	4.6	7-Dec	13.4
21-Jan	7.4	7-Mar	11.2	22-Apr	6.0	7-Jun	15.0	23-Jul	12.8	7-Sep	15.8	23-Oct	6.1	8-Dec	10.5
22-Jan	13.5	8-Mar	5.5	23-Apr	9.1	8-Jun	22.3	24-Jul	7.9	8-Sep	23.4	24-Oct	4.6	9-Dec	9.3
23-Jan	16.0	9-Mar	8.8	24-Apr	10.3	9-Jun	27.9	25-Jul	15.7	9-Sep	11.5	25-Oct	4.5	10-Dec	6.5
24-Jan	9.4	10-Mar	11.0	25-Apr	12.0	10-Jun	21.6	26-Jul	24.9	10-Sep	6.0	26-Oct	10.5	11-Dec	3.0
25-Jan	12.6	11-Mar	12.1	26-Apr	12.5	11-Jun	19.4	27-Jul	22.2	11-Sep	11.8	27-Oct	6.4	12-Dec	3.5
26-Jan	13.6	12-Mar	9.7	27-Apr	11.3	12-Jun	21.2	28-Jul	17.5	12-Sep	10.7	28-Oct	4.6	13-Dec	10.2
27-Jan	16.1	13-Mar	15.1	28-Apr	7.6	13-Jun	29.1	29-Jul	19.1	13-Sep	7.6	29-Oct	5.6	14-Dec	17.6
28-Jan	10.0	14-Mar	21.6	29-Apr	7.4	14-Jun	15.6	30-Jul	21.1	14-Sep	7.5	30-Oct	7.6	15-Dec	12.4
29-Jan	10.4	15-Mar	16.6	30-Apr	11.4	15-Jun	14.8	31-Jul	18.0	15-Sep	7.1	31-Oct	11.2	16-Dec	9.7
30-Jan	6.9	16-Mar	7.9	1-May	12.6	16-Jun	17.8	1-Aug	16.3	16-Sep	7.7	1-Nov	16.2	17-Dec	7.0
31-Jan	4.9	17-Mar	9.6	2-May	10.0	17-Jun	12.6	2-Aug	19.3	17-Sep	11.3	2-Nov	17.3	18-Dec	7.9
1-Feb	5.4	18-Mar	10.3	3-May	11.2	18-Jun	10.5	3-Aug	17.9	18-Sep	16.8	3-Nov	18.3	19-Dec	6.9
2-Feb	7.1	19-Mar	8.4	4-May	10.4	19-Jun	15.0	4-Aug	25.1	19-Sep	14.8	4-Nov	8.9	20-Dec	8.1
3-Feb	10.9	20-Mar	4.9	5-May	15.7	20-Jun	22.7	5-Aug	29.3	20-Sep	8.0	5-Nov	5.8	21-Dec	4.9
4-Feb	12.1	21-Mar	8.7	6-May	16.1	21-Jun	18.7	6-Aug	19.1	21-Sep	10.8	6-Nov	8.6	22-Dec	7.7
5-Feb	17.1	22-Mar	13.3	7-May	16.8	22-Jun	15.2	7-Aug	14.0	22-Sep	14.5	7-Nov	15.0	23-Dec	7.7
6-Feb	10.3	23-Mar	12.2	8-May	14.5	23-Jun	16.8	8-Aug	10.8	23-Sep	21.2	8-Nov	8.3	24-Dec	10.5
7-Feb	4.0	24-Mar	10.3	9-May	11.7	24-Jun	15.1	9-Aug	15.0	24-Sep	8.6	9-Nov	10.0	25-Dec	6.5
8-Feb	9.7	25-Mar	11.9	10-May	9.0	25-Jun	20.7	10-Aug	21.7	25-Sep	1.2	10-Nov	12.8	26-Dec	7.6
9-Feb	11.5	26-Mar	20.1	11-May	6.7	26-Jun	23.0	11-Aug	14.3	26-Sep	16.0	11-Nov	11.8	27-Dec	13.3
10-Feb	3.0	27-Mar	22.5	12-May	7.9	27-Jun	17.8	12-Aug	14.7	27-Sep	12.1	12-Nov	14.8	28-Dec	6.4
11-Feb	5.5	28-Mar	18.2	13-May	8.3	28-Jun	12.4	13-Aug	13.0	28-Sep	18.0	13-Nov	14.5	29-Dec	3.7
12-Feb	18.9	29-Mar	10.8	14-May	12.2	29-Jun	12.7	14-Aug	13.5	29-Sep	17.8	14-Nov	7.7	30-Dec	4.7
13-Feb	17.6	30-Mar	6.4	15-May	13.1	30-Jun	8.9	15-Aug	17.5	30-Sep	16.4	15-Nov	3.6	31-Dec	4.4
14-Feb	11.2	31-Mar	3.3	16-May	8.8	1-Jul	7.1	16-Aug	23.9	1-Oct	12.3	16-Nov	4.6		
15-Feb	14.4	1-Apr	7.8	17-May	8.2	2-Jul	13.8	17-Aug	18.4	2-Oct	8.2	17-Nov	7.8		

Annual 98th Percentile Concentration = 25.1 µg/m^3

Table E-2. 2008 Daily $PM_{2.5}$ Concentrations Less Than or Equal to the 98th Percentile

Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.	Date	Conc.
1-Jan	10.4	16-Feb	15.1	2-Apr	10.5	18-May	11.1	3-Jul	17.1	18-Aug	18.7	3-Oct	12.3	18-Nov	4.4
2-Jan	5.4	17-Feb	11.8	3-Apr	8.2	19-May	7.7	4-Jul	19.8	19-Aug	21.5	4-Oct	19.5	19-Nov	8.2
3-Jan	10.0	18-Feb	3.4	4-Apr	9.7	20-May	13.6	5-Jul	14.3	20-Aug	20.1	5-Oct	23.7	20-Nov	11.1
4-Jan	16.4	19-Feb	4.5	5-Apr	6.9	21-May	12.1	6-Jul	11.5	21-Aug	18.4	6-Oct	19.8	21-Nov	5.3
5-Jan	11.2	20-Feb	4.8	6-Apr	6.3	22-May	10.0	7-Jul	14.3	22-Aug	16.7	7-Oct	21.7	22-Nov	8.9
6-Jan	11.1	21-Feb	11.9	7-Apr	7.9	23-May	13.3	8-Jul	12.2	23-Aug	13.8	8-Oct	12.2	23-Nov	14.0
7-Jan	10.2	22-Feb	20.1	8-Apr	9.8	24-May	11.2	9-Jul	11.1	24-Aug	19.0	9-Oct	5.1	24-Nov	12.7
8-Jan	11.4	23-Feb	11.4	9-Apr	16.5	25-May	17.7	10-Jul	9.7	25-Aug	17.6	10-Oct	10.2	25-Nov	9.7
9-Jan	8.1	24-Feb	19.3	10-Apr	13.3	26-May	14.2	11-Jul	16.4	26-Aug	15.4	11-Oct	10.7	26-Nov	12.8
10-Jan	9.4	25-Feb	18.2	11-Apr	11.0	27-May	15.4	12-Jul	21.5	27-Aug	12.6	12-Oct	5.6	27-Nov	16.6
11-Jan	5.7	26-Feb	12.8	12-Apr	8.8	28-May	13.9	13-Jul	RC	28-Aug	12.1	13-Oct	5.9	28-Nov	17.2
12-Jan	8.9	27-Feb	5.5	13-Apr	6.3	29-May	9.3	14-Jul	11.7	29-Aug	10.1	14-Oct	9.7	29-Nov	16.6
13-Jan	18.1	28-Feb	9.7	14-Apr	5.1	30-May	14.5	15-Jul	18.9	30-Aug	17.2	15-Oct	12.8	30-Nov	4.5
14-Jan	11.0	29-Feb	12.1	15-Apr	7.9	31-May	20.5	16-Jul	RC	31-Aug	19.9	16-Oct	16.4	1-Dec	7.5
15-Jan	11.8	1-Mar	9.6	16-Apr	8.2	1-Jun	15.3	17-Jul	RC	1-Sep	19.4	17-Oct	12.0	2-Dec	10.6
16-Jan	10.7	2-Mar	5.6	17-Apr	14.7	2-Jun	11.5	18-Jul	12.8	2-Sep	18.2	18-Oct	7.9	3-Dec	16.7
17-Jan	10.0	3-Mar	12.5	18-Apr	22.5	3-Jun	17.9	19-Jul	6.2	3-Sep	24.0	19-Oct	6.6	4-Dec	12.5
18-Jan	15.6	4-Mar	7.1	19-Apr	12.8	4-Jun	21.1	20-Jul	20.1	4-Sep	15.4	20-Oct	8.1	5-Dec	7.3
19-Jan	18.0	5-Mar	4.9	20-Apr	6.9	5-Jun	17.9	21-Jul	RC	5-Sep	12.4	21-Oct	12.2	6-Dec	10.4
20-Jan	6.6	6-Mar	9.9	21-Apr	7.5	6-Jun	17.6	22-Jul	16.9	6-Sep	12.5	22-Oct	4.6	7-Dec	13.4
21-Jan	7.4	7-Mar	11.2	22-Apr	6.0	7-Jun	15.0	23-Jul	12.8	7-Sep	15.8	23-Oct	6.1	8-Dec	10.5
22-Jan	13.5	8-Mar	5.5	23-Apr	9.1	8-Jun	22.3	24-Jul	7.9	8-Sep	23.4	24-Oct	4.6	9-Dec	9.3
23-Jan	16.0	9-Mar	8.8	24-Apr	10.3	9-Jun	RC	25-Jul	15.7	9-Sep	11.5	25-Oct	4.5	10-Dec	6.5
24-Jan	9.4	10-Mar	11.0	25-Apr	12.0	10-Jun	21.6	26-Jul	24.9	10-Sep	6.0	26-Oct	10.5	11-Dec	3.0
25-Jan	12.6	11-Mar	12.1	26-Apr	12.5	11-Jun	19.4	27-Jul	22.2	11-Sep	11.8	27-Oct	6.4	12-Dec	3.5
26-Jan	13.6	12-Mar	9.7	27-Apr	11.3	12-Jun	21.2	28-Jul	17.5	12-Sep	10.7	28-Oct	4.6	13-Dec	10.2
27-Jan	16.1	13-Mar	15.1	28-Apr	7.6	13-Jun	RC	29-Jul	19.1	13-Sep	7.6	29-Oct	5.6	14-Dec	17.6
28-Jan	10.0	14-Mar	21.6	29-Apr	7.4	14-Jun	15.6	30-Jul	21.1	14-Sep	7.5	30-Oct	7.6	15-Dec	12.4
29-Jan	10.4	15-Mar	16.6	30-Apr	11.4	15-Jun	14.8	31-Jul	18.0	15-Sep	7.1	31-Oct	11.2	16-Dec	9.7
30-Jan	6.9	16-Mar	7.9	1-May	12.6	16-Jun	17.8	1-Aug	16.3	16-Sep	7.7	1-Nov	16.2	17-Dec	7.0
31-Jan	4.9	17-Mar	9.6	2-May	10.0	17-Jun	12.6	2-Aug	19.3	17-Sep	11.3	2-Nov	17.3	18-Dec	7.9
1-Feb	5.4	18-Mar	10.3	3-May	11.2	18-Jun	10.5	3-Aug	17.9	18-Sep	16.8	3-Nov	18.3	19-Dec	6.9
2-Feb	7.1	19-Mar	8.4	4-May	10.4	19-Jun	15.0	4-Aug	25.1	19-Sep	14.8	4-Nov	8.9	20-Dec	8.1
3-Feb	10.9	20-Mar	4.9	5-May	15.7	20-Jun	22.7	5-Aug	RC	20-Sep	8.0	5-Nov	5.8	21-Dec	4.9
4-Feb	12.1	21-Mar	8.7	6-May	16.1	21-Jun	18.7	6-Aug	19.1	21-Sep	10.8	6-Nov	8.6	22-Dec	7.7
5-Feb	17.1	22-Mar	13.3	7-May	16.8	22-Jun	15.2	7-Aug	14.0	22-Sep	14.5	7-Nov	15.0	23-Dec	7.7
6-Feb	10.3	23-Mar	12.2	8-May	14.5	23-Jun	16.8	8-Aug	10.8	23-Sep	21.2	8-Nov	8.3	24-Dec	10.5
7-Feb	4.0	24-Mar	10.3	9-May	11.7	24-Jun	15.1	9-Aug	15.0	24-Sep	8.6	9-Nov	10.0	25-Dec	6.5
8-Feb	9.7	25-Mar	11.9	10-May	9.0	25-Jun	20.7	10-Aug	21.7	25-Sep	1.2	10-Nov	12.8	26-Dec	7.6
9-Feb	11.5	26-Mar	20.1	11-May	6.7	26-Jun	23.0	11-Aug	14.3	26-Sep	16.0	11-Nov	11.8	27-Dec	13.3
10-Feb	3.0	27-Mar	22.5	12-May	7.9	27-Jun	17.8	12-Aug	14.7	27-Sep	12.1	12-Nov	14.8	28-Dec	6.4
11-Feb	5.5	28-Mar	18.2	13-May	8.3	28-Jun	12.4	13-Aug	13.0	28-Sep	18.0	13-Nov	14.5	29-Dec	3.7
12-Feb	18.9	29-Mar	10.8	14-May	12.2	29-Jun	12.7	14-Aug	13.5	29-Sep	17.8	14-Nov	7.7	30-Dec	4.7
13-Feb	17.6	30-Mar	6.4	15-May	13.1	30-Jun	8.9	15-Aug	17.5	30-Sep	16.4	15-Nov	3.6	31-Dec	4.4
14-Feb	11.2	31-Mar	3.3	16-May	8.8	1-Jul	7.1	16-Aug	23.9	1-Oct	12.3	16-Nov	4.6		
15-Feb	14.4	1-Apr	7.8	17-May	8.2	2-Jul	13.8	17-Aug	18.4	2-Oct	8.2	17-Nov	7.8		

Annual 98th Percentile Concentration = 25.1 µg/m^3
RC = Above 98th Percentile and Removed from Consideration

Table E-3. 2008 Daily $PM_{2.5}$ Concentrations Less Than or Equal to the 98th Percentile by Quarter

Season / Quarter 1			
Date	Conc.	Date	Conc.
1-Jan	10.4	16-Feb	15.1
2-Jan	5.4	17-Feb	11.8
3-Jan	10.0	18-Feb	3.4
4-Jan	16.4	19-Feb	4.5
5-Jan	11.2	20-Feb	4.8
6-Jan	11.1	21-Feb	11.9
7-Jan	10.2	22-Feb	20.1
8-Jan	11.4	23-Feb	11.4
9-Jan	8.1	24-Feb	19.3
10-Jan	9.4	25-Feb	18.2
11-Jan	5.7	26-Feb	12.8
12-Jan	8.9	27-Feb	5.5
13-Jan	18.1	28-Feb	9.7
14-Jan	11.0	29-Feb	12.1
15-Jan	11.8	1-Mar	9.6
16-Jan	10.7	2-Mar	5.6
17-Jan	10.0	3-Mar	12.5
18-Jan	15.6	4-Mar	7.1
19-Jan	18.0	5-Mar	4.9
20-Jan	6.6	6-Mar	9.9
21-Jan	7.4	7-Mar	11.2
22-Jan	13.5	8-Mar	5.5
23-Jan	16.0	9-Mar	8.8
24-Jan	9.4	10-Mar	11.0
25-Jan	12.6	11-Mar	12.1
26-Jan	13.6	12-Mar	9.7
27-Jan	16.1	13-Mar	15.1
28-Jan	10.0	14-Mar	21.6
29-Jan	10.4	15-Mar	16.6
30-Jan	6.9	16-Mar	7.9
31-Jan	4.9	17-Mar	9.6
1-Feb	5.4	18-Mar	10.3
2-Feb	7.1	19-Mar	8.4
3-Feb	10.9	20-Mar	4.9
4-Feb	12.1	21-Mar	8.7
5-Feb	17.1	22-Mar	13.3
6-Feb	10.3	23-Mar	12.2
7-Feb	4.0	24-Mar	10.3
8-Feb	9.7	25-Mar	11.9
9-Feb	11.5	26-Mar	20.1
10-Feb	3.0	27-Mar	22.5
11-Feb	5.5	28-Mar	18.2
12-Feb	18.9	29-Mar	10.8
13-Feb	17.6	30-Mar	6.4
14-Feb	11.2	31-Mar	3.3
15-Feb	14.4		
Seasonal / Quarterly Maximum			22.5

Season / Quarter 2			
Date	Conc.	Date	Conc.
1-Apr	7.8	17-May	8.2
2-Apr	10.5	18-May	11.1
3-Apr	8.2	19-May	7.7
4-Apr	9.7	20-May	13.6
5-Apr	6.9	21-May	12.1
6-Apr	6.3	22-May	10.0
7-Apr	7.9	23-May	13.3
8-Apr	9.8	24-May	11.2
9-Apr	16.5	25-May	17.7
10-Apr	13.3	26-May	14.2
11-Apr	11.0	27-May	15.4
12-Apr	8.8	28-May	13.9
13-Apr	6.3	29-May	9.3
14-Apr	5.1	30-May	14.5
15-Apr	7.9	31-May	20.5
16-Apr	8.2	1-Jun	15.3
17-Apr	14.7	2-Jun	11.5
18-Apr	22.5	3-Jun	17.9
19-Apr	12.8	4-Jun	21.1
20-Apr	6.9	5-Jun	17.9
21-Apr	7.5	6-Jun	17.6
22-Apr	6.0	7-Jun	15.0
23-Apr	9.1	8-Jun	22.3
24-Apr	10.3	9-Jun	RC
25-Apr	12.0	10-Jun	21.6
26-Apr	12.5	11-Jun	19.4
27-Apr	11.3	12-Jun	21.2
28-Apr	7.6	13-Jun	RC
29-Apr	7.4	14-Jun	15.6
30-Apr	11.4	15-Jun	14.8
1-May	12.6	16-Jun	17.8
2-May	10.0	17-Jun	12.6
3-May	11.2	18-Jun	10.5
4-May	10.4	19-Jun	15.0
5-May	15.7	20-Jun	22.7
6-May	16.1	21-Jun	18.7
7-May	16.8	22-Jun	15.2
8-May	14.5	23-Jun	16.8
9-May	11.7	24-Jun	15.1
10-May	9.0	25-Jun	20.7
11-May	6.7	26-Jun	23.0
12-May	7.9	27-Jun	17.8
13-May	8.3	28-Jun	12.4
14-May	12.2	29-Jun	12.7
15-May	13.1	30-Jun	8.9
16-May	8.8		
Seasonal / Quarterly Maximum			23.0

Season / Quarter 3			
Date	Conc.	Date	Conc.
1-Jul	7.1	16-Aug	23.9
2-Jul	13.8	17-Aug	18.4
3-Jul	17.1	18-Aug	18.7
4-Jul	19.8	19-Aug	21.5
5-Jul	14.3	20-Aug	20.1
6-Jul	11.5	21-Aug	18.4
7-Jul	14.3	22-Aug	16.7
8-Jul	12.2	23-Aug	13.8
9-Jul	11.1	24-Aug	19.0
10-Jul	9.7	25-Aug	17.6
11-Jul	16.4	26-Aug	15.4
12-Jul	21.5	27-Aug	12.6
13-Jul	RC	28-Aug	12.1
14-Jul	11.7	29-Aug	10.1
15-Jul	18.9	30-Aug	17.2
16-Jul	RC	31-Aug	19.9
17-Jul	RC	1-Sep	19.4
18-Jul	12.8	2-Sep	18.2
19-Jul	6.2	3-Sep	24.0
20-Jul	20.1	4-Sep	15.4
21-Jul	RC	5-Sep	12.4
22-Jul	16.9	6-Sep	12.5
23-Jul	12.8	7-Sep	15.8
24-Jul	7.9	8-Sep	23.4
25-Jul	15.7	9-Sep	11.5
26-Jul	24.9	10-Sep	6.0
27-Jul	22.2	11-Sep	11.8
28-Jul	17.5	12-Sep	10.7
29-Jul	19.1	13-Sep	7.6
30-Jul	21.1	14-Sep	7.5
31-Jul	18.0	15-Sep	7.1
1-Aug	16.3	16-Sep	7.7
2-Aug	19.3	17-Sep	11.3
3-Aug	17.9	18-Sep	16.8
4-Aug	25.1	19-Sep	14.8
5-Aug	RC	20-Sep	8.0
6-Aug	19.1	21-Sep	10.8
7-Aug	14.0	22-Sep	14.5
8-Aug	10.8	23-Sep	21.2
9-Aug	15.0	24-Sep	8.6
10-Aug	21.7	25-Sep	1.2
11-Aug	14.3	26-Sep	16.0
12-Aug	14.7	27-Sep	12.1
13-Aug	13.0	28-Sep	18.0
14-Aug	13.5	29-Sep	17.8
15-Aug	17.5	30-Sep	16.4
Seasonal / Quarterly Maximum			25.1

Season / Quarter 4			
Date	Conc.	Date	Conc.
1-Oct	12.3	16-Nov	4.6
2-Oct	8.2	17-Nov	7.8
3-Oct	12.3	18-Nov	4.4
4-Oct	19.5	19-Nov	8.2
5-Oct	23.7	20-Nov	11.1
6-Oct	19.8	21-Nov	5.3
7-Oct	21.7	22-Nov	8.9
8-Oct	12.2	23-Nov	14.0
9-Oct	5.1	24-Nov	12.7
10-Oct	10.2	25-Nov	9.7
11-Oct	10.7	26-Nov	12.8
12-Oct	5.6	27-Nov	16.6
13-Oct	5.9	28-Nov	17.2
14-Oct	9.7	29-Nov	16.6
15-Oct	12.8	30-Nov	4.5
16-Oct	16.4	1-Dec	7.5
17-Oct	12.0	2-Dec	10.6
18-Oct	7.9	3-Dec	16.7
19-Oct	6.6	4-Dec	12.5
20-Oct	8.1	5-Dec	7.3
21-Oct	12.2	6-Dec	10.4
22-Oct	4.6	7-Dec	13.4
23-Oct	6.1	8-Dec	10.5
24-Oct	4.6	9-Dec	9.3
25-Oct	4.5	10-Dec	6.5
26-Oct	10.5	11-Dec	3.0
27-Oct	6.4	12-Dec	3.5
28-Oct	4.6	13-Dec	10.2
29-Oct	5.6	14-Dec	17.6
30-Oct	7.6	15-Dec	12.4
31-Oct	11.2	16-Dec	9.7
1-Nov	16.2	17-Dec	7.0
2-Nov	17.3	18-Dec	7.9
3-Nov	18.3	19-Dec	6.9
4-Nov	8.9	20-Dec	8.1
5-Nov	5.8	21-Dec	4.9
6-Nov	8.6	22-Dec	7.7
7-Nov	15.0	23-Dec	7.7
8-Nov	8.3	24-Dec	10.5
9-Nov	10.0	25-Dec	6.5
10-Nov	12.8	26-Dec	7.6
11-Nov	11.8	27-Dec	13.3
12-Nov	14.8	28-Dec	6.4
13-Nov	14.5	29-Dec	3.7
14-Nov	7.7	30-Dec	4.7
15-Nov	3.6	31-Dec	4.4
Seasonal / Quarterly Maximum			23.7

Seasonal / Quarterly Maximum Concentration
RC = Above 98th Percentile and Removed from Consideration

Table E-4. Resulting Average of Seasonal (or Quarterly) Maximums for Inclusion into AERMOD

Seasonal / Quarterly Average Highest Monitored Concentration

(From Annual Datasets Equal To and Less Than the 98th Percentile)

	Q1	Q2	Q3	Q4
2008	22.5	23.0	25.1	23.7
2009	21.1	20.7	21.2	19.8
2010	20.7	22.6	23.5	20.7
Average	**21.433**	**22.100**	**23.267**	**21.400**

(Note, the complete datasets for 2009 and 2010 are not shown in Appendix D but would follow the same steps as for 2008)

United States
Environmental Protection
Agency

Office of Air Quality Planning and Standards
Air Quality Assessment Division
Research Triangle Park, NC

Publication No. EPA-457/P-20-002
February 2020

NMED
EXHIBIT 5

STATE OF NEW MEXICO
ENVIRONMENTAL IMPROVEMENT BOARD

IN THE MATTER OF THE APPEALS OF THE AIR QUALITY PERMIT NO. 7482-M1 ISSUED TO 3 BEAR DELAWARE OPERATING – NM LLC **EIB No. 20-21(A)**

AND

REGISTRATION NOS. 8729, 8730, AND 8733 UNDER GENERAL CONSTRUCTION PERMIT FOR OIL AND GAS FACILITIES **EIB No. 20-33(A)**

WildEarth Guardians,
Petitioner

TECHNICAL TESTIMONY OF ELIZABETH BISBEY-KUEHN

I. INTRODUCTION

My name is Elizabeth Bisbey-Kuehn. I am the Bureau Chief of the Air Quality Bureau ("AQB" or "Bureau") of the New Mexico Environment Department ("NMED" or "Department"). I present this written testimony on behalf of the Department for the consolidated public hearings on the appeal petitions filed by WildEarth Guardians ("WEG") in EIB 20-21(A) and EIB 20-33(A). In EIB 20-21(A), WEG challenges the Department's approval of Air Quality Permit No. 7482-M1, issued to 3-Bear Delaware Operating – NM LLC ("3-Bear Permit") for the Libby Gas Plant in Lea County, New Mexico. WEG contends that the Department failed to perform air quality modeling or other technical analysis on the impacts of the permitted activities on ambient ozone levels in the area. WEG further objects that monitors in Hobbs and Carlsbad are registering ozone levels in excess of the U.S. Environmental Protection Agency's ("EPA") National Ambient Air Quality Standard ("NAAQS"), and therefore the Department's decision to approve the Permit was arbitrary and capricious because it authorized additional ozone precursors that would necessarily "cause or contribute to air contaminant levels in excess of any [NAAQS]."

In EIB 20-33(A), WEG challenges the Department's approval of General Construction Permit for Oil and Gas Facilities ("GCP O&G") Registration Nos. 8729, 8730, and 8733 (collectively, the "Registrations") for XTO Energy Co.'s Corral Canyon 23 and Big Eddy Unit DI 38 (Nos. 8729 and 8730, respectively), and Spur Energy Partners LLC's Dorami 2H, 4H and 9H Federal Oil Tank Battery (No. 8733), all located in Eddy County. WEG points to Table 103 in the GCP O&G, which lists all applicable regulations that a registrant must comply with and includes ambient air quality standards. WEG contends that because monitors in the area are registering exceedances of the ozone NAAQS, it is impossible for the facilities to demonstrate compliance with the requirements of the GCP O&G, and therefore the Department's approval of the Registrations was unlawful, arbitrary and capricious.

As the Air Quality Bureau Chief, I am charged with overseeing the permitting program and ensuring that the program is administered in accordance with the Department's enabling statutes and the Board's regulations, and that the permits issued by the Bureau meet the requirements of the federal Clean Air Act ("CAA") and regulations promulgated by EPA pursuant to the CAA, as well as the New Mexico Air Quality Control Act ("AQCA") and the regulations promulgated by the Board pursuant to the AQCA. My testimony will address the following topics: the regulatory regime for ozone set forth under the CAA and the State of New Mexico's role in that regime; the New Mexico statutory and regulatory framework for regulating ozone pollution; the Department's Ozone Attainment Initiative and the steps that the Department is currently taking to address areas of the State where monitors are registering exceedances of the ozone NAAQS; the path forward for the State in addressing ozone pollution.

II. QUALIFICATIONS

I have been an employee of the Bureau for over fifteen years, working as a staff member for six years, staff manager for seven years, and in my current position as Bureau Chief for over two years. As a staff member and staff manager, I oversaw several complex, high-profile projects for the Department, including serving as the Department's technical expert for the Best Available Retrofit Technology analysis for the San Juan Generation Station. I developed multiple general construction permits for the oil and gas industry, led bi-monthly technical meetings for the State's Associated Contractors, drafted technical guidance and policy documents, and represented the Department in multiple public meetings and public hearings. As Bureau Chief, I manage the four Section Chiefs who oversee the four Sections of the Bureau. I direct the overall management of the Bureau, including the Bureau's resources; staff who enforce the state and federal air quality standards; air quality related planning and policy, operational, permitting, and compliance and enforcement services; financial oversight of the bureau's federal grant and state matching funds; and support services for the Bureau.

My full background and qualifications are set forth in my resume, which is marked as NMED Exhibit 5.

III. THE CLEAN AIR ACT REGULATORY FRAMEWORK FOR OZONE

The CAA requires EPA to set NAAQS for pollutants that EPA determines are harmful to public health and the environment. The CAA identifies two sets of NAAQS to accomplish this. Primary standards provide public health protection, including protecting the health of vulnerable populations such as asthmatics, children, and the elderly. Secondary standards provide public welfare protection, including protection against decreased visibility and damage to animals, crops, vegetation, and buildings.

The EPA has set NAAQS for six principal pollutants, known as "criteria" air pollutants: ozone, nitrogen dioxide, sulfur dioxide, carbon monoxide, particulate matter 10 microns or less, particulate matter 2.5 microns or less, and lead. The CAA requires EPA to review the standards on a periodic basis, which may result in the standards being revised based on health and environmental criteria that apply to the concentration of a pollutant in outdoor air to limit harmful exposures and detrimental effects.

Following promulgation of a new NAAQS or revised NAAQS, EPA undertakes a process of "designating" areas as in attainment or nonattainment with the standard. This process entails collaborating with states and tribes and considering data and information from air quality monitors and modeling. If the air quality in a geographic area meets or exceeds the national standard, it is designated as an "attainment" area. Areas that do not meet the national standard are designated as "nonattainment" areas. Areas that do not have monitoring data available are designated as "attainment/unclassifiable". EPA is required to designate areas of the States within two years of promulgating a new or revised NAAQS.

The process of determining whether an area is in attainment or nonattainment of the ozone NAAQS is triggered when the "design value" for ozone is shown to be in excess of the standard. The design value is determined by calculating the three-year average of the annual fourth highest daily maximum 8-hour ozone concentration. It is important to note that readings from monitors showing design values that exceed the ozone NAAQS do not in themselves constitute a nonattainment designation or trigger changes to permitting or other actions on the part of the Department. Under the CAA, the AQCA, and the Regulations, an ozone "nonattainment area" means an area that has gone through the formal nonattainment designation process and has been designated as such by EPA.

Designated nonattainment areas are further classified based on the extent to which they exceed the standard. These classifications are marginal, moderate, serious, severe, or extreme. State and local governments are required to develop a plan, known as a state implementation plan ("SIP"), that details how nonattainment areas will improve the air quality to attain and maintain the standards. Once a nonattainment area meets the standards, states can petition EPA to designate the area as a maintenance area. Until the promulgation of the 2015 ozone NAAQS, New Mexico had no designated nonattainment areas in the State.

In October 2015, following a periodic review, EPA revised the ozone NAAQS downward from 0.075 parts per million (ppm) to 0.070 ppm. For the 2015 ozone NAAQS, all states were required to submit their designation recommendations to EPA by October 1, 2016. Ozone data collected by NMED from 2014 through 2016 showed that a monitor located in the Sunland Park area in southern New Mexico was exceeding the revised ozone standard. NMED submitted a nonattainment area recommendation for the Sunland Park area and recommended attainment or attainment/unclassifiable designations for the remainder of areas in New Mexico. EPA concurred with the recommendations and finalized the area designations for New Mexico on August 3, 2018.

EPA classified the Sunland Park nonattainment area as marginal, allowing NMED 3 years to develop a SIP revision that includes the planning elements required for a marginal nonattainment classification. The SIP revision outlines the strategies and emissions control measures that are expected to reduce the amount of ozone precursors emitted to the atmosphere and improve air quality in the area by August 3, 2021. States may rely on current or upcoming federal rules, new or revised state rules, and other programs, such as the New Mexico Volkswagen mitigation plan projects and the 2021 Regional Haze SIP revision.

On July 13, 2020, EPA proposed to retain the existing 2015 ozone NAAQS. The CAA does not require EPA to promulgate area designations when an existing NAAQS is retained following the periodic review process. Historically, EPA has not designated new nonattainment areas when a NAAQS is not revised during a periodic review. Thus, New Mexico's current ozone designations under the CAA will remain in place unless and until the ozone NAAQS is revised, or EPA or the State seeks a redesignation.

Ozone monitoring data for 2017-2019 indicate that other areas of the state are approaching or violating the 2015 ozone NAAQS. In particular, the counties of Eddy, Lea, and the remainder of Doña Ana are monitoring ozone levels in violation of the standard, while San Juan, Rio Arriba, Sandoval and Valencia County are within 95% of it. The AQCA requires the State to plan for ozone mitigation in areas where monitors indicate ozone levels greater than or equal to 95% of the ozone standard. NMED is addressing these areas through the Ozone Attainment Initiative and EPA's Ozone Advance program, as discussed below.

IV. OZONE REGULATION UNDER THE NEW MEXICO AIR QUALITY CONTROL ACT AND REGULATIONS

Section 74-2-5.3 of the AQCA specifically mandates that the Board take action to control VOC and NOx emissions when the Board determines that emissions from sources within its jurisdiction cause or contribute to ozone concentrations in excess of ninety-five percent of the ozone NAAQS. Under this statutory provision, the Board is required to adopt a plan, including regulations, to control emissions of oxides of nitrogen, or NO_X, and volatile organic compounds, or VOCs, to provide for the attainment and maintenance of the ozone standard for those areas that exceed 95% of the ozone standard.

In accordance with this section, the Board is required to consider the following in the adoption of regulations:

(1) the public interest, including the social and economic value of the sources of emissions and subjects of air contaminants;

(2) previous experience with equipment and methods available to control the air contaminants involved;

(3) energy, environmental and economic impacts and other social costs;

(4) efforts by sources of emissions to reduce emissions prior to the effective date of regulations adopted under this section; and

(5) for existing sources of emissions, the remaining useful life of any existing source to which the regulation would apply.

V. THE DEPARTMENT'S OZONE ATTAINMENT INITIATIVE

Currently, seven counties under the Board's jurisdiction are registering or contributing to ozone design values exceeding 95% of the NAAQS: San Juan, Rio Arriba, Sandoval, Valencia, Eddy, Lea, and Doña Ana.

To address this statutory requirement, the Bureau has embarked upon the Ozone Attainment Initiative ("OAI") to develop a series of rules and voluntary measures to mitigate emissions of NO_X and VOCs in the aforementioned counties. A proposed rule to control NO_X and VOC emissions from various types of equipment related to the production of oil and gas in the South San Juan and Permian Basins has been developed, and the Bureau intends to bring this proposal to the Board for a hearing in December of this year. The Bureau has contracted with the Western States Air Resources Council and Ramboll to conduct photochemical grid modeling for ozone to support our rulemaking efforts. The results of this modeling will identify anthropogenic natural, and state and international contributions to the ozone concentrations monitored in the counties of concern. The results of this modeling effort are expected in October of 2020.

The oil and gas industry is not the only significant contributor to monitored ozone concentrations in New Mexico; previously conducted regional modeling efforts, including the Southern New Mexico Ozone Study ("SNMOS") completed in 2016, have shown that emissions from onroad mobile sources are the largest New Mexico anthropogenic contribution to the design values at most monitors in southern New Mexico. A copy of the Technical Support Document from the SNMOS is attached as NMED Exhibit 6. Section 177 of the Clean Air Act allows other states to adopt California's motor vehicle emission standards, and the Department intends to bring before the Board regulations setting standards for low emission vehicles ("LEV"), and zero emission vehicles ("ZEV") for adoption in 2021 that will provide further mitigation of ozone precursors.

The Department has also submitted a letter of participation to EPA for the Advance Program. The Advance Program is a means to promote local actions in areas designated as in attainment to reduce ozone and/or fine particulate pollution ($PM_{2.5}$) for the continued maintenance of the NAAQS. The Bureau will coordinate efforts with local governments that wish to take proactive steps towards the protection of air quality. In addition to positioning areas to avoid a nonattainment designation, it can allow communities to choose control measures that are cost effective and that make the most sense for their area, potentially resulting in multi-pollutant benefits.

Because the ozone design value in Bernalillo County also exceeds 95% of the ozone NAAQS, the Bureau is coordinating its efforts for ozone mitigation with the City of Albuquerque's Environmental Health Department, which has jurisdiction over air quality in Bernalillo County.

In addition to the OAI and Ozone Advance, the Bureau is also working with the City of Albuquerque on preparing revised Regional Haze State Implementation Plans for submittal to EPA

in July of 2021. The goal of the Regional Haze provisions of the CAA is to improve visibility in national parks and wilderness areas (referred to as Class I areas), and states are required to make reasonable progress over time towards the long-term goal of attaining natural visibility conditions by 2064. The Regional Haze program requires states to submit Regional Haze State Implementation Plans approximately once every ten years. Based on data collected at monitors operated by federal land managers, visibility impairment at the Class I areas in New Mexico is driven by sulfates and nitrates, so the Department is evaluating potential additional controls for sulfur dioxide (SO_2) and NO_X emissions from twenty-three major sources within our jurisdiction. Two of these sources are electric generating units, and the remainder are in the oil and gas sector. The additional controls for certain emission units adopted as part of this Regional Haze SIP revision will also serve to reduce the formation of ozone.

While the Department will use its authority to reduce the contribution from New Mexico anthropogenic sources that contribute to ozone design values, contributions from other sources are beyond our control. The aforementioned Southern New Mexico Ozone Study evaluated contributions to design values at monitors in southern New Mexico in the base year (2011) and a future year (2025). The most frequent contributors to the design values of the six Doña Ana County monitors were on-road mobile sources (New Mexico, Texas, and Mexico), natural sources (Mexico), electric generating units ("EGUs") (Mexico), non-EGU point sources (Mexico), and oil and gas (Texas). *See* SNMOS Technical Support Document, at p. 67. Therefore, it is possible that, even with all the regulatory efforts of the OAI, some areas may not be able to reach or stay in attainment of the ozone NAAQS. In that case, the regulatory path will be a formal nonattainment designation by EPA, with attendant demonstrations by the Department showing that the primary

causes of such nonattainment are outside of the State's control either because they are due to natural events/conditions or interstate and international transport.

VI. CONCLUSION

The Department acknowledges that the monitors in the Southeastern part of the state are registering design values above the 2015 ozone NAAQS. The Department is taking comprehensive action to address that situation in a manner that is consistent with its statutory and regulatory authority. If the Department were to simply deny every single permit application or GCP registration, it would be acting outside its authority and without scientific or technical basis, and would be subject to challenge on every single permit or registration. The Board should uphold the Department's decision to approve the Permit and the Registrations and should await the upcoming rulemakings that will be brought before it shortly to address the issue of ozone pollution in the State.

NMED
EXHIBIT 6

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Bureau Chief
Air Quality Bureau
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Santa Fe, NM 87507
505-476-4305

Education

Attended M.Sc. Program in Soil Science, 08/2003-12/2004
University of Kentucky, Lexington, KY

B.S. in Environmental Studies
University of Iowa, Iowa City, IA., conferred May 2002.

Employment Experience

08/2013 to 03/2018 - Bureau Chief, Air Quality Bureau, NMED
My responsibilities include providing leadership and supervision of the administrative, financial, compliance, permitting, operations, and planning sections of the Air Quality Bureau. I direct the overall management of resources, including staff who enforce the state and federal air quality standards; provide air quality related planning and policy, operational, permitting, and compliance and enforcement services to New Mexico employers; financial oversight of the Bureau's federal grant and state matching funds, and support services for the Bureau.

08/2013 to 03/2018 - Minor Source Section Manager, Air Quality Bureau, NMED
My responsibilities included management of the Minor Source Permitting Section and direct management of six (6) full time Environmental Scientists and Specialists. The Section reviews complex air quality permit applications for the most technically complex and diverse industrial facilities, including oil and gas, construction, manufacturing, agricultural, power generation, and chemical processing plants.

01/2013 to 08/2013 - Acting Technical Services Manager, Air Quality Bureau, NMED

05/2012 – 10/2012 - Acting Minor Source Section Manager, Air Quality Bureau, NMED

02/28/2005 to 08/2013 - Permit Specialist, Minor and Major Source Permit Section, Air Quality Bureau, NMED
My primary responsibilities involve performing technical analyses of air quality permit applications; drafting permits in accordance with federal and state regulations; accomplishing special projects in support of the section, mentoring new staff, and assisting the regulated community and concerned citizens.

08/2002-05/2003 and 08/2003-12/2004
Teaching and Research Assistant, University of Kentucky, Lexington, KY
Introduction to Soil Science, Agronomy Department

Teaching Assistant, University of Iowa, Iowa City, IA
Introduction to Earth Systems Science, Geography Department
Introduction to Environmental Science, Geoscience Department

Professional Development and Training Courses

Effective Permit Writing
Sources and Control of PM Emissions
Introduction to Hazardous Air Pollutants
Control of Gaseous Emissions
Advance PSD Permitting
Permit Practices and Procedures I and II
NSR Reform and Advanced PSD
Basic NSR/PSD
Environmental Negotiations

NMED
EXHIBIT 7

Southern New Mexico Ozone Study
Technical Support Document

Prepared by:

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October 19, 2016

UNC INSTITUTE FOR THE ENVIRONMENT

RAMBOLL ENVIRON

NMED Exhibit 7

CONTENTS

TABLES

FIGURES

ACRONYMS AND ABBREVIATIONS

3SAQS	Three-State Air Quality Study
AIRS	Aerometric Information Retrieval System
AMET	Atmospheric Model Evaluation Tool
APCA	Anthropogenic Precursor Culpability Assessment
AQ	Air Quality
AQS	Air Quality System
BC	Boundary Condition
CAMx	Comprehensive Air-quality Model with extensions
CARB	California Air Resources Board
CASTNet	Clean Air Status and Trends Network
CB6r2	Carbon Bond mechanism version 6, revision 2
CMAQ	Community Multiscale Air Quality modeling system
CONUS	Continental United States
CPC	Center for Prediction of Climate
CSAPR	Cross State Air Pollution Rule
CSN	Chemical Speciation Network
EC	Elemental Carbon Fine Particulate Matter
ECMWF	European Center for Medium Range Weather Forecasting
EGU	Electrical Generating Units
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
FB	Fractional Bias
FE	Fractional Error
FRM	Federal Reference Method
GCM	Global Chemistry Model
GEOS-Chem	Goddard Earth Observing System (GEOS) global chemistry model
GIRAS	Geographic Information Retrieval and Analysis System
IMPROVE	Interagency Monitoring of Protected Visual Environments
IWDW	Intermountain West Data Warehouse
LCP	Lambert Conformal Projection
LSM	Land Surface Model
MADIS	Meteorological Assimilation Data Ingest System
MATS	Modeled Attainment Test Software
MCIP	Meteorology-Chemistry Interface Processor
MEGAN	Model of Emissions of Gases and Aerosols in Nature
MNGE	Mean Normalized Gross Error
MNB	Mean Normalized Bias
MNE	Mean Normalized Error
MOVES	Motor Vehicle Emissions Simulator
MOZART	Model for OZone And Related chemical Tracers
MPE	Model Performance Evaluation
MSKF	Multi-Scale Kain-Fritsch Cumulus Parameterization

NAAQS	National Ambient Air Quality Standard
NAM	North American Mesoscale Forecast System
NCAR	National Center for Atmospheric Research
NCEP	National Center for Environmental Prediction
NCDC	National Climatic Data Center
NEI	National Emissions Inventory
NEPA	National Environmental Policy Act
NH_4	Ammonium Fine Particulate Matter
NMB	Normalized Mean Bias
NME	Normalized Mean Error
NO_2	Nitrogen Dioxide
NO_3	Nitrate Fine Particulate Matter
NOAA	National Oceanic and Atmospheric Administration
OA	Organic Aerosol Fine Particulate Matter
OC	Organic Carbon Fine Particulate Matter
OSAT	Ozone Source Apportionment Technology
PAVE	Package for Analysis and Visualization
PBL	Planetary Boundary Layer
PGM	Photochemical Grid Model
PM	Particulate Matter
PPM	Piecewise Parabolic Method
QA	Quality Assurance
QC	Quality Control
RMP	Resource Management Plan
RRF	Relative Reduction Factor
SCC	Source Classification Code
SIP	State Implementation Plan
SMOKE	Sparse Matrix Kernel Emissions modeling system
SNMOS	Southern New Mexico Ozone Study
SOA	Secondary Organic Aerosol
SO_2	Sulfur Dioxide
SO_4	Sulfate Fine Particulate Matter
TCEQ	Texas Commission on Environmental Quality
UNC-IE	University of North Carolina Institute for the Environment
USFS	United States Forest Service
VERDI	Visualization Environment for Rich Data Interpretation
VMT	Vehicle Miles Traveled
WBD	Wind Blown Dust model
WAQS	Western Air Quality Study
WESTAR	Western States Air Resources Council
WESTUS	Western United States
WRAP	Western Regional Air Partnership
WGA	Western Governors' Association
WRF	Weather Research Forecasting model

1.0 EXECUTIVE SUMMARY

The Southern New Mexico Ozone Study (SNMOS) studied the factors contributing to high ozone in Doña Ana County. Photochemical modeling was carried out for May 1 – September 30, 2011 using emissions scenarios for a 2011 base year and a 2025 future year. The SNMOS modeling platform was derived from the Western Air Quality Study (WAQS) regional modeling platform that was available through the Intermountain West Data Warehouse (IWDW) with adjustments and updates to the meteorology and modeling domains to optimize the platform for application to Southern New Mexico and surrounding regions.

The Weather Research Forecasting (WRF) model was used to provide meteorology data for use in the photochemical modeling. Emissions processing was primarily conducted using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system using emissions data from the EPA 2011-based modeling platform (2011v6) version 2 and the WAQS (2011b) inventories. Photochemical grid modeling was done with the Comprehensive Air-quality Model with extensions (CAMx) version 6.20. A model performance evaluation was carried out for the meteorological and photochemical models; performance was determined to be acceptable through comparison with EPA Modeling Guidance (EPA, 2014) and to be consistent with performance in similar regional modeling studies. The major findings of the SNMOS are listed below:

- 2025 future year design value projections indicate that all Doña Ana County ozone monitors are expected to attain the 70 ppb National Ambient Air Quality Standard for ozone (NAAQS) in 2025.
- The modeled decreases in Doña Ana County ozone design values between 2011 and 2025 are mainly driven by projected reductions in emissions from cars, trucks and other on-road mobile sources
- All Doña Ana County ozone monitors would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico
- Regional emissions sources contributing the most ozone to 2011 Doña Ana County ozone were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions (mainly from plants as well as lightning and fires) from Mexico.
- Regional emissions sources contributing the most ozone to Doña Ana County ozone monitors in 2025 were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant and non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.
- Ozone transport plays an important role in determining ozone levels in Doña Ana County. Ozone from emissions sources outside the region was the largest contributor of ozone; this is a typical result for a regional modeling study. For all Doña Ana County monitors except Solano, the individual ozone contribution from Texas and Mexico was larger than that of New Mexico.

- New Mexico anthropogenic emission sources that contributed the most ozone to Southern New Mexico monitors were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants.

We provide recommendations for model improvement and further study at the end of this report.

2.0 INTRODUCTION

2.1 Project Background

Doña Ana County in Southern New Mexico experiences some of the highest observed ground-level ozone concentrations in the state. The Sunland Park Ozone Nonattainment Area (NAA) which lies within Doña Ana County was designated as marginal nonattainment for the 1-hour ozone standard on June 12, 1995 (60 FR 30789). With the revocation of the 1-hour ozone standard in 2004, the Sunland Park NAA was designated a maintenance area for 8-hour ozone (NMED, 2007). Lowering of the 8-hour ozone standard by EPA in 2008 to 0.75 ppm (75 ppb) and again in 2015 to 0.70 ppm (70 ppb) will likely lead to the Sunland Park NAA receiving a nonattainment designation for 8-hour ozone. In addition, the New Mexico Air Quality Control Act (NMAQCA) requires the New Mexico Environment Department (NMED) to develop a plan for reducing ozone levels in areas that are within 95% of the ozone standard (NMSA 1978, § 74-2-5.3). Table 2-1 shows the 1st through 4th highest daily maximum 8-hour average ozone (MDA8) concentrations measured from 2011 to 2014 at the EPA Air Quality System (AQS) monitors in Doña Ana County. This table shows that all but a handful of the measurements at these monitors exceeded either the 2015 NAAQS for ozone (orange) or the NMAQCA 95% threshold (yellow).

Table 2-1. Daily maximum 8-hour average ozone measurements from 2011-2014 at AQS sites in Doña Ana County, NM.

	1st Highest		2nd Highest		3rd Highest		4th Highest	
Station	Date	ppmV	Date	ppmV	Date	ppmV	Date	ppmV
La Union	5/24/2011	0.064	6/22/2011	0.064	7/28/2011	0.064	4/26/2011	0.063
SPCY	6/22/2011	0.078	6/4/2011	0.076	7/28/2011	0.068	6/27/2011	0.067
Chaparral	8/2/2011	0.074	5/24/2011	0.073	5/25/2011	0.071	6/22/2011	0.07
Desert V	6/4/2011	0.084	6/22/2011	0.081	8/27/2011	0.073	7/28/2011	0.072
Sta Teresa	6/22/2011	0.078	5/24/2011	0.074	4/26/2011	0.07	6/27/2011	0.07
Solano	5/24/2011	0.068	5/25/2011	0.068	8/6/2011	0.068	8/27/2011	0.067
La Union	8/31/2012	0.079	7/13/2012	0.078	6/28/2012	0.075	7/14/2012	0.074
SPCY	8/31/2012	0.078	7/13/2012	0.076	7/12/2012	0.075	6/28/2012	0.073
Chaparral	6/2/2012	0.075	6/1/2012	0.07	7/13/2012	0.069	6/3/2012	0.067
Desert V	7/13/2012	0.077	8/31/2012	0.077	7/12/2012	0.076	6/28/2012	0.075
Sta Teresa	8/31/2012	0.083	7/13/2012	0.08	7/12/2012	0.078	9/1/2012	0.077
Solano	5/16/2012	0.069	6/3/2012	0.068	7/13/2012	0.067	6/2/2012	0.066
La Union	8/17/2013	0.066	8/16/2013	0.065	8/21/2013	0.065	8/4/2013	0.064
SPCY	7/3/2013	0.068	6/11/2013	0.063	6/9/2013	0.063	8/17/2013	0.062
Chaparral	5/24/2013	0.074	6/15/2013	0.074	7/3/2013	0.071	7/5/2013	0.07
Desert V	7/3/2013	0.076	8/16/2013	0.072	7/27/2013	0.072	6/9/2013	0.071
Sta Teresa	7/27/2013	0.089	7/3/2013	0.081	7/25/2013	0.081	7/7/2013	0.08
Solano	7/31/2013	0.066	7/27/2013	0.065	7/16/2013	0.065	5/20/2013	0.064
La Union	6/10/2014	0.07	5/29/2014	0.07	8/18/2014	0.068	5/28/2014	0.066
SPCY	6/10/2014	0.073	5/29/2014	0.068	8/30/2014	0.068	7/22/2014	0.068
Chaparral	8/6/2014	0.075	6/10/2014	0.071	7/18/2014	0.069	5/29/2014	0.068
Desert V	6/10/2014	0.077	5/29/2014	0.074	7/15/2014	0.073	5/28/2014	0.072

Station	1st Highest		2nd Highest		3rd Highest		4th Highest	
	Date	ppmV	Date	ppmV	Date	ppmV	Date	ppmV
Sta Teresa	7/15/2014	0.071	8/18/2014	0.07	7/31/2014	0.069	6/10/2014	0.067
Solano	6/10/2014	0.072	6/7/2014	0.069	5/29/2014	0.068	6/9/2014	0.067

The statutory requirements of both the NAAQS and the NMAQCA include the development of a plan to control the emissions of sources pursuant to attainment and maintenance of the NAAQS. In the case of a NAAQS NAA State Implementation Plan (SIP), air quality modeling is required to identify the causes of high pollution and to propose emissions control strategies that will bring the area into attainment.

The Southern New Mexico Ozone Study (SNMOS) studied the factors contributing to high ozone in Doña Ana County and investigated future emissions scenarios that will produce NAAQS attainment. The SNMOS is a collaborative project between NMED, the Western Regional Air Partnership (WRAP), the Western Air Resources Council (WESTAR), Ramboll Environ US Corporation (RE), and the University of North Carolina Institute for the Environment (UNC-IE). This Study built off of the Western Air Quality Study (WAQS), a cooperative project that is intended to facilitate air resource analyses for federal and state agencies in the intermountain western U.S. toward improved information for the public and stakeholders as a part of air quality planning. The Intermountain West Data Warehouse (IWDW) at the Cooperative Institute for Research in the Atmosphere (CIRA) at Colorado State University was the source for the regional air quality modeling data and software resources from the WAQS. The SNMOS leveraged the WAQS 2011 version B (WAQS_2011b) modeling platform to conduct base and future year air quality modeling for Doña Ana County.

2.2 Organization of the Technical Support Document

This Technical Support Document (TSD) summarizes the objectives, methods and results of the SNMOS. In the remainder of Section 2, we provide a summary of the SNMOS modeling approach. In Section 3, we present an overview of the results of the study. The organization of Section 3 of the TSD follows that of the SNMOS, which was broken into 13 separate Tasks:

- **Task 1**: 2011 WRF 36/12/4-km modeling with 4-km grid focused on Dona Ana/El Paso/Juárez and Data Analysis/Modeling Work Plan
- **Task 2**: 2011 update of Permian Basin oil and gas emission inventory
- **Task 3**: 2011 update of emissions inventories for Juárez and nearby Mexico and 2025 Mexico emissions
- **Task 4**: SMOKE modeling of current 2011 National Emission Inventory for 4-km domain
- **Task 5**: Gridded 2011 biogenic, fires, wind-blown dust, lightning emissions for 4-km domain
- **Task 6**: Develop 2011 4-km CAMx database and perform base case modeling
- **Task 7**: 2011 CAMx model performance evaluation and sensitivity modeling for Doña Ana County
- **Task 8**: SMOKE current 2025 US emission inventory and Mexico emissions update

- **Task 9**: Future year (2025) 12/4-km CAMx simulation
- **Task 10**: FY (2025) ozone design value projections (MATS)
- **Task 11**: 2025 emissions sensitivity tests/controls
- **Task 12:** Ozone source apportionment modeling of 2011 and 2025
- **Task 13**: Technical Support Document (TSD)

For each Task, we outline the methods, data used and results. Then we summarize the major findings of the Task. Finally, we list the Task deliverables and their completion dates. A PowerPoint presentation and/or written documentation describing each Task in more detail are available on the WRAP SNMOS website.

In Section 4, we provide a summary of results and conclusions of the SNMOS and make recommendations for future work.

2.3 Overview of the SNMOS Modeling Approach

The SNMOS modeling platform was derived from the WAQS_2011b regional modeling platform. A regional modeling platform is the suite of data and software required for conducting a regional-scale air quality modeling study. The procedures for the SNMOS 2011 modeling followed those performed for the 2011 WAQS with adjustments to the meteorology and modeling domains to optimize the modeling platform for application to southern New Mexico. The SNMOS 2011 modeling platform included nested 36, 12 and 4-km resolution meteorology modeling domains. The regional air quality modeling was conducted at 12 and 4-km resolution.

The SNMOS modeling domains were selected to facilitate high resolution modeling for sources around Doña Ana County and to enable regional source apportionment modeling among all of the surrounding Western states. The SNMOS 12 and 4-km domains, shown in Figure 2-1, were designed to encompass the meteorology and emissions features that are most important to ground-level ozone formation in southern New Mexico. Also shown in Figure 2-1 are the locations of EPA's Air Quality System (AQS) ozone monitors (green) and point sources of nitrogen oxide (NOx) emissions (blue).

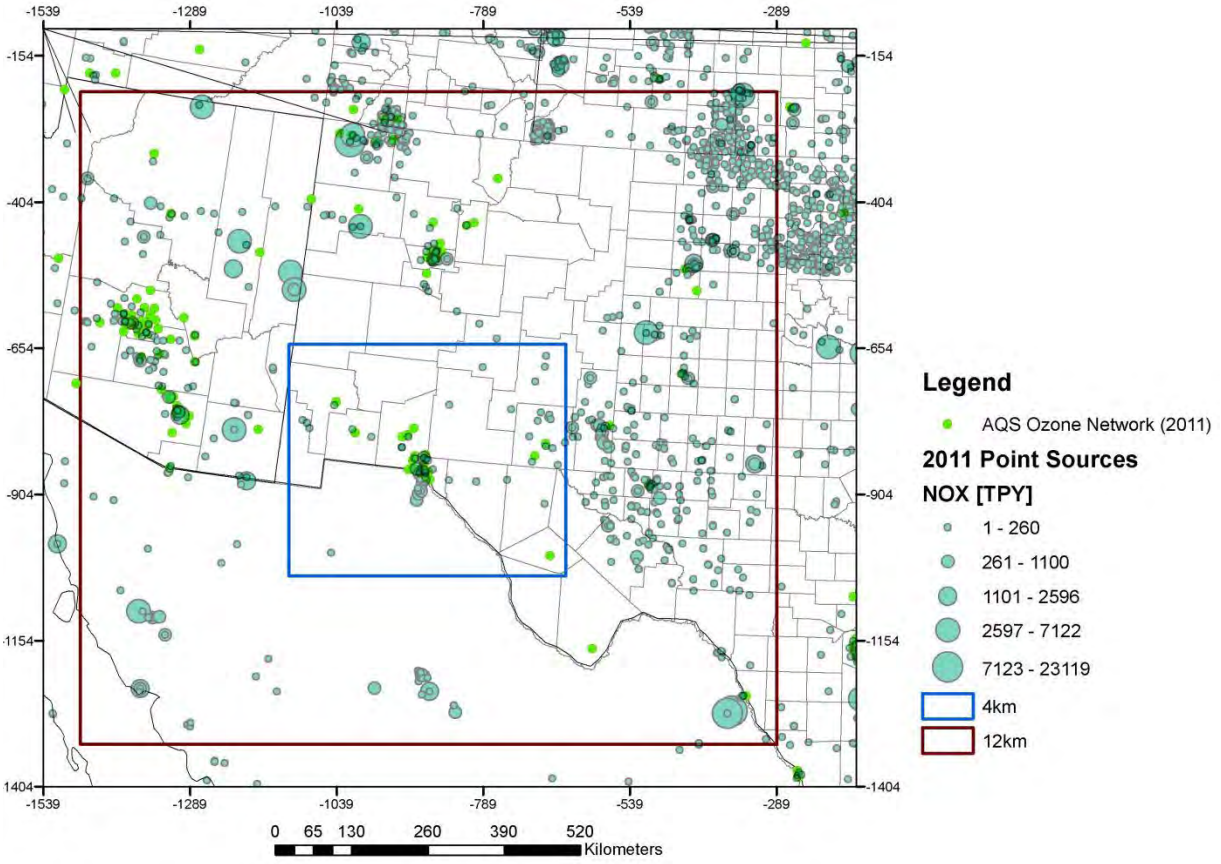


Figure 2-1. SNMOS 2011 CAMx 12/4-km modeling domains.

The CAMx and emissions domains for modeling of 2011 were chosen for the following reasons:

- New continental-scale coarse grid modeling was not needed for the SNMOS because we were able to extract BCs for the 12-km domain from the WAQS 2011 CAMx modeling results. The WAQS modeling used the 36-km RPO grid and a 12-km modeling domain that encompassed much of the western U.S. As we used the same emissions data and CAMx configuration for the SNMOS as were used for the WAQS, there was consistency between these simulations enabling the use of the WAQS modeling as lateral boundary conditions (BCs) for the SNMOS domains.
- The SNMOS 12-km CAMx domain encompasses all of New Mexico, extends west to include the metropolitan area of Phoenix, east to include East Texas, and south to include the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña Ana County on high ozone days during 2011. The SNMOS 12-km domain was designed to balance computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution.
- The SNMOS 4-km Doña Ana County domain focuses on Southern New Mexico and the major emissions source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX.

We simulated the 2011 ozone season and evaluated the meteorology and air quality model performance against surface and aloft monitors that operated in the modeling domains during the study period. Following the base year model performance evaluation, we used projected emissions data to simulate air quality in the year 2025. Along with future year attainment tests, the future year modeling included emissions sensitivity testing and ozone source apportionment modeling of emissions source region and source category contributions to ozone concentrations and ozone design values at ozone monitoring sites in Doña Ana County (and elsewhere in the region). A summary of the SNMOS modeling approach is given below.

- The 2011 ozone season for New Mexico (May 1 – September 30) was selected for the modeling period.
- Year 2011 and 2025 inventories were used to estimate base and future year emissions.
- The Weather Research Forecasting (WRF) version 3.7.1 was used to simulate meteorology data for this study.
- Emissions processing was primarily conducted using the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system version 3.7 using emissions data from the EPA 2011-based modeling platform (2011v6) version 2 and the WAQS (2011b).
- Photochemical grid modeling (PGM) was done with the Comprehensive Air-quality Model with extensions (CAMx) version 6.20. The Carbon Bond 6 revision 2 (CB6r2) photochemical mechanism was used for the SNMOS modeling.
- For the SNMOS 2011 modeling, hourly BCs for the portion of the lateral boundaries of the SNMOS 12-km PGM domain that lies within the larger WAQS 12-km domain were extracted from the WAQS 36-km continental U.S. CAMx modeling.

- Model performance evaluation was conducted for meteorology, ozone, and ozone precursor and product species.
- Diagnostic sensitivity testing was conducted to determine sensitivity of the PGM model estimates to the WRF model configuration and to improve the 2011 base year model performance in simulating ground-level ozone in Southern New Mexico and the surrounding region.
- Future year modeling was used to estimate air quality in 2025 and to conduct attainment tests for Doña Ana County.
- Future year emissions sensitivity modeling was used to evaluate the impacts of emissions reductions on future attainment of the ozone NAAQS.
- Future year CAMx source apportionment modeling was used to quantify the source region and source category contributions to ozone concentrations and ozone design values at ozone monitoring in Dona Ana County.

2.4 Project Participants

The SNMOS was facilitated and managed by the Western States Air Resources Council (WESTAR). RE and UNC-IE conducted the meteorology, emissions, and air quality modeling and analysis. Key contacts and their roles in the SNMOS are listed in Table 2-2.

Table 2-2. SNMOS key contacts.

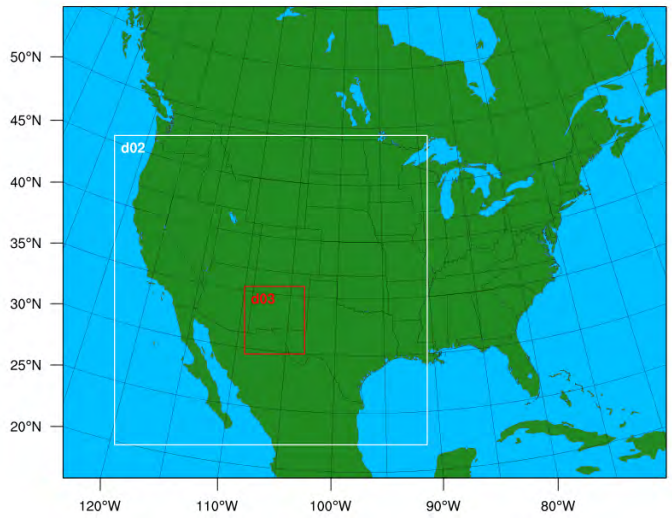
Name	Role	Organization/Contact
Tom Moore	Project Manager	WESTAR c/o CSU/CIRA 1375 Campus Delivery Fort Collins, CO 80523 (970) 491-8837 tmoore@westar.org
Zac Adelman	UNC-IE Lead	University of North Carolina Institute for the Environment 100 Europa Dr., Suite 490, CB 1105 Chapel Hill, NC 27517 (919) 962-8510 zac@unc.edu
Ralph Morris	Ramboll Environ Lead	Ramboll Environ 773 San Marin Drive, Suite 2115 Novato, CA 94998 (415) 899-0708 rmorris@environcorp.com

3.0 SNMOS TASK SUMMARIES

3.1 Task 1: Weather Research Forecast (WRF) Meteorological Modeling

3.1.1 Task Summary

The objective of this task was to simulate and evaluate WRF meteorology for modeling 2011 summer season ozone in Doña Ana County, New Mexico. We coordinated with WRF modelers in the western U.S. to find a candidate model configuration for best simulating ozone in the southwestern U.S. We used the most recent version of WRF (v3.7.1) available at the time of the study to test four different WRF configurations in simulating summer season (April 15-August 30, 2012) meteorology on 33 vertical layer (Table 3-1) 36-km U.S. EPA Continental U.S. (CONUS), 12-km Western U.S. and 4-km SNMOS modeling domains (Figure 3-1). After conducting an operational model performance evaluation on all of the WRF simulations and selecting the best performing configuration, we converted the WRF output to CAMx inputs using the WRFCAMx software. Additional details of the WRF sensitivities, evaluation, and final configuration are provided below.



Parameter	Value
Projection	Lambert-Conformal
1st True Lat	33 degrees N
2nd True Latitude	45 degrees N
Central Lon	97 degrees W
Central Lat	40 degrees N
dX (km)	d01 = 36, d02 = 12, d03 = 4
dY (km)	d01 = 36, d02 = 12, d03 = 4
X-orig (km)	d01 = -2736, d02 = -2196, d03 = -912
Y-orig (km)	d01 = -2088, d02 = -1728, d03 = -828
# cols	d01 = 165, d02 = 256, d03 = 148
# rows	d01 = 129, d02 = 253, d03 = 166

Figure 3-1. WRF modeling domains.

Table 3-1. Vertical layer interfaces for the WRF and CAMx simulations

WRF and CAMx Levels				
WRF Level	Sigma	Pressure (mb)	Height (m)	Thickness (m)
33	0.0000	50.00	19260	2055
32	0.0270	75.65	17205	1850
31	0.0600	107.00	15355	1725
30	0.1000	145.00	13630	1701
29	0.1500	192.50	11930	1389
28	0.2000	240.00	10541	1181
27	0.2500	287.50	9360	1032
26	0.3000	335.00	8328	920

WRF and CAMx Levels				
WRF Level	Sigma	Pressure (mb)	Height (m)	Thickness (m)
25	0.3500	382.50	7408	832
24	0.4000	430.00	6576	760
23	0.4500	477.50	5816	701
22	0.5000	525.00	5115	652
21	0.5500	572.50	4463	609
20	0.6000	620.00	3854	461
19	0.6400	658.00	3393	440
18	0.6800	696.00	2954	421
17	0.7200	734.00	2533	403
16	0.7600	772.00	2130	388
15	0.8000	810.00	1742	373
14	0.8400	848.00	1369	271
13	0.8700	876.50	1098	177
12	0.8900	895.50	921	174
11	0.9100	914.50	747	171
10	0.9300	933.50	577	84
9	0.9400	943.00	492	84
8	0.9500	952.50	409	83
7	0.9600	962.00	326	83
6	0.9700	971.50	243	81
5	0.9800	981.00	162	65
4	0.9880	988.60	97	41
3	0.9930	993.35	56	32
2	0.9970	997.15	24	24
1	1.0000	1000	0	

The WRF configuration sensitivity tests that we ran were based on previous WRF modeling studies of the region. Our objective for these tests was to maximize the skill of the model in simulating conditions conducive to surface ozone build up in southern New Mexico. One key issue that we wanted to address was the known performance problem that WRF has in simulating precipitation in the Western U.S. Accurately capturing the timing and location of both convective precipitation events and events driven by the North American monsoon is important in developing a reliable model of ozone formation in the region. The prior WRF modeling studies that we considered in our design for the SNMOS included,

- The Bureau of Land Management's Montana-Dakotas (BLM-MT/DK) Study examined the sensitivity of WRF model performance in the Montana/Dakotas region for different WRF model configurations used in recent studies (McAlpine et al., 2014). In the initial Montana-Dakotas modeling, WRF overstated precipitation over the 4-km modeling domain during the summer months. The initial WRF run used surface temperature and humidity observation nudging in the 4-km domain. The temperature and humidity observation nudging introduced instabilities in the WRF simulation that resulted in increased convective activity and rainfall. BLM-MT/DK Study sensitivity testing

demonstrated that removing temperature and humidity observation nudging and using the Grell-Freitas cumulus parameterization on the 4-km domain for the final WRF simulation improved rainfall, wind speed, and wind direction model performance. The reduction in explicit convective activity allowed WRF to more accurately simulate the observed winds.

- In the San Juan Mercury Modeling (Ramboll Environ and Systech Water Resources, 2015), WRF overpredicted precipitation in a 12-km domain focused on the Four Corners region, but was much more accurate at the 4-km resolution. Observational nudging was applied to the 12-km and 4-km domains for winds, but not for temperature or humidity. Several cumulus parameterizations were evaluated to determine their effect on modeled precipitation.
- The 2011 WRF evaluation for the 3-State Air Quality Study (3SAQS) compared WRF 3.6.1 estimates to monthly PRISM observations (UNC and ENVIRON, 2014). While summertime WRF precipitation was generally too high relative to PRISM and the model did not resolve the local convective features well, there were questions about the PRISM analysis fields and their reliability at capturing isolated convective cells.

In consideration of these studies, we conducted a series of WRF simulations and selected the best performer (lowest bias and error for surface temperature, winds, humidity, and precipitation at sites in the 4-km SNMOS domain) for the operational simulations. The sensitivities were based off of the WAQS (UNC and ENVIRON, 2014) and San Juan Mercury Modeling (Ramboll Environ and Systech Water Resources, 2015) studies. Table 3-2 summarizes the base configuration that we used for the SNMOS WRF sensitivities and compares this configuration to the WAQS WRF modeling. The WRF version 3.7.1 sensitivity simulations that we ran included the following:

- Configuration 1 (NAM KF Mods): Base WRF configuration using settings from the 3SAQS/WAQS 2011 configuration. The key parameters here for the WRF sensitivity tests are the North American Model (NAM) Initial and Boundary Conditions (ICBCs) and the modified Kain-Fritsch (KF) cumulus scheme (Alapaty et al., 2012). The modified convective parameterization scheme provides subgrid-scale cloud fraction and condensate feedback to the shortwave and longwave radiation schemes. The impact of including the subgrid-scale cloud fraction is a reduction in the shortwave radiation, leading to less buoyant energy, thereby alleviating the overly energetic convection and reducing precipitation.
- Configuration 2 (NAM MSKF): Same as Configuration 1 with the multi-scale (grid-aware) Kain-Fritsch (MSKF) cumulus scheme (Alapaty et al., 2014). Additional changes were made to the modified KF scheme to improve the accuracy of precipitation at grey zone resolutions (<10 km). These include scale dependent features of convection such as scale dependent consumption of the convective available potential energy and entrainment of environmental air.
- Configuration 3 (ERA MSKF): Same as Configuration 2 but using the European Centre for Medium-range Weather Forecasts (ECMWF) ERA-Interim analysis as the ICBC fields.

Experience from the San Juan Hg WRF tests indicate that the ERA-Interim ICBC fields may improve simulated precipitation associated with the North American Monsoon.

- Configuration 4 (ERA MSKF No AN): Same as Configuration 3 but based on prior experiences from the San Juan Hg study, analysis nudging was not applied in domain 2.

Table 3-2. Base configuration for the SNMOS WRF sensitivity modeling.

WRF Treatment	3SAQS/WAQS	SNMOS
Microphysics	Thompson	Thompson
Longwave Radiation	RRTMG	RRTMG
Shortwave Radiation	RRTMG	RRTMG
Minutes between radiation physics calls	20	20
Land Surface Model (LSM)	NOAH	NOAH
Planetary Boundary Layer (PBL) scheme	YSU	YSU
Cumulus parameterization	Kain-Fritsch in the 36-km and 12-km domains only.	Multiscale (grid-aware) Kain-Fritsch.
Analysis nudging	Applied to winds (uv), temperature (t) and moisture (q) in the 36-km and 12-km domains	Applied to winds (uv), temperature (t) and moisture (q) in the 36-km and 12-km domains
Analysis nudging coefficients	uv: 5e-4 (d01), 3e-4 (d02) t: 5e-4 (d01), 3e-4 (d02) q: 1e-5 (d01 and d02)	uv: 5e-4 (d01), 3e-4 (d02) t: 5e-4 (d01), 3e-4 (d02) q: 1e-5 (d01 and d02)
Observation Nudging	Applied to surface wind and temperature in the 4-km domain	None
Observation nudging coefficients	uv: 1.2e-3 (d03) t: 6e-4 (d03)	N/A
Initialization Dataset	12-km North American Model (NAM)	12-km (NAM)
Top (mb)	50	50
Vertical Levels (Layers)	37 (36)	33 (32)

We ran the WRF model in 5-day blocks initialized at 12Z every 5 days with a 90-second integration time step. Model results were output every 60 minutes and output files split at 24-hour intervals. Twelve hours of spin-up were included in each 5-day block before the data were used in the subsequent evaluation. The model was run at 36-km, 12-km and 4-km grid resolution from May 15 through September 1, 2011 using one-way grid nesting with no feedback (i.e., the meteorological conditions are allowed to propagate from the coarser grid to the finer grid but not vice versa).

The evaluation for these simulations focused on simulating the North American Monsoon with an emphasis on the timing, location, and magnitude of precipitation in southern New Mexico. The model evaluation approach was based on a combination of qualitative and quantitative analyses. The quantitative analyses were divided into monthly summaries of 2-m temperature, 2-m mixing ratio, and 10-m wind speed using the boreal seasons to help generalize the model

bias and error relative to a standard benchmark. We supplemented the WRF evaluation with select diurnal and time series analyses at specific sites in the 4-km SNMOS modeling domain. Additional analysis included a qualitative evaluation of the daily total WRF precipitation fields against PRISM fields. The PRISM data were mapped to the WRF domains and grid resolution. The observed database for winds, temperature, and water mixing ratio used in this analysis were the National Oceanic and Atmospheric Administration (NOAA) Earth System Research Laboratory (ESRL) Meteorological Assimilation Data Ingest System (MADIS).

Table 3-3 shows the 4-km domain average performance statistics for temperature, moisture, and winds. The performance trends illustrate that initializing WRF with the North American Model (NAM) produces a WRF model that has a warm and dry bias with underestimated wind speeds. The ERA initialization produces a WRF model with a warm and wet bias that also underestimates the wind speeds. Including the MSKF convective cloud module slightly improved the moisture bias in the model and we found that the performance of this option was sensitive to the initialization dataset that we selected.

Table 3-3. 4-km domain average model performance statistics

	Temperature (deg K)		**Mixing Ratio (g/kg)**		**Wind Speed (m/s)**		**Wind Direction (degrees)**	
	Bias	Error	Bias	Error	Bias	RMSE	Bias	Error
Benchmark: Simple	≤ ±0.5	≤ 2.0	≤ ±0.5	≤ 1.0	≤ ±0.5	≤ 2.0	≤ ±5	≤ 40
Benchmark: Complex	≤ ±1.0	≤ 3.0	≤ ±1.0	≤ 2.0	≤ ±1.0	≤ 3.0	≤ ±10	≤ 80
NAM KFmods	**0.21**	**1.77**	-0.53	1.05	**-0.30**	2.12	5.46	43.6
NAM MSKF	0.22	**1.77**	-0.46	**1.03**	-0.34	2.12	5.02	43.9
ERA MSKF	0.24	1.87	**0.14**	1.12	-0.43	**2.08**	**3.95**	**42.8**
ERA MSKF no AN	0.40	2.05	-0.39	1.18	-0.34	2.28	4.73	49.1

Figure 3-2 shows August 2011 wind roses, indicating the mean monthly wind direction and speeds, for all sites in the 4-km SNMOS modeling domain. The figures in this plot compare the wind data for observations relative to the four WRF configurations that we tested. Figure 3-3 is a plot of PRISM precipitation observations compared to the WRF modeling results. We generated and evaluated many of these types of plots for all simulation months, for days during high ozone episodes, and where applicable, for each meteorological observation site in southern Doña Ana County. Additional evaluation plots included time series plots, bias-error (soccer) plots, temperature spatial plots with wind vector overlays, and scatter plots.

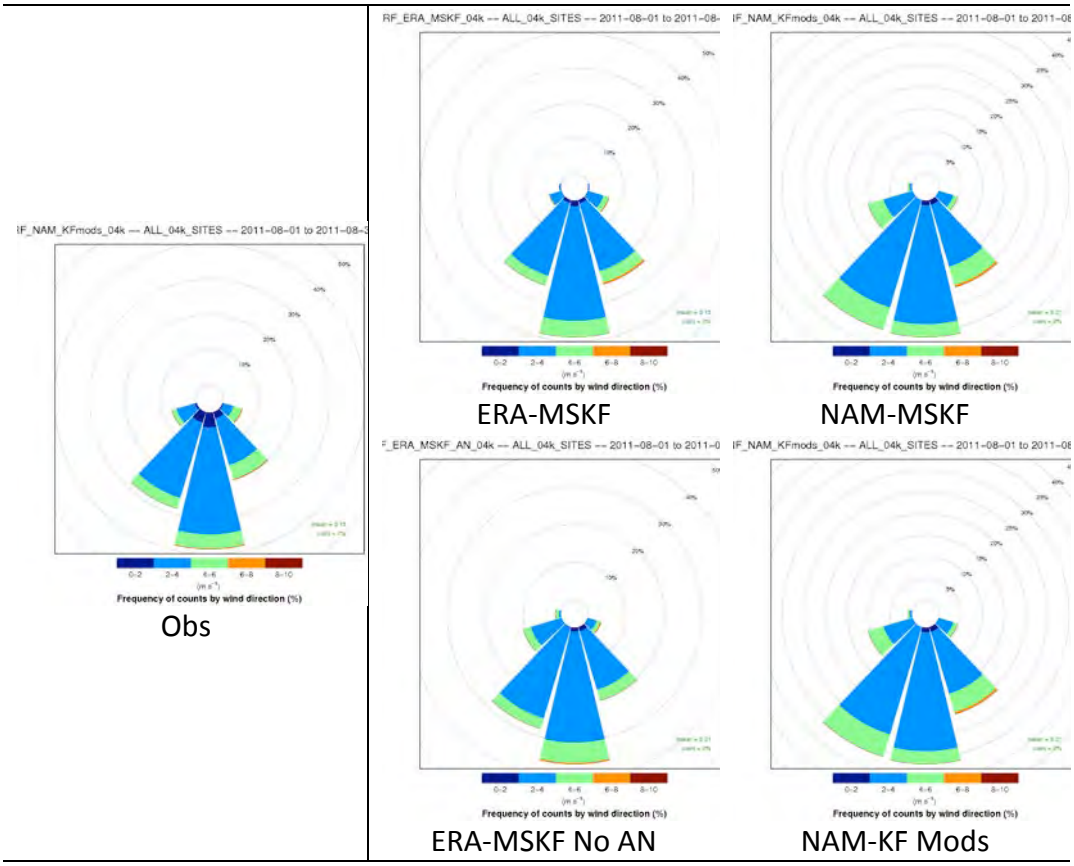


Figure 3-2. August 2011 wind roses, all sites in the 4-km domain

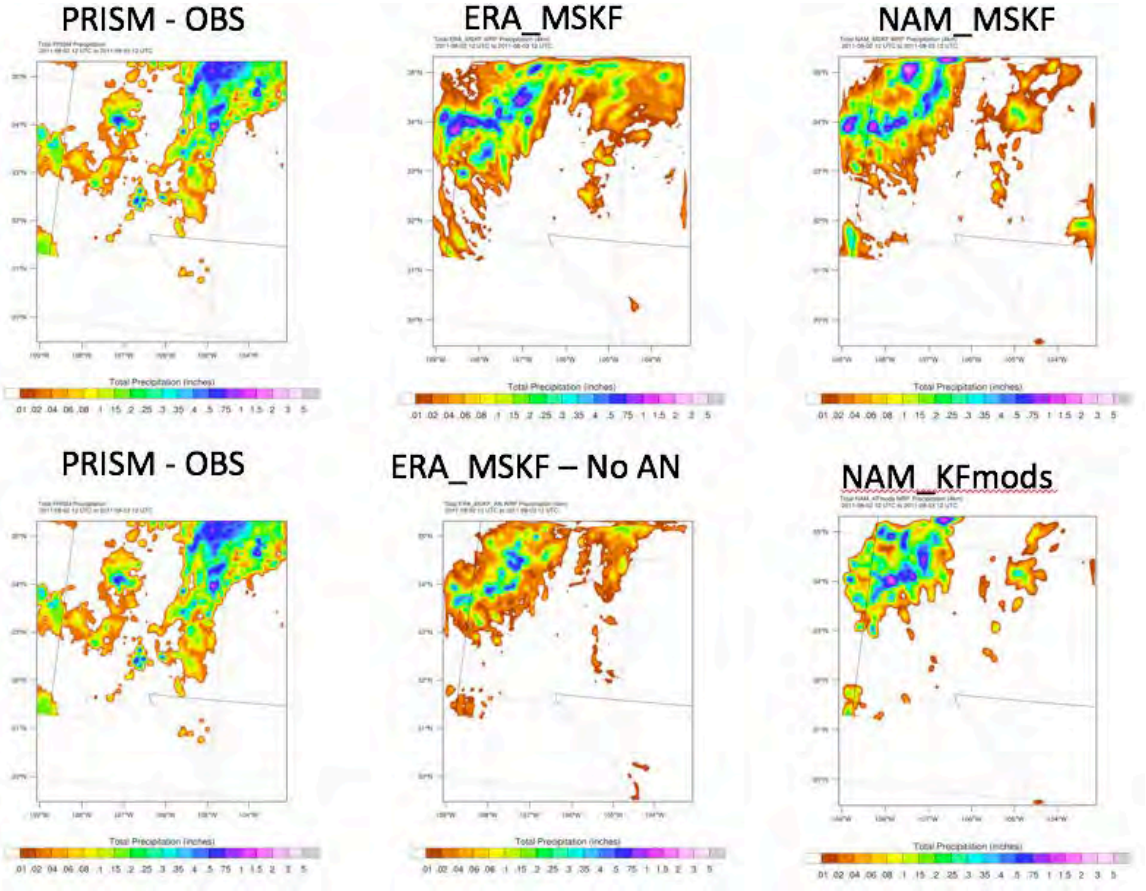


Figure 3-3. August 3, 2011 PRISM precipitation plots.

We ultimately selected NAM as the initialization dataset for the SNMOS WRF modeling. While NAM and ERA had comparable performance in simulating winds, we selected the NAM configuration with the MSKF convection cloud option because it tended to be dryer than ERA and exhibited better skill at simulating temperature. We judged that for ozone simulations, it was better to have simulated meteorology with a dry rather than wet bias in order to allow more solar insolation for ozone production.

Additional details about the WRF evaluation and configurations are available in the final Power Point deliverable for this task (UNC-IE and Ramboll Environ, 2015).

3.1.2 Significant Findings

The North American Model (NAM) and the European Centre for Medium Range Weather Forecasts model (ERA) initialization datasets provided comparable performance for WRF simulations of warm season meteorology in Southern New Mexico. While WRF performance was improved using the Multiscale (grid-aware) Kain-Fritsch cumulative cloud scheme, the model was still unable to consistently simulate precipitation patterns related to the North American monsoon. With the focus of the SNMOS on warm season ozone, we selected the NAM configuration with the multiscale Kain-Fritsch option because it tended to be dryer than ERA and exhibited better skill at simulating temperature. We judged that for ozone

simulations, it was better to have simulated meteorology with a dry rather than wet bias in order to allow more solar insolation for ozone production.

3.1.3 Milestones and Deliverables

- Prepare a work plan for the WRF modeling and other aspects of study. (Completed 11/30/2015)
- Power Point Presentation of WRF Results/Recommendations (Completed 11/30/2015)

3.2 Task 2: Permian Basin Oil & Gas Inventory

3.2.1 Task Summary

Ramboll Environ reviewed available Permian Basin oil and gas (O&G) inventories and recommended 2011 and future year inventories for the SNMOS. Figure 3-4 shows Permian Basin active O&G well locations circa-2014 in New Mexico and Texas. The Doña Ana study base and future year Permian Basin emission inventories were based on the 2011NEIv2-based Platform (2011v6.2). The 2011NEIv2-based Platform base year emission inventory is for 2011, the base year of the Doña Ana County study; it includes the 2011 TCEQ well site emission inventory for Texas, and is consistent with the latest available well site emission inventory inputs for the Permian Basin in New Mexico. 2011 base year emissions from the 2011NEIv2-based Platform and 2025 2011NEIv2-based Platform emission inventories were used as is.

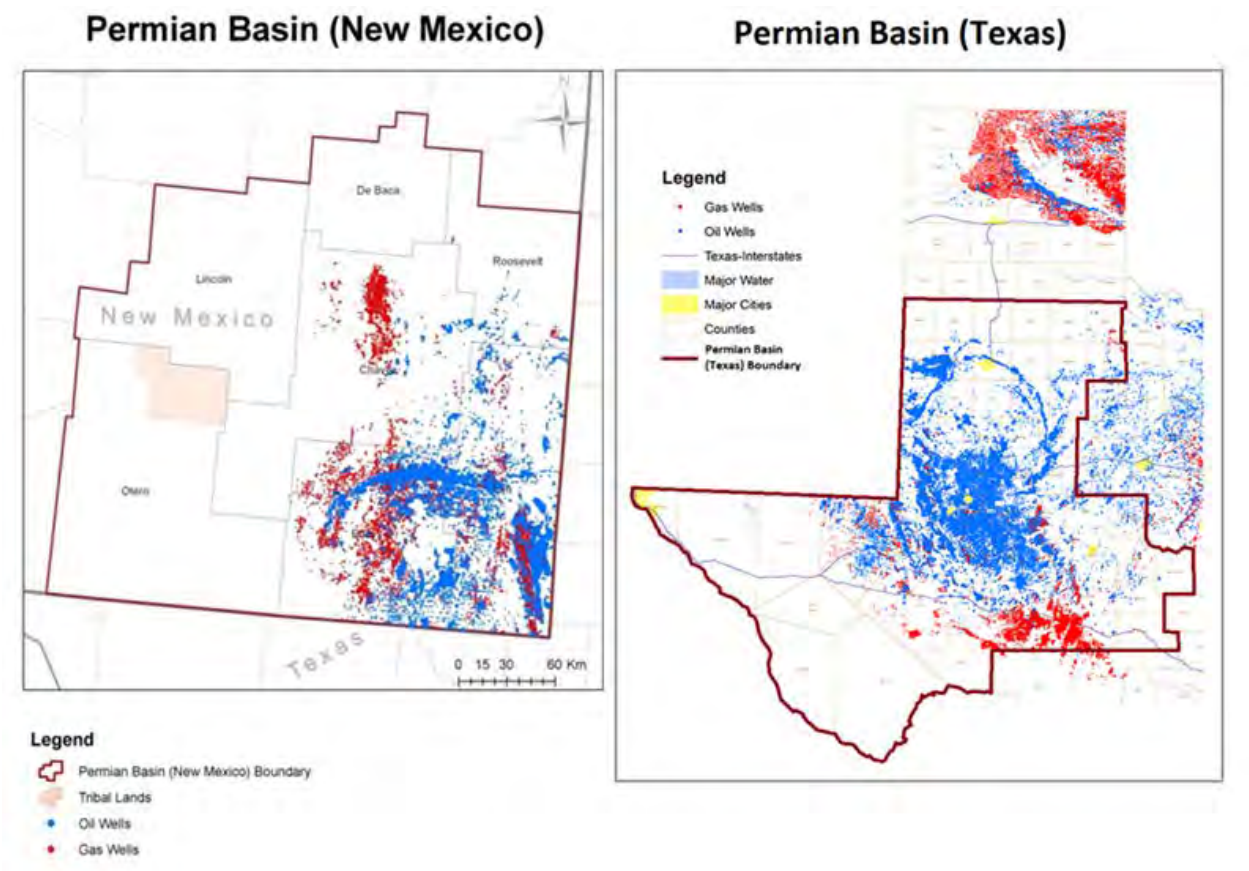


Figure 3-4. Permian Basin Well Locations (circa 2014). Source: Adapted from TCEQ Texas Oil and Gas Wells Map[1].

Figure 3-5 shows 2011 Permian Basin NOx and VOC Emissions broken down by state. NOx emissions totalled 99,577 tpy; 60% of the NOx emissions were from area sources and 40% were from point sources. Of the area source emissions (59,275 tpy), 50% were from compressor engines, 26% from artificial lift engines, 15% from heaters, and 7% from drill rigs (Figure 3-6). The sum of the other remaining categories was <3% of the emissions total. Texas was the source of 71% of the NOx emissions, and 29% of NOx emissions were from New Mexico (Figure 3-5).

Permian Basin 2011 VOC emissions were 507,813 tpy, and nearly all (99 %) emissions were from area sources, and 1% were from point sources. The largest category of VOC area sources (498,889 tpy) was oil tanks (55%) followed by wellhead venting (18%). Pneumatic devices, truck loading, and produced water each contributed 4% of area source VOC emissions and the remaining categories total <11%. Like NOx emissions, VOC emissions were heavily concentrated in Texas (83%) with New Mexico contributing the other 17% of emissions.

[1] http://www.tceq.state.tx.us/assets/public/implementation/barnett_shale/bs_images/txOilGasWells.png

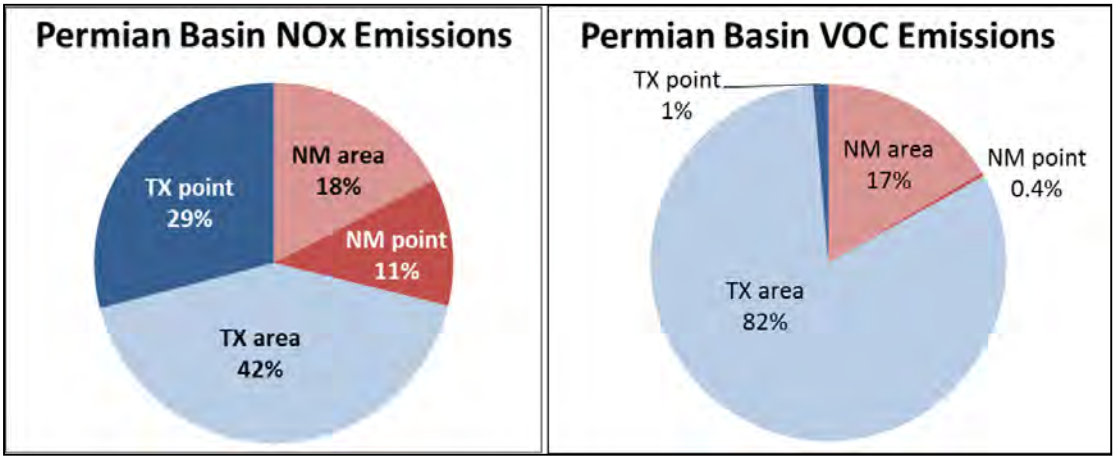


Figure 3-5. Permian Basin 2011 NOx and VOC emissions breakdown by state.

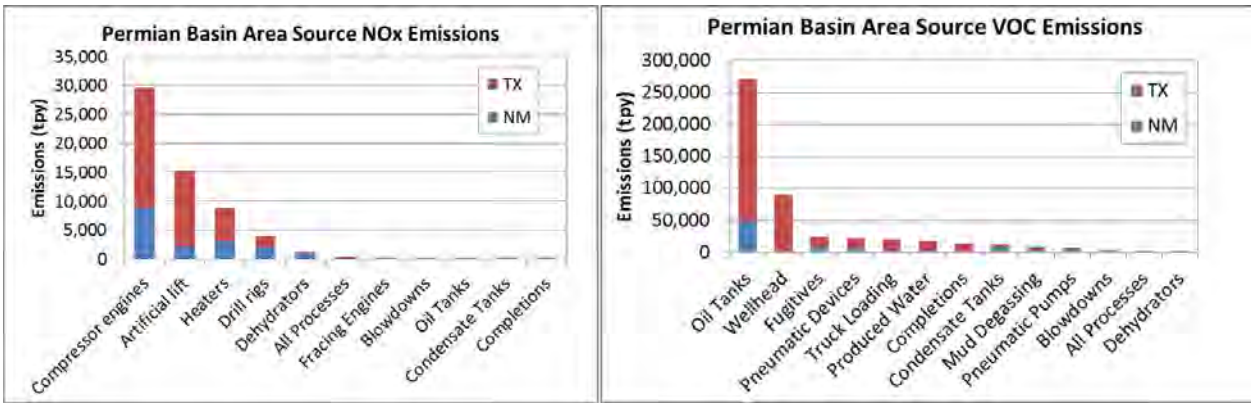


Figure 3-6. Permian Basin 2011 NOx and VOC emissions breakdown by emissions source category.

2011 point source emissions sources (40,302 tpy) were comprised of emissions from gas plants (59%), compressor stations (39%) and other sources such as tank batteries (3%) (Figure 3-7). A summary of Permian Basin-wide emissions for 2011 is given in Table 3-4.

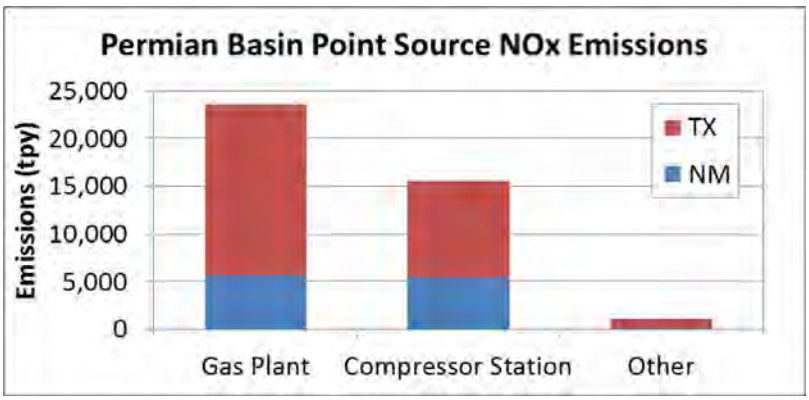


Figure 3-7. Permian Basin 2011 NOx point source emissions breakdown by state and emissions source category.

Table 3-4. Permian Basin 2011 inventory criteria pollutant emissions summary.

State	Type	2011 Permian Basin O&G Emissions (tpy)					
		NOX	VOC	CO	SO_2	PM_{10}	$PM_{2.5}$
NM	area	17,354	84,140	20,694	190	518	516
	point	11,367	1,887	5,428	12,340	171	170
NM Total		***28,721***	***86,027***	***26,123***	***12,530***	***689***	***686***
TX	area	41,921	414,749	36,820	2,728	707	705
	point	28,935	7,036	16,699	5,136	935	920
TX Total		***70,856***	***421,786***	***53,519***	***7,864***	***1,642***	***1,626***
Grand Total		**99,577**	**507,813**	**79,642**	**20,395**	**2,331**	**2,312**

For the SNMOS future year emissions modeling, activity growth for the Permian Basin was forecast. O&G activity growth factors for each play within the Permian Basin were based on the U.S. Energy Information Administration's Annual Energy Outlook (AEO) for 2014[2] (Figure 3-8). Southwest region growth factors were used outside of the specified plays. Table 3-5 shows the ratio of 2025:2011 sources for oil, gas and oil/gas wells. For all three defined plays within the Permian Basin and the Southwest Region, the number of oil, gas and oil/gas wells is forecast to increase.

AEO 2014 forecasts were released in April 2014, when the Cushing, Oklahoma (OK) West Texas Intermediate (WTI) crude oil price was about $100 per barrel. In August 2014, crude oil prices began to decline sharply and since November 2014, the Cushing, OK WTI crude oil price has

[2] http://www.eia.gov/forecasts/aeo/pdf/0383(2014).pdf

remained between $40 and $60 per barrel[3]. The AEO 2015 forecast for the Cushing, OK WTI crude oil price for calendar year 2025 is 12% lower than the AEO 2014 estimate; AEO 2015 forecasts overall Southwest Region oil production to be 21% higher than the AEO 2014. While any oil and gas production forecasts are uncertain, the consistency in forecast crude oil production increases for the AEO 2014 and AEO 2015 indicate that the sharp increases in EPA's forecasts based on the AEO 2014 are reasonable, even with marked decreases in crude oil prices since August 2014.

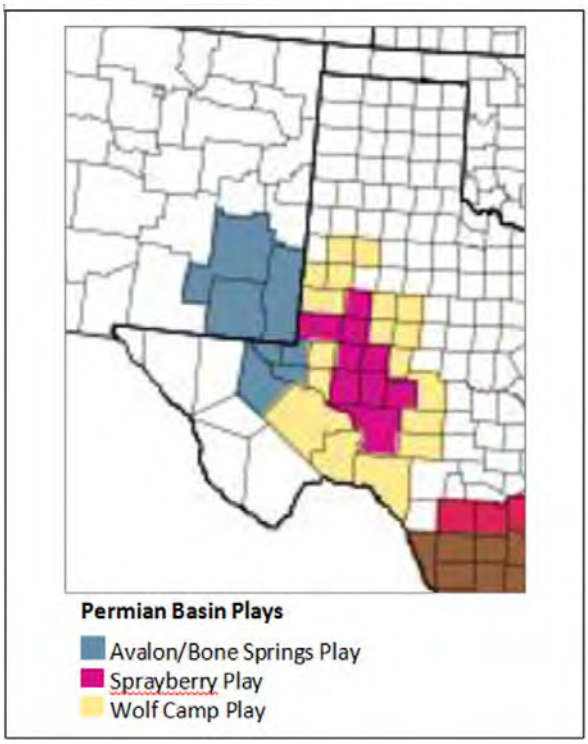


Figure 3-8. Permian Basin plays. Source: 2011v6.2 Modeling Platform TSD, excerpt from Figure 4-1.

Table 3-5. Permian Basin growth forecast by play.

Play / US Region	Oil Well Sources	Gas Well Sources	Oil and Gas Well Sources
Ratio 2025:2011			
Sprayberry Play	2.500	2.500	2.500
Wolfcamp Play	2.500	2.500	2.500
Avalon/Bone Springs Play	1.862	1.571	1.841
Southwest Region	1.448	1.384	1.006

In addition to the effects of activity growth, EPA considers the control effects of on-the-books regulations for the O&G sector (EPA, 2015) when developing emissions forecasts. The control

[3] Spot Prices for Crude Oil and Petroleum Products, http://www.eia.gov/dnav/pet/PET_PRI_SPT_S1_M.htm

effects of the following rulemakings are considered in the 2011NEIv2-based Platform 2017 and 2018 forecasts:

- New Source Performance Standards (NSPS) Subpart OOOO (area and point sources)
- Reciprocating internal combustion engine (RICE) NSPS Subparts JJJJ and IIII and NESHAP Subpart ZZZZ (area and point sources)
- Industrial/Commercial/Institutional Boilers and Process Heaters Maximum Achievable Control Technology (MACT) Rule (point sources)
- Standards of Performance for Turbines 40 CFR Part 60 - Subpart KKKK (point sources)
- Process Heaters NSPS (point sources)

3.2.2 Significant Findings

Emissions for the Permian Basin for 2011 and 2025 were developed using 2011NEIv2-based platform, growth based on the U.S. EIA AEO for 2014 and controls from pertinent rulemakings. Growth in activity is projected for the Permian Basin between 2011 and 2025; therefore, emissions of ozone precursors are projected to increase in 2025 relative to 2011.

3.2.3 Milestones and Deliverables

- Power Point Presentation on Permian Basin oil and gas 2011 and future year emission update (Completed 11/30/2015)
- Memo on available Permian Basin oil and gas 2011 and future year emissions data (Completed 11/10/2015)

3.3 Task 3: Juárez and Mexico Border Inventory (Current and Future Years)

3.3.1 Task Summary

The objective of this task was to recommend 2011 and future year emission inventory data covering the Mexico Border States and Ciudad Juárez for use in the SNMOS. We coordinated with NMED and the U.S. EPA to gather the best available data. We reviewed the available emissions data for these regions, including both inventories and ancillary data, and determined that the 2008-based Mexico National Emission Inventory (MNEI) were the best available data and the most appropriate of the available data to use for the SNMOS. These data were available as part of the U.S. EPA 2011v6.2 National Emissions Inventory (NEI) Emissions Modeling Platform (EMP).

The U.S. EPA distributed Mexico emissions data as part of the 2011v6.0 and 2011v6.2 EMPs. The 2011v6.0 EMP included a 1999-based version of the MNEI with projections to 2008, 2012, and 2030 (USEPA, 2014; Wolf et al., 2009). The 2011v6.2 EMP included a 2008-based version of the MNEI with projections to 2018 and 2025 (ERG, 2014). Figure 3-9 shows state total comparisons of the two Mexico inventories for the three major inventory sectors: on-road mobile, nonpoint, and point sources.

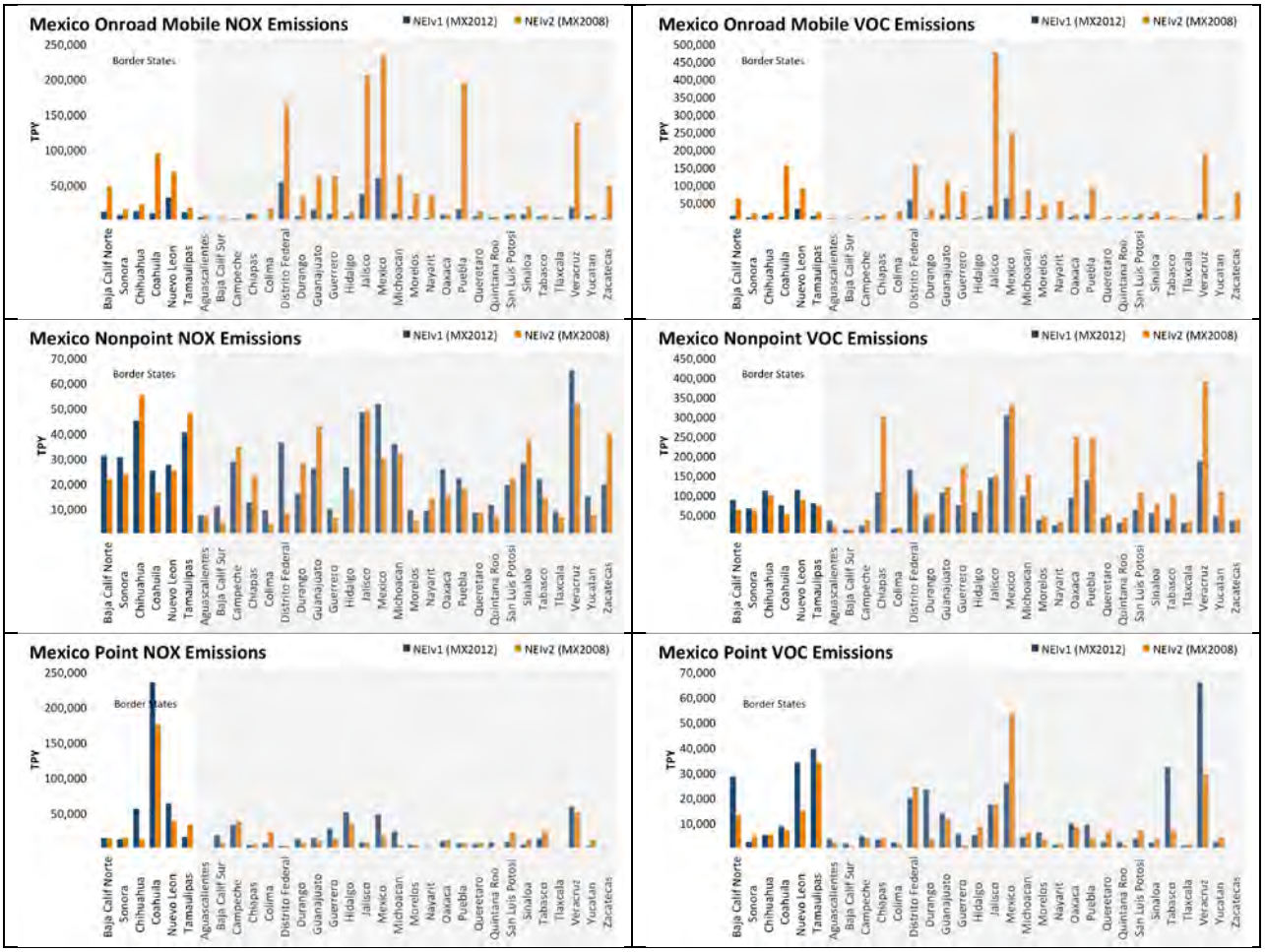


Figure 3-9. Mexico state inventory comparisons

As the 2008-based MNEI uses the most recent activity data that are publically available for Mexico, we decided with NMED that we would use these data for the SNMOS ozone modeling. We determined that this version of the MNEI, which is distributed with the U.S. EPA 2011v6.2 EMP, is the best available anthropogenic emissions data for Mexico. We used the 2008 MNEI as is for the 2011 SNMOS modeling and the 2025 projections for the future year SNMOS modeling. Natural emissions sources in Mexico were estimated using the same data and approaches used to estimate these emissions for the U.S. (see Task 5).

Our analyses of the MNEI anthropogenic emissions data included comparisons of the emissions totals between 2008 and 2025 at the state level (Figure 3-10) and for the municipalities in the immediate vicinity of Doña Ana County.

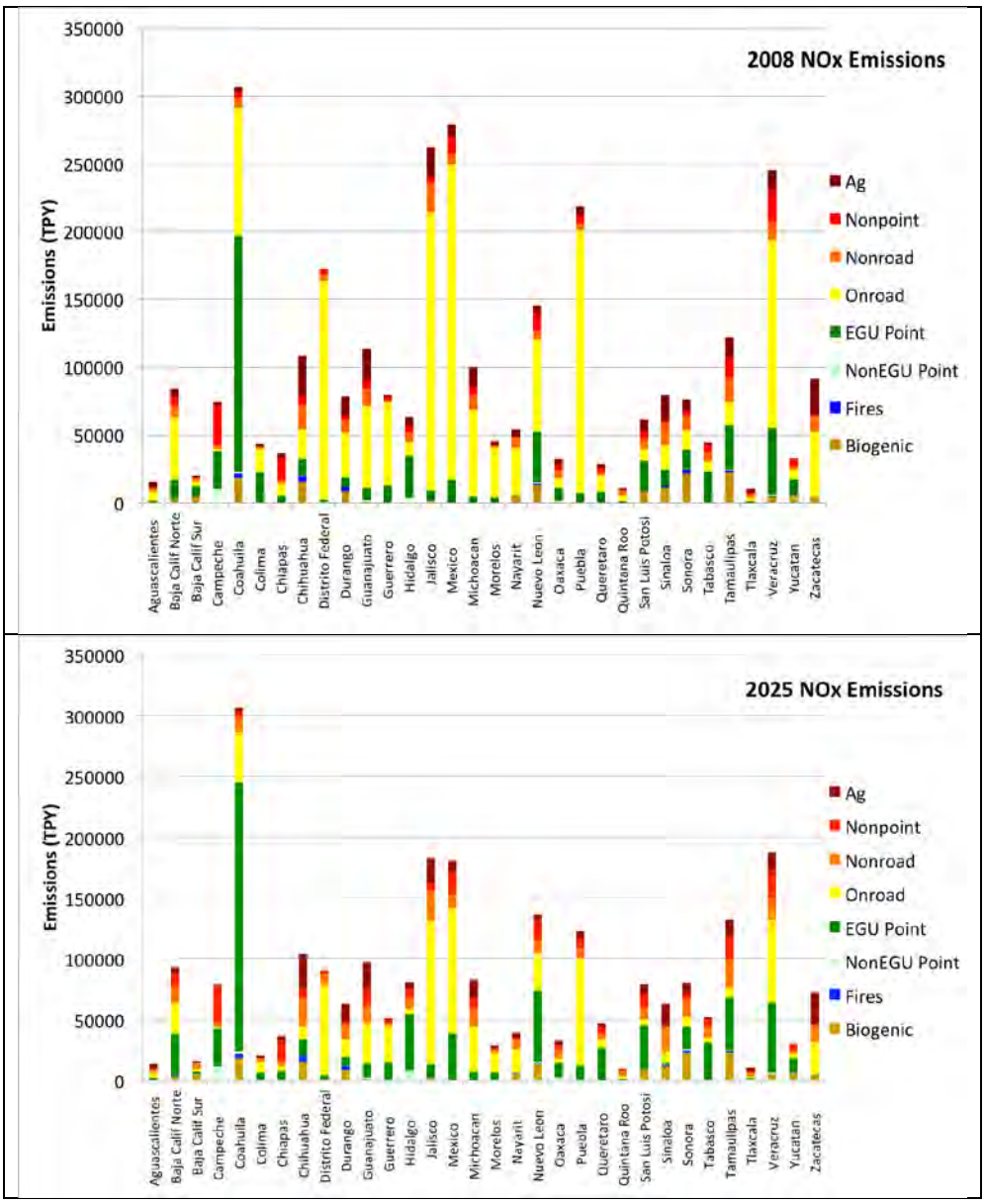


Figure 3-10. 2008 (top) and 2025 (bottom) Mexico state total NOx emissions

Additional details about the Mexico emissions data evaluation are available in the final Power Point deliverable for this task (UNC-IE and Ramboll Environ, 2015).

3.3.2 Significant Findings

The 2008-based Mexico NEI, which is distributed with the U.S. EPA 2011v6.2 emissions modeling platform, is the best available database of current and future year emissions estimates for Mexico. The 2008 base year emissions and 2025 emissions projections for Mexico were selected for the SNMOS.

3.3.3 Milestones and Deliverables

- Power Point presentation on Mexico emissions to be used in 2011 base and future year modeling (Completed 11/30/2015).

3.4 Task 4: Prepare Base Year Emissions with SMOKE

3.4.1 Task Summary

We developed anthropogenic emissions estimates for the SNMOS from the WAQS 2011 version B (2011b) emissions modeling platform available from the IWDW[4]. The data sources for the WAQS 2011b emissions estimates included the U.S. EPA, Ramboll Environ, and the states of Colorado, Utah, and Wyoming. As part of the WAQS, UNC-IE formatted the data for input to the Sparse Matrix Operator Kernel Emissions (SMOKE[5]) system, processed the data into CAMx input files with SMOKE, and performed quality assurance and quality control (QA/QC) on the emissions data and modeling.

We used all of the anthropogenic emissions data (e.g., non-road mobile, nonpoint, electricity generating units) collected and prepared for the WAQS 2011b simulation to generate CAMx-ready emissions for the SNMOS. The significant effort invested in the WAQS in collating and quality assuring these data was inherited by the SNMOS through adaptation of the WAQS 2011b modeling platform. As the modeling domains and meteorology data are different between the studies, adapting the WAQS data involved generating emissions for the SNMOS modeling domains and time period.

The SNMOS used 12-km and 4-km modeling domains focused on southern New Mexico. The standard continental U.S. (CONUS) Lambert Conformal Conic Projection (LCP) was used in the SNMOS for the domains shown in Figure 3-11 and described below.

- The SNMOS WESTUS12 CAMx domain encompasses all of New Mexico, extends west to include the metropolitan area of Phoenix, east to include West Texas, and South to include the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña County on high ozone days during 2011. The SNMOS WESTUS12 domain was designed as a trade-off between computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution.
- The SNMOS 4-km Doña Ana County domain focuses on Southern New Mexico and the major source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX.

[4] http://views.cira.colostate.edu/tsdw
[5] http://www.smoke-model.org

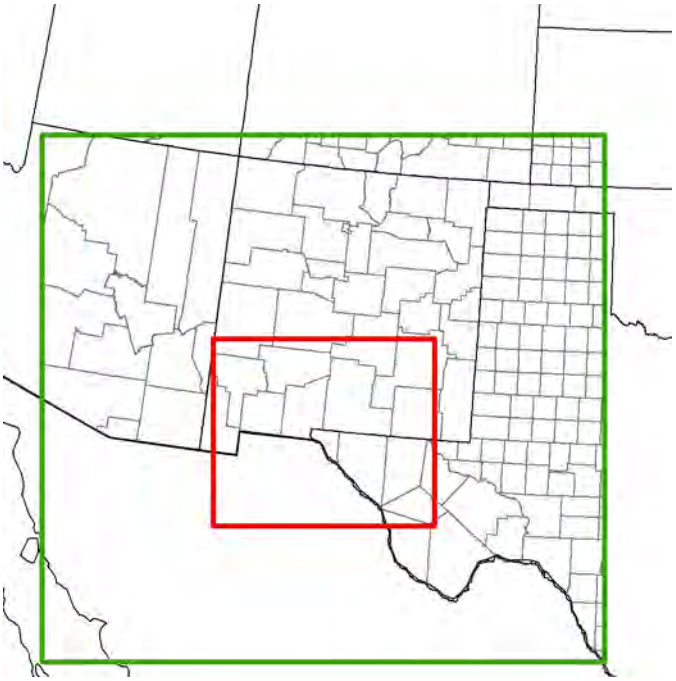


Figure 3-11. SNMOS 12-km (green) and 4-km (red) nested CAMx modeling domains.

We prepared emissions on these domains for April 15 through August 30, 2011 using SMOKE version 3.7. The first 15 days of emissions (April 15-30) were prepared to initialize the CAMx simulation for the air quality analysis period beginning on May 1.

Consistent with the WAQS 2011b emissions modeling platform, all of the non-O&G anthropogenic emission inventories for the SNMOS base year 2011 simulations were taken from the U.S. EPA National Emission Inventory (NEI). EPA publically released the 2011v6 platform in February 2014 and updated it twice, version 6.2 being the most recent. Details of the inventory, sectors, and preparation procedures for these data are available in the NEI2011v6.2 Technical Support Document (US EPA, 2015). The exception was the O&G inventories for most of the basins in Northern New Mexico, Colorado, Utah, and Wyoming, which were provided by Ramboll Environ. Ramboll Environ also developed emissions estimates for natural emissions sources for the SNMOS, including fires, biogenics and lightning (see Task 5 summary).

In coordination with NMED, we determined that the 2008 Mexico National Emission Inventory (MNEI), which is packaged with the NEI2011v6.2, was the most appropriate publically available Mexico inventory to use for the SNMOS (see Task 3 summary).

Ramboll Environ also conducted a review of the available Permian Basin O&G inventories and determined that the inventory and ancillary emissions data that are part of the NEI2011v6.2 are the best available data for these sources (Grant and Kemball-Cook, 2015; and see Task 2 summary).

The SNMOS project used MOVES to estimate on-road mobile emissions for U.S. sources. The U.S. EPA provided MOVES input emission-factors for 2011. The SMOKE-ready on-road mobile inventory data are a combination of county-level activity data and emissions factor look-up tables output from MOVES for representative counties. The on-road mobile activity data included county-level vehicle miles travelled (VMT), vehicle population (VPOP), and averaged speed profiles by vehicle type and road class. The look-up tables for representative counties, which are output from MOVES emissions rate mode simulations, contained county-level emissions factors as a function of temperature, relative humidity, and speeds. Land cover data and biogenic emissions factors by land cover type were used to estimate biogenic emissions fluxes. We used non-inventory, or ancillary emissions data provided by the U.S. EPA, to convert the inventories into the format required by CAMx.

Part of the preparation process for the inventory data included splitting the inventories into detailed subsectors. We split up many of the U.S. EPA NEI inventories to support the application of source-specific parameterizations of temporal and spatial patterns, to facilitate source-based emissions sensitivities, and to support targeted quality assurance of important inventory sectors. Although anthropogenic inventories can be generally classified as point, non-point, or mobile sources, we used over 20 individual anthropogenic inventory sectors in the SNMOS modeling. Table 3-6 is a listing of the inventory processing sectors used for the SNMOS. The table lists the inventory processing sectors, the source of the inventory data, the type of inventory (i.e., point, nonpoint, or gridded), the inventory year, and brief descriptions of the inventory sources included in the sector.

Table 3-6.SNMOS emissions processing sectors

Sector	Source	Type	Inventory Period and Year	Description
Locomotive/ marine	NEI 2011v6.2	Point and Nonpoint	Annual 2011 and 2025	The locomotive/marine sector is a subset of the non-point/area sector. It includes county-level emissions for line haul locomotives (nonpoint), train yards (point), and class 1 and 2 in- and near-shore commercial marine.
Off-road mobile	NEI 2011v6.2	Nonpoint	Monthly 2011 and 2025	NMIM county-level inventories for recreational vehicles, logging equipment, agricultural equipment, construction equipment, industrial equipment, lawn and garden equipment, leaf and snow blowers, and recreational marine. The CA and TX NONROAD estimates were normalized to emissions values provided by these states.
On-road mobile (US)	NEI 2011v6.2	MOVES	Annual and Daily 2011 and 2025	EPA ran MOVES2014 for 2011 in emissions factor mode. The MOVES lookup tables include on-network (RPD), on-network for CA (RPD_CA), off-network starts/stops (RPV), off-network starts/stops for CA (RPV_CA), off-network vapor venting (RPP), off-network vapor venting sources for CA (RPP_CAT, off-network hotelling (RPH). These data include the reference county and reference fuel month assignments that EPA used for the MOVES

Sector	Source	Type	Inventory Period and Year	Description
				simulations. The CA MOVES estimates were normalized to emissions values provided by these states.
Non-point/ Area	NEI 2011v6.2	Nonpoint	Annual 2011 and 2025	County-level emissions for sources that individually are too small in magnitude or too numerous to inventory as individual point sources. Includes small industrial, residential, and commercial sources; broken out into nonpoint, residential wood combustion, livestock, and fertilizer processor sectors.
Refueling	NEI 2011v6.2	Nonpoint	Annual 2011 and 2025	Nonpoint, gasoline stage 2 refueling.
Area Oil & Gas	WAQS 2011 and NEI 2011v6.2	Nonpoint	Annual 2011 and 2020	Non-point oil and gas sources are survey-based and typically unpermitted sources of emissions from up-stream oil and gas exploration, development, and operations. The non-point O&G sector consists of the WAQS Phase II and the NEI 2011v6.2 inventory for all basins outside of the WAQS inventory coverage area.
Point Oil & Gas	WAQS 2011 and NEI 2011v6.2	Point	Annual 2011 and 2020	Point oil and gas sources are permitted sources of emission from up-stream oil and gas exploration, development, and operations. The point O&G sector consists of the WAQS Phase II and the NEI 2011v6.2 inventory for all areas outside of the WAQS inventory coverage area.
CEM Point	2011v6.2 and CAMD	Point	Hourly 2011 and 2025	2011 Clean Air Markets Division (CAMD) hourly Continuous Emissions Monitor (CEM) data and Integrated Planning Model (IPM) projections to 2025.
non-CEM Point	2011v6.2	Point	Annual 2011 and 2025	Elevated and low-level combustion and industrial sources, airports, and offshore drilling platforms.
Offshore Shipping	2011v6.2	Point	Annual 2011 and 2025	Elevated point C3 commercial marine sources in offshore commercial shipping lanes.
Fires	PMDETAIL	Point	Daily 2011	PMDETAIL version 2 wildfire, prescribed burns and agricultural burning open land fires.
Canada Sources	NPRI 2010	Nonpoint and Point	Annual 2010	Canadian 2010 National Pollutant Release Inventory; there are no future year projections from the 2010 NPRI.
Mexico Sources	MNEI 2012	Nonpoint and Point	Annual 2008 and 2025	Mexican NEI 2008 and projections to 2025.
Biogenic	MEGAN v2.10	Gridded	Hourly 2011	MEGANv2.10 estimated with 2011 meteorology.
Lightning	Ramboll Environ	Gridded	Daily 2011	Lightning NOx emissions estimated with 2011 meteorology.

Several gridded emissions datasets were used for either directly estimating air emissions or as ancillary data for processing/adjusting the emissions data. The following datasets are key gridded data used in the SNMOS. We included neither sea salt nor windblown dust emissions in the SNMOS because of the study emphasis on O_3.

In addition to the inventory and gridded emissions data, ancillary datasets provide temporal, chemical, and spatial allocation specifications to the emissions. The ancillary data for SNMOS were taken directly from the WAQS 2011b modeling, which was derived primarily from the EPA 2011v6.2 modeling platform.

Additional details about the U.S. emissions data used for the SNMOS is available in the final emissions modeling memo for this task (Adelman and Baek, 2016).

3.4.2 Significant Findings

The Western Air Quality Study 2011b emissions modeling platform was used to develop summer season 2011 emissions for the SNMOS. On an annual basis, on-road mobile sources were the largest source of NOx and biogenic sources the largest source of VOC in Doña Ana County in 2011. In the immediate vicinity of Doña County, El Paso County, TX was the largest source NOx and Ahumada Municipality the largest source of VOC in 2011.

3.4.3 Milestones and Deliverables

- Technical memo for 2011 base year emission modeling with SMOKE (Completed 2/29/2016)

- CAMx-ready 2011 base year emissions on the project 12-km and 4-km modeling domains (Completed 2/29/2016)

3.5 Task 5: Prepare Natural Emissions for the Project Modeling

3.5.1 Task Summary

Ramboll Environ prepared natural emissions for the SNMOS 2011 Base Case 12/4 km domain CAMx modeling. Natural emissions are unrelated to human activities and for SNMOS, the natural emission inventory consisted of biogenic emissions and emissions from fires and lightning.

3.5.1.1 Biogenic Emissions Modeling

The Model of Emissions of Gases and Aerosols in Nature (MEGAN) is a modeling system for estimating the net emission of gases and aerosols from terrestrial ecosystems into the atmosphere (Guenther et al., 2006; Guenther et al., 2012). Driving variables include land cover, weather, and atmospheric chemical composition. MEGAN is a global model with a base resolution of ~1 km and so is suitable for regional and global models. A FORTRAN code is available for generating emission estimates for the CAMx regional air quality model. WRAP has recently updated the MEGAN biogenic emissions model using western U.S. data and higher resolution inputs (Sakulyanontvittaya et al., 2012). MEGAN v2.1 was used for the SNMOS biogenic emissions modeling

MEGAN generates hourly, gridded biogenic emissions and requires gridded inputs. Land cover data specify the type of plants present in each model grid box as well as the density of the foliage. Global distributions of land cover variables (Emission Factors, Leaf Area Index, and Plant

Functional Types) are available for spatial resolutions ranging from ~ 1 to 100 km. Leaf Area Index (LAI) quantifies the amount of foliage at a given location and the age of the foliage and is derived from satellite measurements. Satellite-observed radiances at several wavelengths are related to chlorophyll activity and leaf area. The LAI variable defines the number of equivalent layers of leaves relative to a unit of ground area. The data are composited every 8 days at 1-kilometer resolution. Plant functional type data are developed from high resolution satellite land cover/crop data and species composition is averaged over ecoregion. The National Land Cover Database (NLCD) includes three products that are used in the development of the MEGAN land cover: tree-cover fraction impervious cover fraction, and a land cover dataset.

Weather determines how active the plants are. MEGAN requires gridded hourly temperature, solar radiation and soil moisture data, which were supplied by the SNMOS 2011 WRF MSKF NAM meteorological model run outputs. The final input data for MEGAN are emission factor maps which are based on vegetation species composition.

Ramboll Environ ran MEGAN for the SNMOS 2011 episode and performed quality assurance of the MEGAN emissions. We prepared county-level emission summaries for NOx, CO and VOC and reviewed spatial maps of the biogenic emissions. The review focused on whether the pattern of emissions appeared reasonable. For example, we expect to see higher biogenic emissions over heavily vegetated regions and that urban areas and deserts should have lower biogenic emissions. Figure 3-12 is an example of the spatial quality assurance of the biogenic emission inventory and shows the episode average isoprene emissions on the 4-km grid. The isoprene emissions show minima in emissions where there is little vegetation (urban areas, deserts) and maxima in emissions in forested areas such as the Lincoln National Forest. Overall, isoprene emissions are larger in Mexico than in the U.S. There is a discontinuity in emissions at the U.S.-Mexico border (white arrow) that is not apparent in the vegetation distribution in the Google Earth satellite imagery. This suggests that there is uncertainty in biogenic emission inventory related to differences in MEGAN inputs for the U.S. and Mexico.

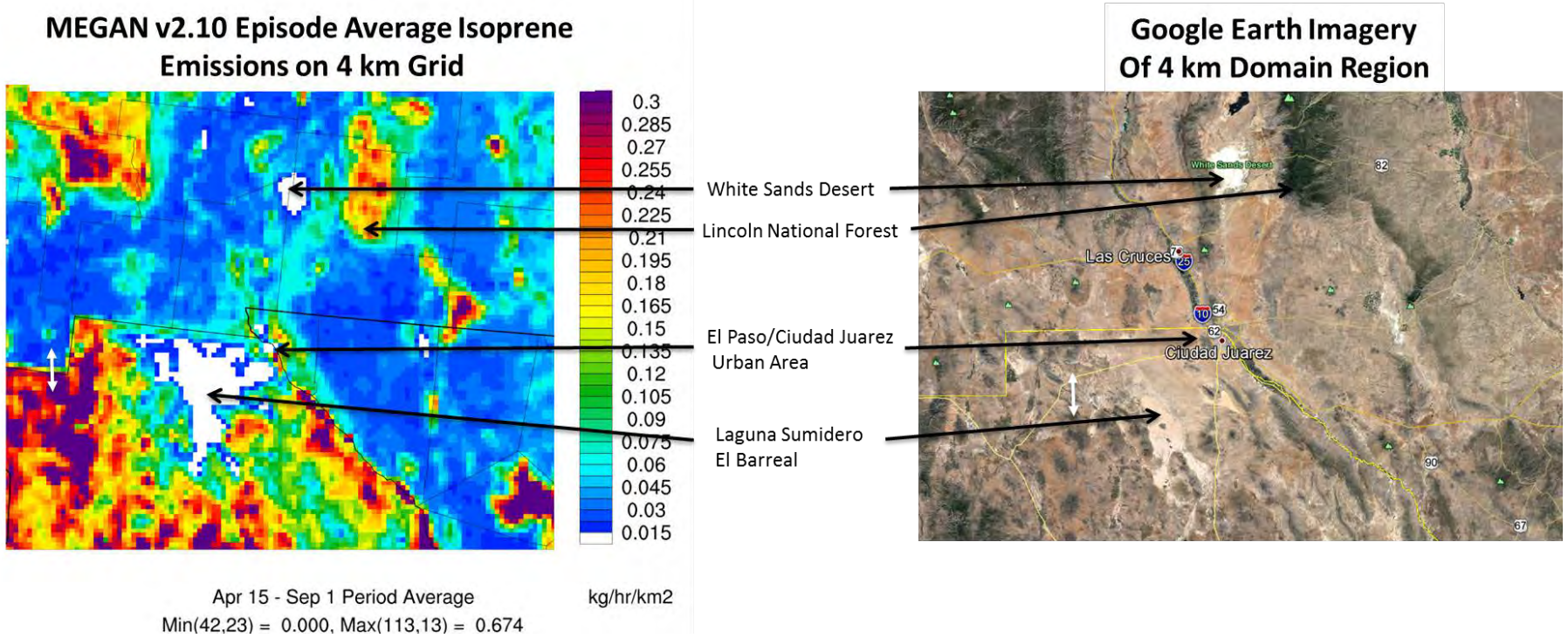


Figure 3-12. Example of biogenic emissions quality assurance. Left panel: SNMOS MEGAN v2.10 2011 episode average isoprene emissions on the 4-km grid. Right panel: Google Earth visible imagery of the region shown in the left panel.

3.5.1.2 Fire Emissions Modeling

Open biomass burning makes up an important part of the total global emissions of greenhouse gases, reactive trace gases, and particulate matter. Although episodic in nature and highly variable, open biomass burning emissions can contribute to local, regional, and global air quality problems and climate forcing. The SNMOS used fire emissions for 2011 that were generated by the Particulate Matter Deterministic and Empirical Tagging and Assessment of Impacts on Levels (PMDETAIL) study. PMDETAIL developed 2011 fire emission using satellite data and ground detect and burn scar, in addition to other data, with a slight modification (Mavko, 2014) to the methodology used in the Deterministic and Empirical Assessment of Smoke's Contribution to Ozone Project (DEASCO3) study for the 2008 modeling year (DEASCO3, 2013). We used a similar plume rise approach as PMDETAIL/DEASCO3 where plume rise depends on fire size and type (Mavko and Morris, 2013). The PMDETAIL 2011 fire inventory was selected over the 2011 Fire INventory from NCAR (FINN) and Smartfire 2011 inventory because it uses a more complete satellite and surface fire dataset.

Day-specific FETS fire activity data was used for all wildfire, agricultural, and prescribed fires within the 12/4 km modeling domain. FETS data included size, location, timing, fuel loading, moisture, and emission fluxes and chemical parameters. Fire emissions were gridded to the SNMOS modeling domains and speciated for the CAMx CB6r2 chemical mechanism. The plume characteristics for each fire event were prescribed based on the fire type and size. Plume rise is weather-dependent is and is characterized by smoldering fraction, plume bottom and plume top. Once PMDETAIL fire emissions were developed for the SNMOS Base Case 2011 modeling period, we developed separate county-level emissions summaries for agricultural burns, wildfires, and prescribed fires. We also made spatial plots of the daily fire emissions and performed spot checks to ensure that the PMDETAIL fire locations matched satellite fire detections from NOAA's Hazard Mapping System (HMS) Fire and Smoke Analysis Product. The HMS product uses data from the GOES Imager, the AVHRR (Advanced Very High Resolution Radiometer) instrument, and MODIS (Moderate Resolution Imaging Spectroradiometer). Fire locations derived by thee algorithms based on different satellite retrievals reviewed by an analyst, who removes false detections and reconciles the three fire location data sets. The analyst outlines the locations of smoke plumes inferred from satellite aerosol optical depth retrievals.

Figure 3-13 shows an example of the fire emissions quality assurance for June 5, 2011. On this day, there were several large fire complexes burning in the 4-km domain. The Wallow Fire in eastern Arizona, the Horseshoe 2 fire in southeastern Arizona and the Monument Fire on the U.S.-Mexico border are shown in the fire emissions plot in the left hand panel and match the satellite fire detections shown in the HMS product.

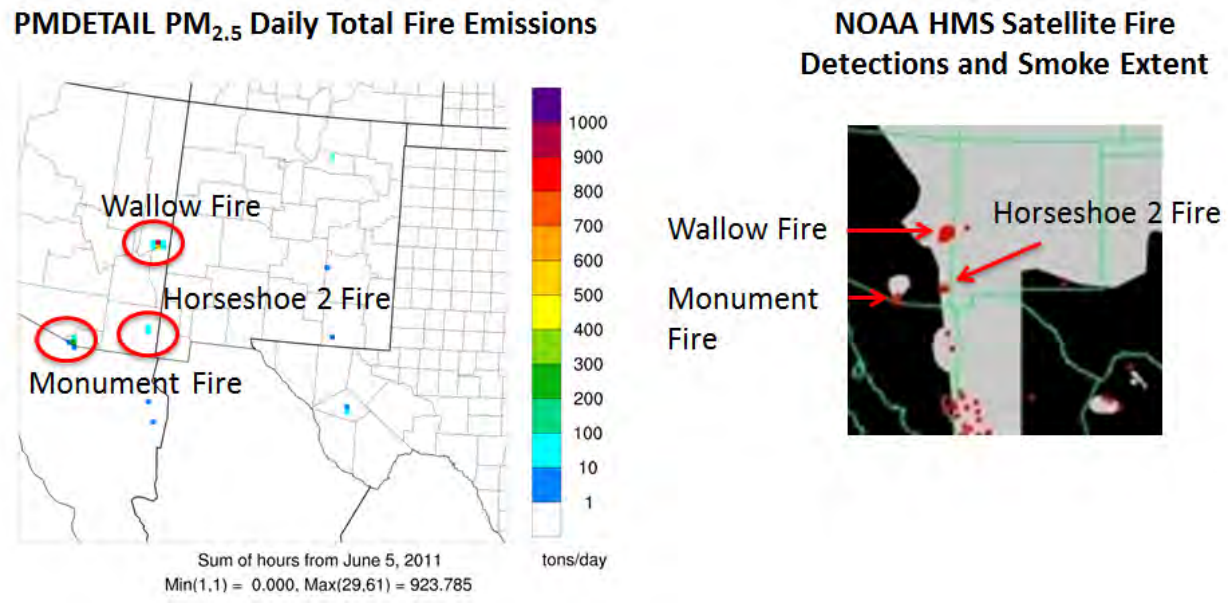


Figure 3-13. Example of fire emissions quality assurance. Left panel: June 5, 2011 PMDETAIL daily total $PM_{2.5}$ emissions HMS product showing fire locations (red dots) and smoke plume (gray area).

3.5.1.3 Lightning Emissions Modeling

NO_X is formed in lightning channels as the heat released by the electrical discharge causes the conversion of N_2 and O_2 to NO. Lightning NOx emissions (LNOx) can be estimated directly based on the number of lightning flashes, the intensity of each flash, the lightning type (cloud-to-ground vs. cloud-to-cloud), and the amount of NOx emitted per flash. Because formation of LNOx is associated with deep convection in the atmosphere, LNOx production is typically parameterized in terms of the modeled convective activity. LNOx production is often assumed to be related to cloud top height or convective rainfall. The modified lightning NOx emissions model of Koo et al. (2010) was used to estimate lightning NOx emissions for the SNMOS. Koo et al. use a hybrid approach that preserves the consistency of the WRF modeled convection and the location of LNOx emissions, but also attempts to constrain the LNOx emissions to match observed distributions of lightning or an estimate of total emissions. Additional details on the development and evaluation of the lightning emissions processor used in the SNMOS are available in the WestJumpAQMS Sea Salt and Lightning memo (Morris et al., 2012) [6]. LNOx emissions were allocated to WRF grid columns where modeled convection occurred using WRF convective precipitation as a proxy for lightning activity. LNOx emissions were distributed in the vertical using profiles derived from aircraft measurements and cloud-resolving models. LNOx emissions were modeled as point sources with zero plume rise in appropriate layer.

Once the LNOx emissions had been generated, we performed quality assurance of the emissions by comparing maps of vertically integrated LNOx emissions with WRF modeled precipitation. An example of this quality assurance is shown in Figure 3-14, which compared

[6] http://www.wrapair2.org/pdf/memo_12_seasalt_lightning_june25_2012_final.pdf

the daily total precipitation from WRF (left panel) with the column-integrated LNOx emissions for a 24-hour period in July 2011. The locations of locally intense (convective) rainfall align well with the maxima in the LNOx emissions, which indicates that the LNOx emissions have been correctly allocated in space.

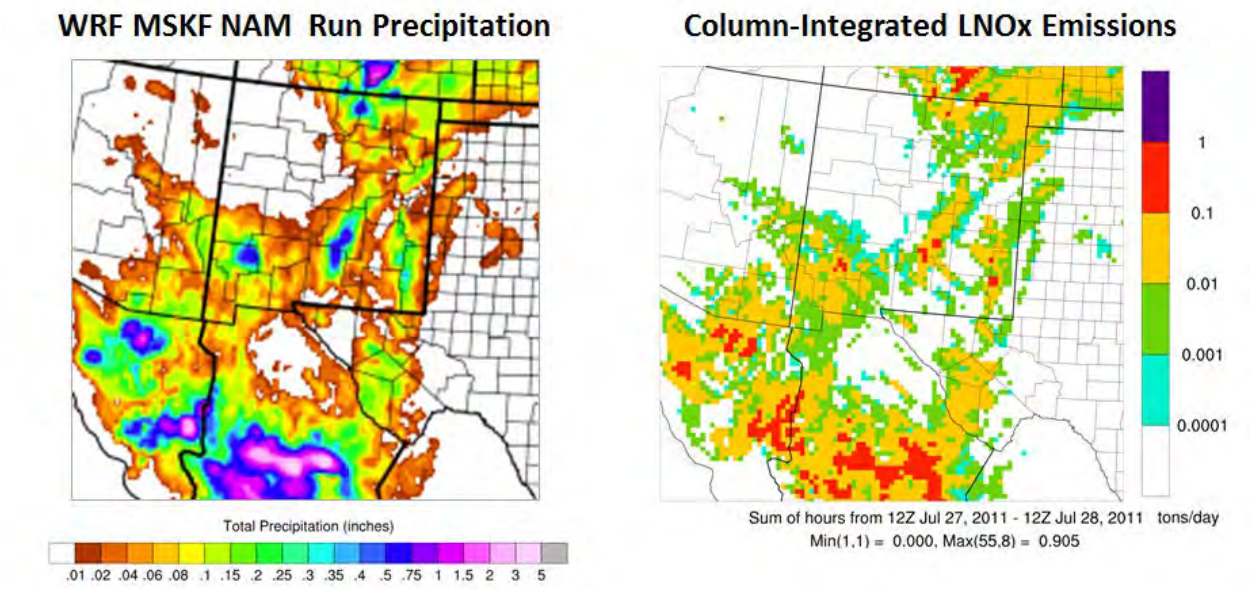


Figure 3-14. LNOx emissions quality assurance for July 27-28, 2011. Left panel: daily total precipitation from the WRF MSKF NAM model run. Right panel: column-integrated LNOx emissions for the July 27-28 period matched in time to the precipitation total shown in the left panel.

3.5.2 Significant Findings

The results of the quality assurance for the natural emissions suggest that the emissions modeling was correctly executed. However, there are significant uncertainties in all three components of the natural emission inventory. For the biogenic inventory, there is a discontinuity in emissions at the U.S.-Mexico border and emissions are larger over Mexico than the U.S. for environments that appear from Google Earth imagery to have comparable vegetation cover. Further investigation of differences in MEGAN inputs for the U.S. and Mexico should be undertaken to understand these differences and to ensure that the most accurate inventories possible are used on both sides of the border. Modeling of fire and lightning emissions are active areas of scientific research, and the SNMOS emission inventories should be considered to have considerable uncertainty associated with them.

3.5.3 Milestones and Deliverables

- Prepared gridded, CAMx ready MEGAN version 2.10 biogenic emissions. (Completed 1/12/2016)
- Prepared gridded, CAMx ready lightning NOx emissions. (Completed 1/15/2016)
- Prepared gridded, CAMx ready PMDETAIL fire emissions. (Completed 1/18/2016)

- Provided natural emissions on the 12/4 km grids to UNC for SMOKE emissions modeling/merge (Completed 1/18/2016)
- PowerPoint presentation on results of natural emissions modeling. (Completed 2/16/2016)

3.6 Task 6: Base Year Air Quality Modeling

3.6.1 Task Summary

The SNMOS performed photochemical grid modeling for the year 2011 using the Comprehensive Air Quality Model with Extensions (CAMx) version 6.20. The SNMOS Work Plan for the 2011 Modeling Year (Adelman et al., 2015a) details the CAMx configuration and justification for the model's selection for the SNMOS. CAMx was run for April–October, 2011 and configured as in the WAQS 2011b study. The model configuration is summarized in Table 3-7.

The SNMOS CAMx modeling grids are shown in Figure 3-15. The 3SAQS 36-km grid 3D CAMx output fields were used as BCs for the SNMOS 12-km grid. While the SNMOS modeling leveraged the WAQS/3SAQS modeling platforms, some changes to the WAQS/3SAQS modeling grids were required simulate ozone in Southern New Mexico as accurately as possible. The brown rectangle in Figure 3-15 shows the extent of the 3SAQS 12-km modeling grid. The SNMOS 12-km modeling domain, shown in green, is smaller than the 3SAQS 12-km grid and is focused on the region surrounding southern New Mexico. The southern boundary of the SNMOS 12-km grid was extended southward beyond the southern boundary of the 3SAQS 12-km grid in order to encompass the NOx emissions sources that are most important to ground-level ozone formation in southern New Mexico (Figure 2-1). The SNMOS 12-km grid boundary lies south of the Carbon II power plant in Coahuila, Mexico. This facility is a large source of NOx emissions and lies in a region that was sometimes upwind of Doña Ana County on high ozone days during 2011. The spatial extent of the SNMOS 12-km domain strikes a balance between computational efficiency and the need to model transport from sources likely to influence Doña Ana County at 12-km resolution. The SNMOS 4-km Doña Ana County domain (shown in red in Figure 3-15) focuses on Southern New Mexico and the major emissions source regions in the immediate vicinity, including Ciudad Juárez, Mexico and El Paso, TX. The 12-km domain provided the BCs for the 4-km domain.

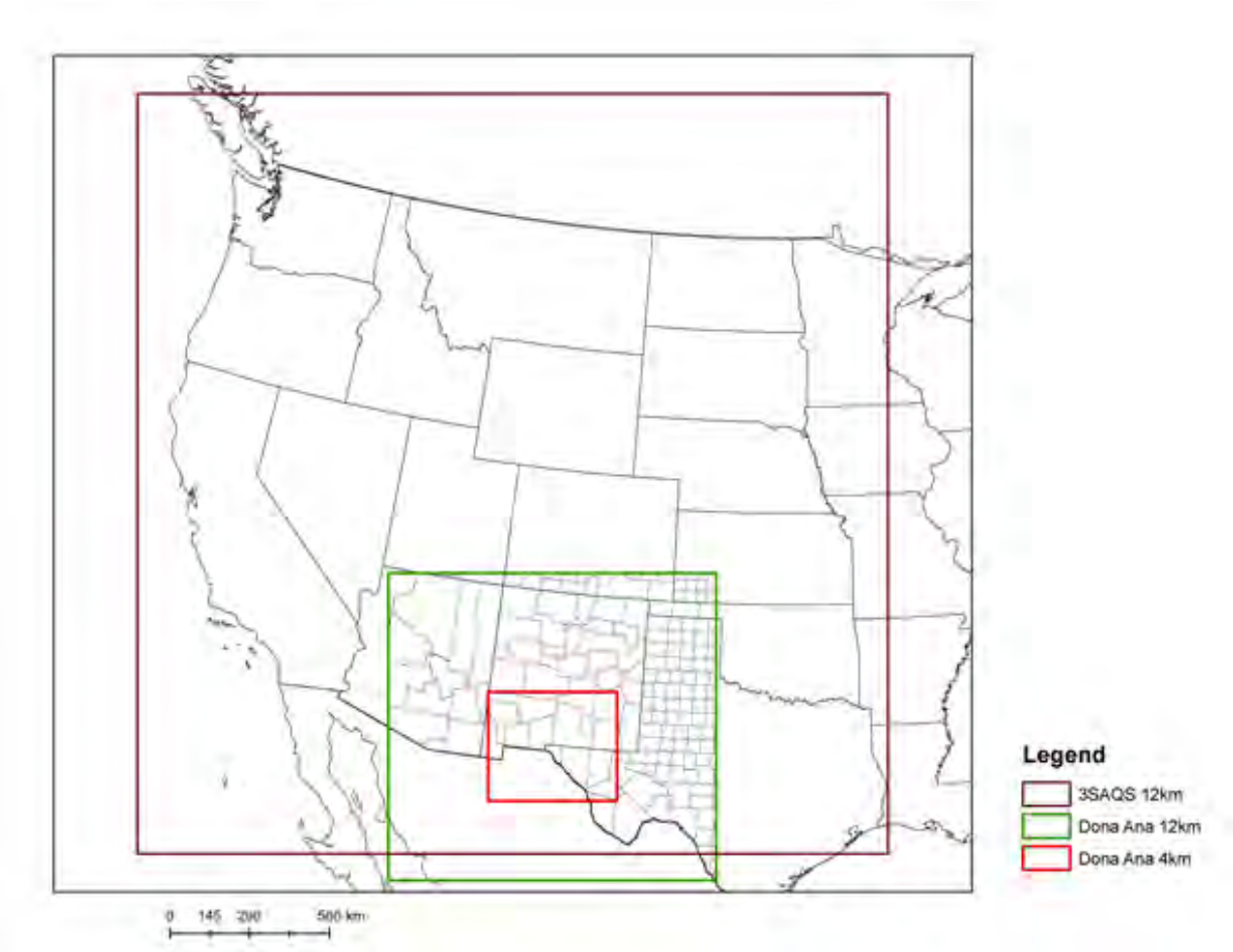


Figure 3-15. CAMx Modeling Domains and Boundary Conditions.

Table 3-7. SNMOS CAMx version 6.20 configuration.

Science Options	Configuration	Details
Model Codes	CAMx V6.20 – March 2015 Release	
Horizontal Grid Mesh	36/12/4 km	
36-km grid	148 x 112 cells	36-km CONUS domain
12-km grid	99 x 93 cells	12-km SNMOS WESTUS12 regional domain
4-km grid	117 x 99 cells	4-km Dona Ana domain
Vertical Grid Mesh	34 vertical layers defined by WRF; no layer collapsing	Layer 1 thickness ~12 m. Model top at ~19-km above MSL
Grid Interaction	12/4-km two-way nesting for CAMx (2011) 36/12/4-km two way nesting for CAMx (2025)	
Initial Conditions	10 day spin-up on 12/4 km grid before first day with MDA8 ozone>70 ppb at any Doña Ana County monitor (2011) 14 day spin-up on 36/12/4 km grid (2025)	Clean initial conditions
Boundary Conditions	12-km SNMOS grid from 36/12-km WAQS modeling (2011) 36-km grid from global chemistry model (2025)	MOZART GCM data for 2011; zero out dust and sea salt.
Emissions		
Baseline Emissions Processing	SMOKE, MOVES and MEGAN	
Sub-grid-scale Plumes		
Chemistry		
Gas Phase Chemistry	CB6r2	Active methane chemistry and ECH4 tracer species
Meteorological Processor	WRFCAMx	Compatible with CAMx V6.20
Horizontal Diffusion	Spatially varying	K-theory with Kh grid size dependence
Vertical Diffusion	CMAQ-like in WRF2CAMx	
Diffusivity Lower Limit	Kz_min = 0.1 to 1.0 m^2/s or 2.0 m^2/s	Land use dependent
Deposition Schemes		
Dry Deposition	Zhang dry deposition scheme (CAMx)	Zhang 2003
Wet Deposition	CAMx-specific formulation	rain/snow/graupel/virga
Numerics		
Gas Phase Chemistry Solver	Euler Backward Iterative (EBI) -- Fast Solver	
Vertical Advection Scheme	Implicit scheme w/ vertical velocity update	

Science Options	Configuration	Details
	(CAMx)	
Horizontal Advection Scheme	Piecewise Parabolic Method (PPM) scheme	Collela and Woodward (1984)
Integration Time Step	Wind speed dependent	~0.1-1 min (4-km), 1-5 min (1 -km), 5-15 min (36 km)

3.6.2 Significant Findings

The CAMx modeling of 2011 was completed successfully.

3.6.3 Milestones and Deliverables

- 2011 base year air quality modeling presentation (Completed 2/22/2016)
- Carry out SNMOS 2011 Base Case CAMx modeling (Completed 3/25/2016)

3.7 Task 7: Model Performance Evaluation and Sensitivity Modeling

3.7.1 Task Summary

Following the completion of the SNMOS 2011 base case modeling, we performed a CAMx model performance evaluation (MPE) for the entire modeling episode. In this section, we present the evaluation of CAMx model performance against concurrent measured ambient concentrations using graphical displays of model performance and statistical model performance measures. We compared these measures against established model performance goals and criteria following the procedures recommended in EPA's photochemical modeling guidance documents (EPA, 2014).

Model performance was evaluated in New Mexico and surrounding regions for two CAMx runs that used different meteorological inputs, but were otherwise identical. UNC-IE carried out a series of Weather Research and Forecasting Model (WRF; Skamarock et al., 2005) meteorological model simulations of the SNMOS modeling episode and compared model performance in each run against observed weather data (Section 3.1; UNC-IE and Ramboll Environ, 2015). The WRF model runs differed in their cumulus parameterizations and the datasets used for initial conditions and analysis nudging. The two WRF runs that produced the best model performance over the SNMOS WRF 12/4 km modeling domains used the MSKF cumulus scheme (Alapaty et al., 2014; Herwehe et al., 2014). One of the MSKF WRF runs used the NCEP NAM analysis for initial conditions and analysis nudging, while the other MSKF run used the ECMWF ERA-Interim analysis. We refer to the two WRF simulations hereafter as the WRF ERA and WRF NAM runs and the two CAMx runs that used these WRF runs as the CAMx ERA and CAMx NAM runs.

For both CAMx runs, model performance was acceptable for daily maximum 8-hour average (MDA8) ozone based on comparison with EPA statistical performance benchmarks (Figure 3-16). Both CAMx runs had an overall high bias when all episode days were considered, but underestimated ozone on high ozone days, which were defined to be days with observed MDA8 ozone > 60 ppb. The CAMx run using ERA WRF meteorology performed slightly better than CAMx with NAM WRF meteorology on days when MDA8 > 60 ppb (Figure 3-16). The CAMx NAM run performed slightly better when all days were considered (i.e., on lower MDA8 ozone days) (Figure 3-16; Figure 3-17).

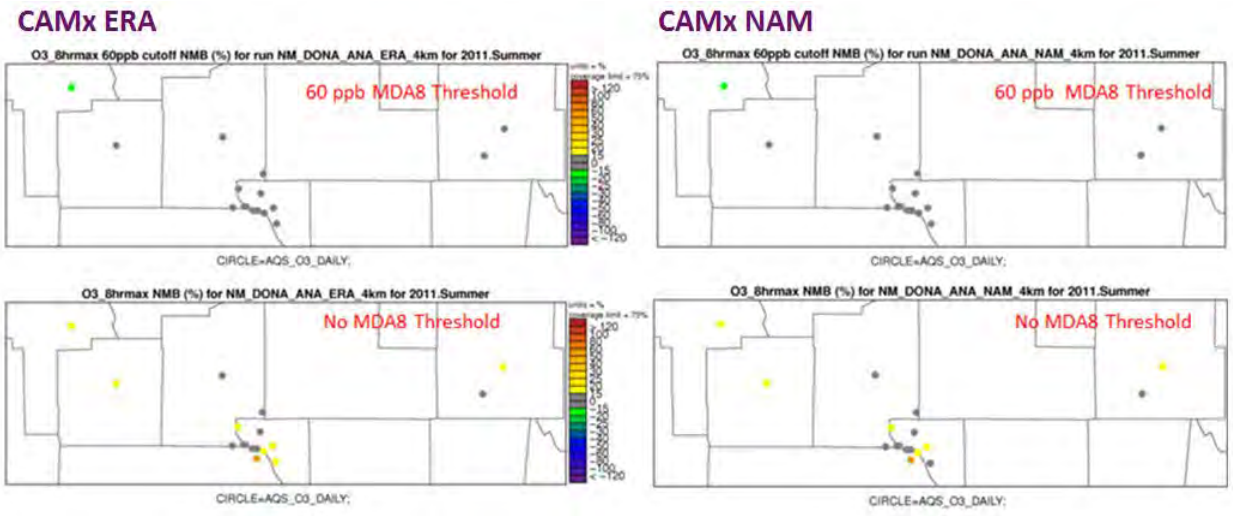


Figure 3-16. Comparison of NMB for the CAMx ERA (left) and CAMx NAM (right) model runs. Upper figures have 60 ppb MDA8 threshold and no threshold was used for the lower figures.

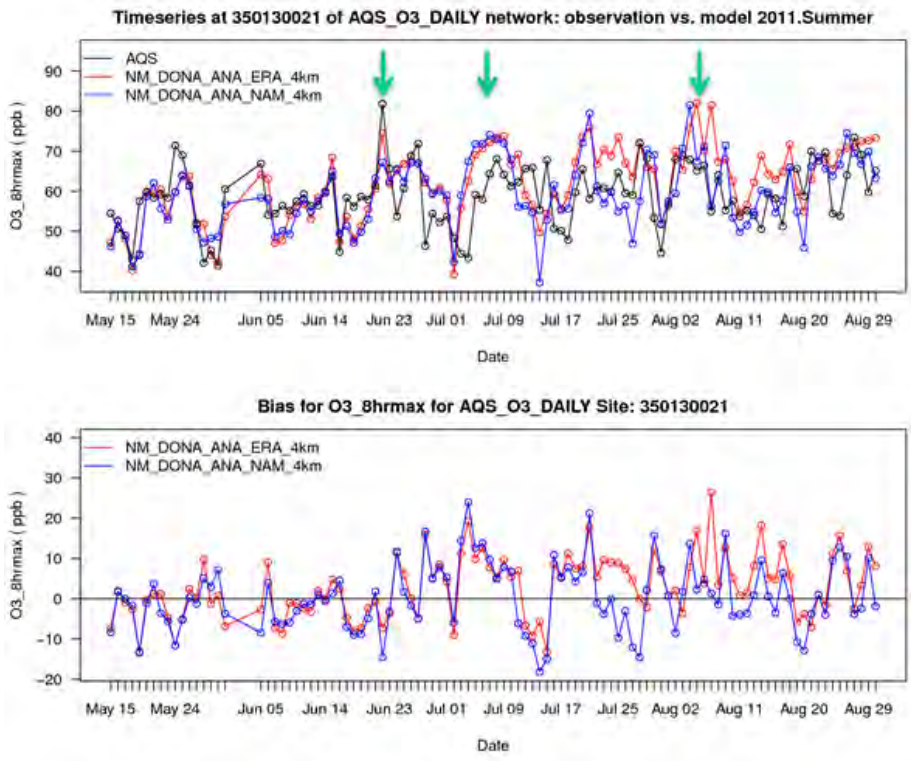


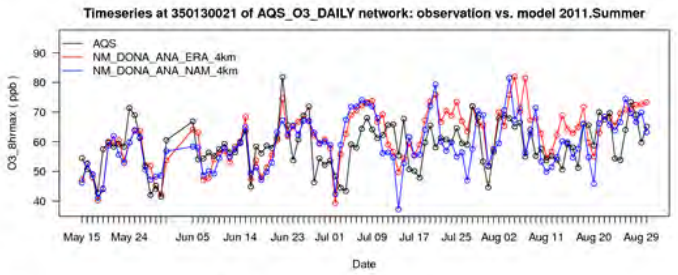
Figure 3-17. Upper panel: time series of observed (black) and modeled MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Lower panel: Model bias in MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Left green arrow shows a day when the model underestimated high values of observed ozone (June 22). Center and right green arrows show examples of July and August periods when the model had a persistent regional high bias for ozone.

We examined performance at the ground level ozone monitors within Doña Ana County in light of the form of the NAAQS for ozone and the EPA's recommended method for performing modeled attainment demonstrations (EPA, 2014) using the Modeled Attainment Test Software (MATS). The MPE focused on the MDA8 ozone on the highest modeled days because the modeling plan called for a modeled attainment demonstration for Doña Ana County using the 2011 base case model and the 2025 future year model. In carrying out the base case model performance, we considered how CAMx performance in the 2011 base year runs would affect the modeled attainment demonstration and selected the CAMx model run that would provide the more reliable future year ozone projection.

Figure 3-18 presents ranked lists of the 10 days with the highest modeled values of modeled MDA8 ozone at the Desert View, NM monitor for the CAMx ERA and CAMx NAM runs. The highest modeled MDA8 ozone days do not correspond well to high observed MDA8 ozone in either CAMx run. In general, the highest modeled days are days on which the model greatly overestimates the observed MDA8 ozone. For example, on the highest modeled MDA8 ozone day in the CAMx ERA run, the modeled MDA8 ozone was 82 ppb, while the observed MDA8 ozone was 65 ppb, corresponding to a model bias of 17 ppb in the MDA8. There was only one day out of the 10 highest modeled days in the CAMx ERA run that corresponded to a day when the observed MDA8 ozone exceeded 70 ppb: June 22. The CAMx ERA bias on June 22 was -7 ppb, consistent with the MPE statistical analysis that showed that CAMx ERA tended to underestimate observed ozone on high observed ozone days.

NM_DONA_ANA_ERA_4km				
Rank	Date	Obs_Average	Model_Average	Bias_Average
1	8/5/2011	65.13	81.97	16.84
2	8/7/2011	55.00	81.43	26.43
3	7/21/2011	58.13	75.84	17.71
4	8/4/2011	67.88	75.79	7.91
5	6/22/2011	81.75	74.45	-7.30
6	7/9/2011	64.13	73.71	9.58
7	7/20/2011	65.50	73.57	8.07
8	7/25/2011	64.63	73.44	8.82
9	7/8/2011	68.00	73.34	5.34
10	8/30/2011	65.13	73.31	8.18

NM_DONA_ANA_NAM_4km				
Rank	Date	Obs_Average	Model_Average	Bias_Average
1	8/4/2011	67.88	81.49	13.62
2	7/21/2011	58.13	79.34	21.22
3	8/26/2011	64.00	74.45	10.45
4	7/7/2011	64.38	74.05	9.67
5	7/8/2011	68.00	72.93	4.93
6	7/20/2011	65.50	72.03	6.53
7	7/9/2011	64.13	71.94	7.81
8	7/6/2011	58.00	71.82	13.82
9	7/5/2011	59.13	71.76	12.64
10	8/9/2011	55.25	71.40	16.15



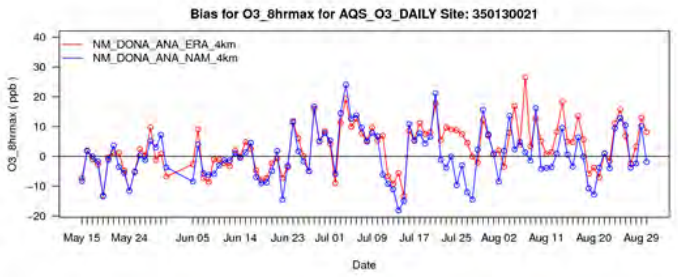


Figure 3-18. Upper (lower) left panel: Ranked list of the 10 days with the highest modeled values of modeled MDA8 ozone (ppb) at the Desert View, NM monitor for the CAMx ERA (NAM) run. Also shown are date, observed MDA8 (ppb) and the model bias (ppb). Upper right panel: time series of observed (black) and modeled MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor. Lower right panel: Model bias in MDA8 ozone for the CAMx ERA (red) and CAMx NAM (blue) runs at the Desert View monitor.

In the CAMx NAM run, none of the 10 highest modeled days corresponded to a day with observed MDA8 exceeding 70 ppb. The CAMx NAM run bias was positive on all 10 of the highest modeled days. For both the CAMx ERA and CAMx NAM runs, the 10 highest modeled days occurred mainly during July and August, which are periods when both runs saw persistent overestimates of MDA8 ozone at the Desert View monitor.

For both CAMx runs, the 10 highest MDA8 ozone days that would form the relative reduction factor (RRF) in the design value calculation for Doña Ana County monitors had significant regional overestimates of ozone, and most of the 10 highest modeled MDA8 ozone days did not have high observed ozone. It is therefore uncertain whether either model run could provide useful results for analyzing local emissions control strategies for Doña Ana County using the EPA MATS default RRF method. Local controls would not be predicted to reduce Doña Ana County ozone if the RRF is formed from days when modeled ozone is driven by an overestimated regional background.

Therefore, we evaluated use of an ozone model performance criterion in selecting days for making RRFs and future year design value projections and using this procedure to determine whether the CAMx NAM or CAMx ERA run should be used as the 2011 base case in the SNMOS. We used only modeled days in which the observed and modeled MDA8 ozone are within a specified % bias of each other. We therefore formed RRFs based on more days with observed high ozone and better model performance. Days on which the model performed poorly would not be used in the RRF. There are precedents for using an MPE filter in selecting days for use in RRFs in making future year ozone projections including modeling done in California (e.g., SCAQMD AQMP[7]).

To illustrate the procedure, we apply a ±10% bias criterion to the 10 highest modeled MDA8 ozone days at the Desert View monitor. If we were to apply the default MATS method to calculate the RRF, the days shaded in blue in Figure 3-19 would be selected. Only one of the top 10 observed MDA8 ozone days (shaded yellow) at the Desert View monitor would be included using this method.

[7] http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2012-air-quality-management-plan/final-2012-aqmp-(february-2013)/appendix-v-final-2012.pdf

		MDA8 (ppb)		Bias	
Rank	Date	Observed	Modeled	(ppb)	(%)
1	8/5/2011	65.125	81.966	16.841	25.86%
2	8/7/2011	55	81.433	26.433	48.06%
3	7/21/2011	58.125	75.839	17.714	30.48%
4	8/4/2011	67.875	75.785	7.91	11.65%
5	6/22/2011	81.75	74.447	-7.303	-8.93%
6	7/9/2011	64.125	73.708	9.583	14.94%
7	7/20/2011	65.5	73.573	8.073	12.33%
8	7/25/2011	64.625	73.442	8.817	13.64%
9	7/8/2011	68	73.339	5.339	7.85%
10	8/30/2011	65.125	73.307	8.182	12.56%

Top 10 observed MDA8 days

Top 10 modeled MDA8 days

Figure 3-19. Desert View monitor: default MATS method for selecting 10 highest modeled days for the RRF.

		MDA8 (ppb)		Bias	
Rank	Date	Observed	Modeled	(ppb)	(%)
1	6/22/2011	81.75	74.447	-7.303	-8.93%
2	7/8/2011	68	73.339	5.339	7.85%
3	8/28/2011	69.125	72.483	3.358	4.86%
4	7/28/2011	72	71.9	-0.1	-0.14%
5	8/18/2011	66	71.665	5.665	8.58%
6	8/27/2011	73.375	70.966	-2.409	-3.28%
7	8/6/2011	66.375	70.191	3.816	5.75%
8	8/2/2011	68	69.984	1.984	2.92%
9	6/26/2011	68.75	68.794	0.044	0.06%
10	8/22/2011	67.5	68.517	1.017	1.51%

Top 10 observed MDA8 days

Top 10 modeled MDA8 days

Figure 3-20. Desert View monitor: alternate method for selecting 10 highest modeled days for the RRF.

If we select only the top 10 modeled MDA8 ozone days on which the bias was < ±10%, we obtain a different population of days (Figure 3-20). The 10 days to be used in the RRF now include 4 of the 10 highest observed days at Desert View, and model performance is reasonably good on all days that would go into the RRF. Observed and modeled MDA8 values are now closer to the observed base year design value than would be the case using the default MATS method shown in Figure 3-19.

We tested this procedure using bias thresholds ranging from 5% to 20% for the CAMx ERA and CAMx NAM runs. For each bias threshold, we determined the number of modeled MDA8 ozone days in the RRF (top 10 days) that were also among the 10 highest observed MDA8 ozone days. For all values of the bias threshold, using the CAMx ERA run produced a higher number of days in the ranked list of the 10 highest modeled MDA8 ozone days that also corresponded to days that were among the top 10 observed MDA8 ozone days at the Doña Ana County monitors. Therefore, the CAMx ERA run was better suited for making future year ozone projections and for emissions control strategy development. The bias threshold that produced the highest number of top 10 observed MDA8 ozone days in the list of 10 highest modeled MDA8 ozone days was the 10% threshold, and we recommended that this threshold be used in making future year ozone projections in the SNMOS in addition to the default method outlined in the EPA Modeling Guidance (EPA, 2014).

Once the ozone MPE was completed, we conducted a model performance evaluation for the CAMx ERA run for ozone precursors and fine particulate matter ($PM_{2.5}$) and its component species with a focus on the modeling results for Doña Ana County. We evaluated the ozone precursors carbon monoxide (CO) and nitrogen dioxide (NO_2), but did not include volatile organic compound (VOC) species due to lack of observed data. Although the main focus of this study was ozone, the $PM_{2.5}$ evaluation included total $PM_{2.5}$ along with the component species sulfate (SO_4), nitrate (NO_3), ammonium (NH_4), elemental carbon (EC), and organic carbon (OC).

NO_2 and CO performance are typical of photochemical model simulations of the Western U.S. and are comparable to performance noted in the WAQS 2011b modeling (Adelman et al., 2016) and the Three State Air Quality Study (3SAQS; Adelman et al., 2015b). The SNMOS PM performance evaluation showed that $PM_{2.5}$ was underestimated across the New Mexico and the surrounding region and that the underestimate of total $PM_{2.5}$ was consistent with modeled underestimates of several of its component species including NH_4, NO_3, and SO_4. While there were shortcomings in model performance for the CAMx ERA simulation of $PM_{2.5}$ and its component species, performance was roughly comparable to that of other similar studies in the western U.S. such as the WAQS and 3SAQS. PM performance was not the main focus of the SNMOS, and so no effort was expended to try to diagnose and improve model performance for PM. We noted the reasonable model performance and concluded that the CAMx 2011 SNMOS model was functioning as expected.

3.7.2 Significant Findings

CAMx base year 2011 model performance was evaluated on the 12/4 km SNMOS domains for two CAMx runs that used different meteorological inputs. For both CAMx runs, model performance for MDA8 ozone was acceptable based on comparison with EPA statistical performance benchmarks.

In both runs, CAMx had an overall high bias when all days were considered, but underestimated ozone on days with observed MDA8 ozone > 60 ppb. The CAMx run using ERA WRF meteorology performed slightly better than CAMx with NAM WRF meteorology when MDA8 ozone > 60 ppb. The CAMx NAM run performed slightly better when all days were considered.

For both CAMx runs, many of the 10 highest MDA8 ozone days that would be used to form an RRF for future year design value projections for Doña Ana County monitors had significant region-wide overestimates of ozone. Most of the 10 highest modeled MDA8 days did not have high observed MDA8 ozone. We proposed an alternate method of making future year projections using a model performance criterion that selects only days when modeled ozone is high and model performance is within acceptable bias limits. When this alternate procedure was used, the CAMx ERA run used more of 10 highest observed days corresponding to high modeled MDA8 ozone days in the projection calculation. In a perfect model run, the 10 highest model days would correspond to the 10 highest observed days, so we selected the run that came closer to this ideal.

We therefore selected the CAMx ERA run as the SNMOS 2011 base year run due to its better performance within the 4-km and 12-km domain on days where observed MDA8 ozone > 60 ppb as well as the fact that RRFs formed with this run had a better correspondence between high modeled and high observed MDA8 days.

In summary, we conclude that model performance for ozone, ozone precursors NO_2 and CO and PM was adequate for the SNMOS in the CAMx ERA run.

3.7.3 Milestones and Deliverables

- Base case modeling and model performance evaluation report. (Completed 4/17/2016)

3.8 Task 8: Prepare Future Year Emissions with SMOKE

3.8.1 Task Summary

The objective of this task was to combine the U.S. EPA 2011v2 modeling platform 2025 projection inventory, WAQS future year O&G inventories, and future year Mexico inventories to estimate future year emissions for the SNMOS. For this task we collected the 2025 emissions inventory and ancillary data from the US EPA 2011v6.2 modeling platform (US EPA, 2015). We applied the same version and configuration of SMOKE used for the SNMOS base year modeling to prepare future year, CAMx-ready emissions on the project 12-km and 4-km modeling domains. All of the natural source emissions and ancillary data were held constant with the 2011 base year modeling. Table 3-8 lists the emissions data used for the SNMOS future year modeling. We summarized the future year emissions inventories and processing results in a series of plots and developed a Power Point presentation on future year emissions modeling.

Table 3-8. SNMOS future year emissions data summary

Category	Data Source	Projection Year	Notes
Non-oil and gas	EPA 2011NEIv6.2	2025	Same categories as base year.
Oil and gas	Ramboll Environ and WAQS	2020 (Phase 2)	Permian basin projections for 2025 from NEI2011v6.2.
Mexico	ERG and EPA	2025	

	2011NEIv6.2		
Biogenic	SNMOS	Same as base year	No projection.
Fires	PMDETAIL version 2	Same as base year	No projection.
Lightning	SNMOS	Same as base year	No projection.
Ancillary Data	WAQS	Same as base year	No projection.

Figure 3-21 through Figure 3-26 summarize the New Mexico county base and future year NOx and VOC emissions. Figure 3-22 illustrates that Doña Ana County is projected to experience a 59.6% decrease in NOx emissions from 2011 to 2025, the majority of which will come from reductions in on-road mobile source emissions. Figure 3-25 shows that Doña Ana County is projected to experience a 42.1% decrease in VOC emissions, also primarily from decreases in on-road mobile emissions.

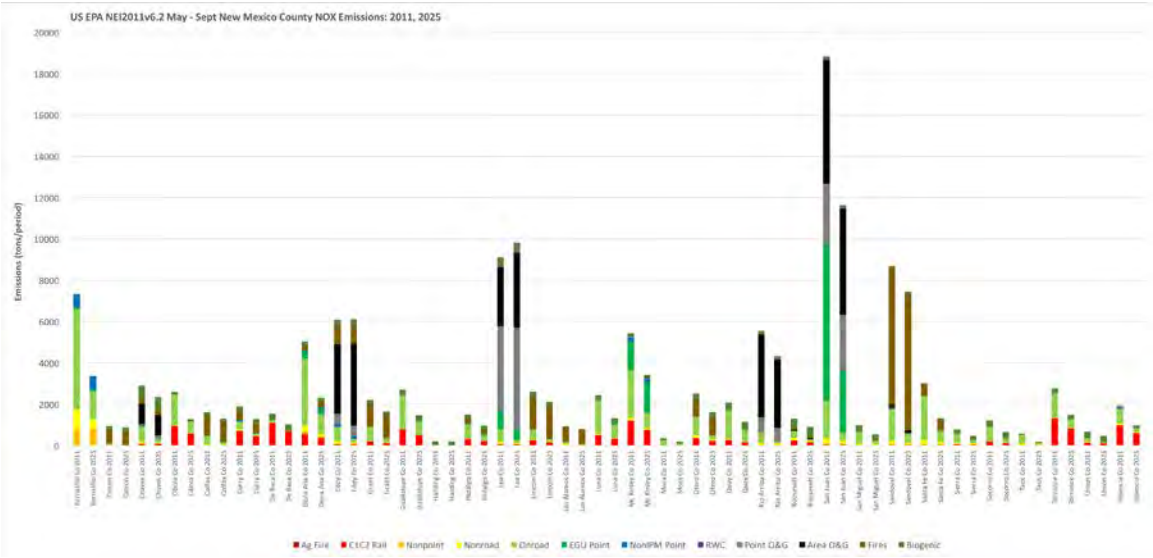


Figure 3-21.New Mexico county 2011 and 2025 NOx emissions.

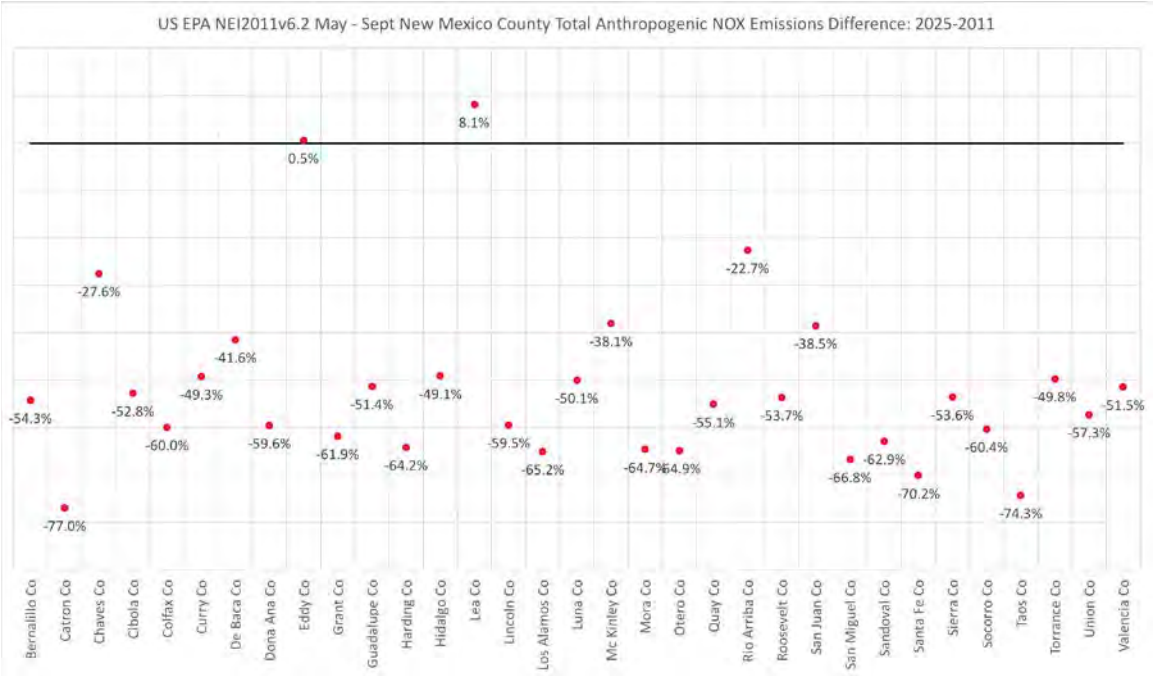


Figure 3-22. New Mexico county total anthropogenic NOx emissions change.

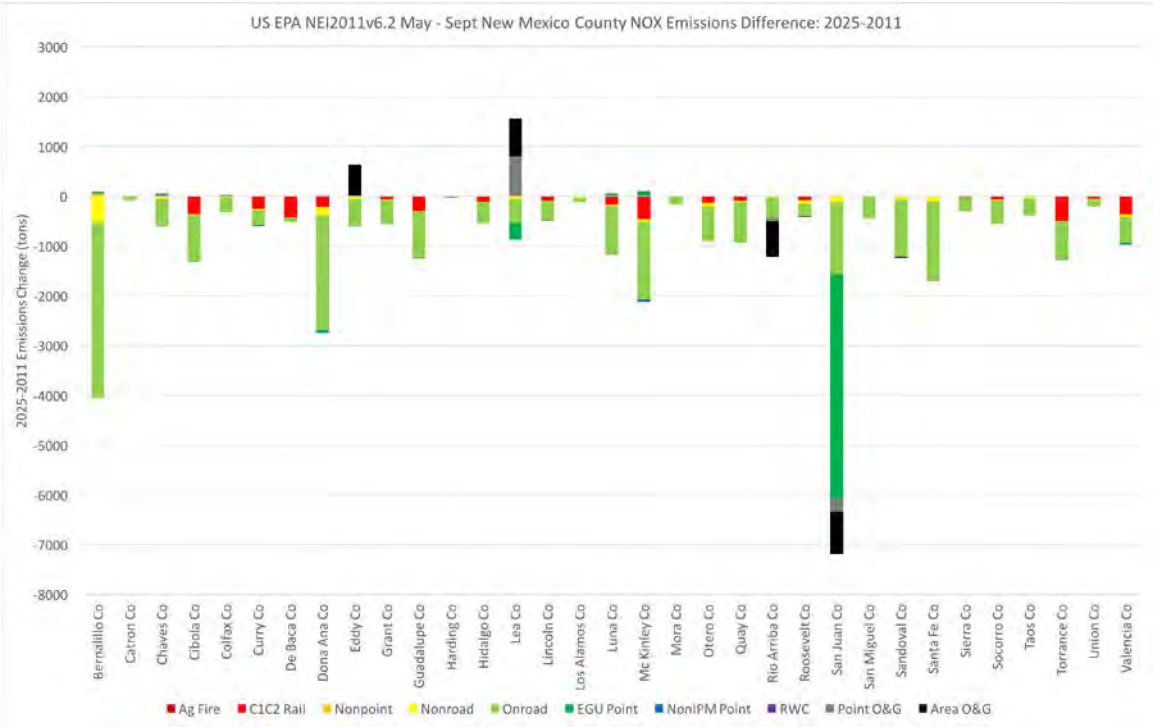


Figure 3-23. New Mexico 2011 and 2025 NOx emissions differences.

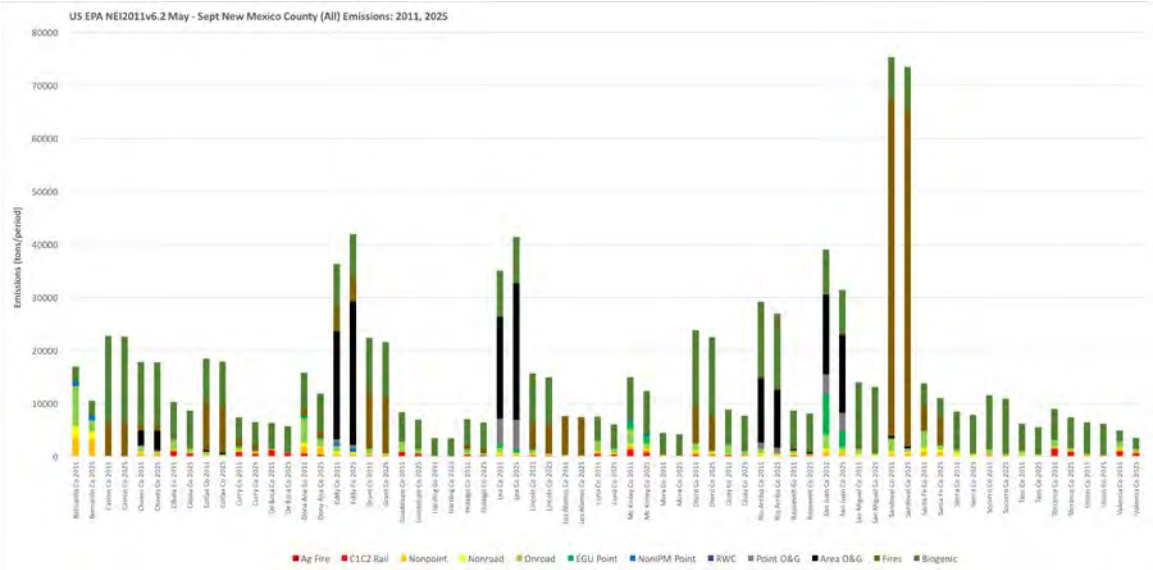


Figure 3-24. New Mexico county 2011 and 2025 VOC emissions.

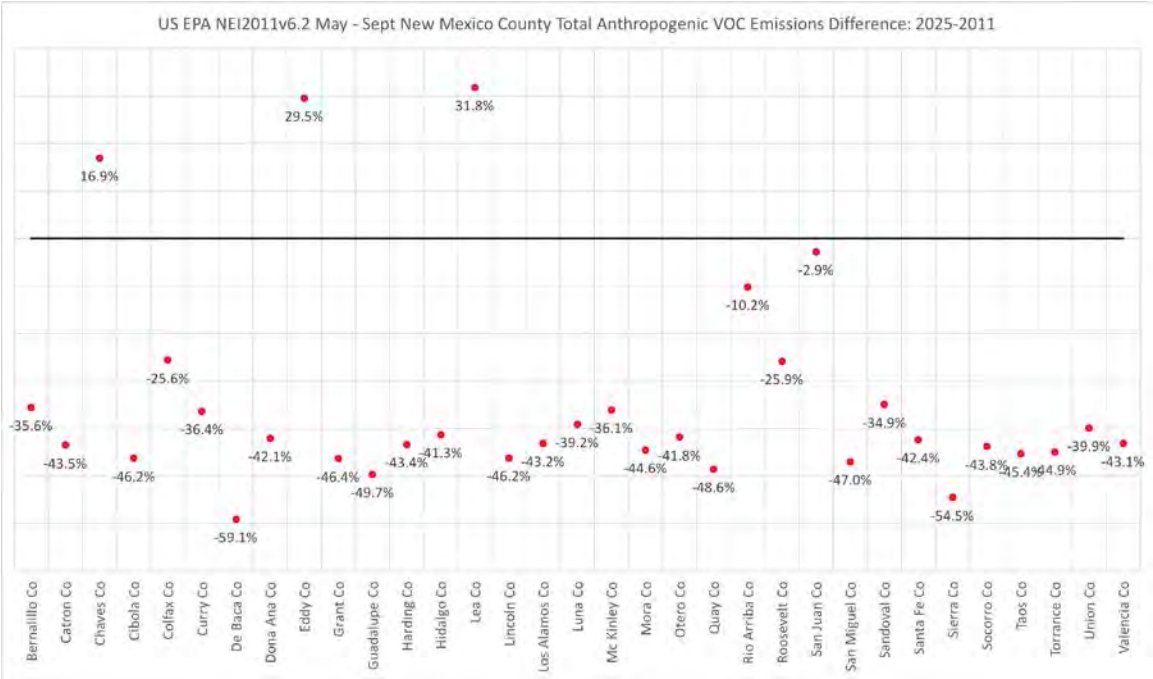


Figure 3-25. New Mexico county total anthropogenic VOC emissions change.

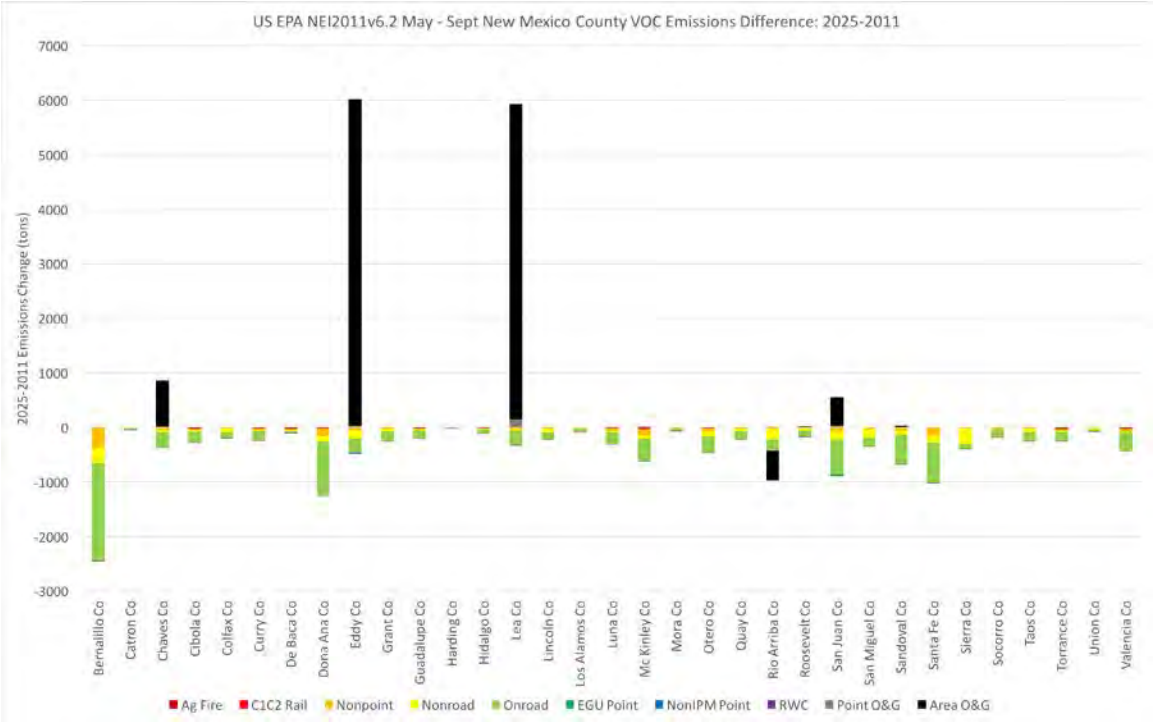


Figure 3-26. New Mexico 2011 and 2025 VOC emissions differences.

Additional details about the future year emissions data used for the SNMOS is available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016a).

3.8.2 Significant Findings

In most of the New Mexico counties, ozone precursor (NOx and VOC) emissions are projected to decrease in 2025 relative to 2011. The exceptions are the oil and gas counties in the Permian Basin, which are projected to experience increases in both NOx and VOC emissions. Doña Ana County ozone precursor emissions are projected to decrease in 2025 relative to 2011, primarily as a result of ~70% reductions in on-road mobile NOx and VOC emissions.

3.8.3 Milestones and Deliverables

- Summarize the future year emissions inventories and processing results (Completed 4/30/2016)
- Power Point Presentation on future year emissions modeling (Completed 4/30/2016)
- CAMx-ready 2025 base year emissions on the project 12-km and 4-km modeling domains (Completed 4/30/2016)

3.9 Task 9: Future Year Air Quality Modeling

3.9.1 Task Summary

The objective of this task was to simulate future year summer season air quality using CAMx. In coordination with NMED we selected 2025 as the future year. We ran CAMx using the same configuration and, with the exception of the emissions, input data as the SNMOS 2011 CAMx simulation (see Task 6). We prepared the 2025 future year emissions estimates in Task 8. Upon completion of the CAMx simulation, we compared the 2025 ozone air quality projections with the 2011 estimates at the locations of ozone air quality monitors in Doña Ana County. The results of the simulation and the comparison to the base year were summarized in a final PowerPoint presentation.

Figure 3-27 compares differences between the CAMx estimates of 2025 and 2011 air quality. This figure also shows differences in the corresponding primary emissions (NOx and VOC) that drive ozone formation. As seen in this figure, CAMx predicted that ozone concentrations will generally decrease across the modeling domain in the entire summer season in 2025 relative to 2011. Large projected decreases in NOx and VOC emissions from on-road mobile sources appeared to be the factor driving the ozone reductions in 2025. Projected increases in oil and gas source emissions in the Permian basin were not predicted to impact future year air quality in Doña Ana County.

Additional details about the future year air quality modeling are available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016b).

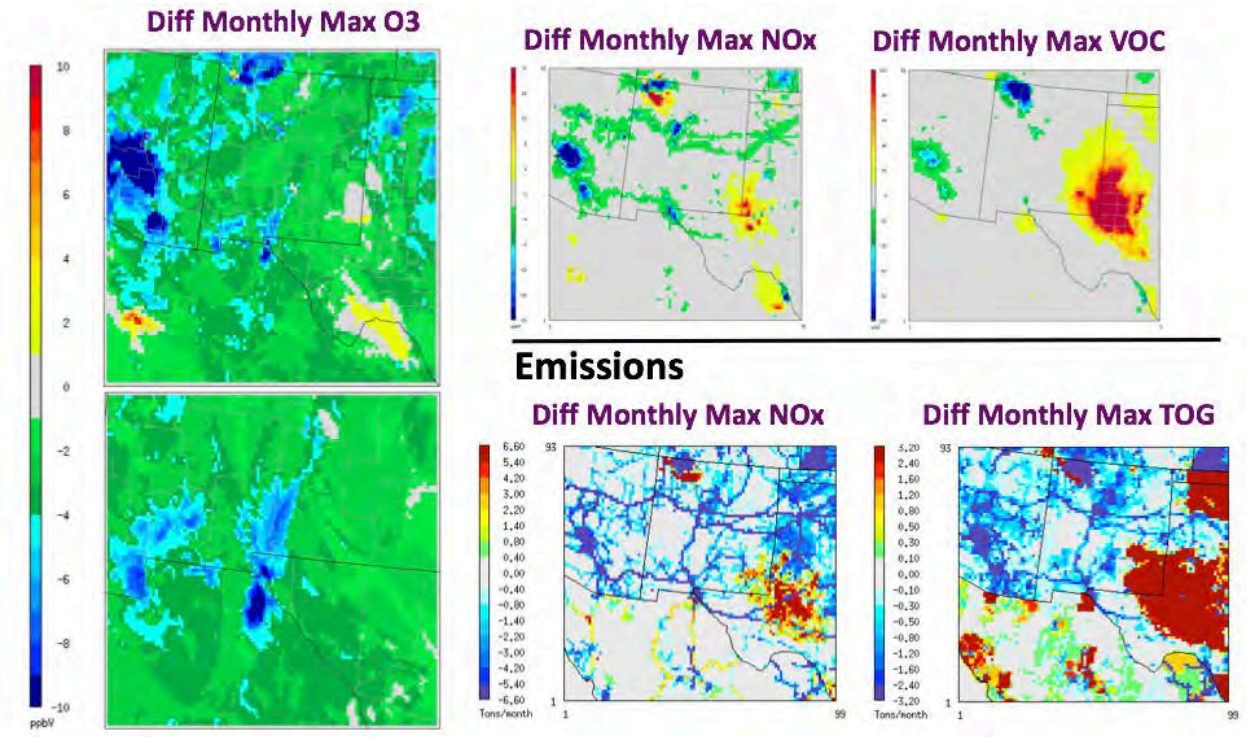


Figure 3-27. July 2011 differences (2025-2011) in CAMx monthly maximum O_3, NOx, VOC and corresponding emissions differences.

3.9.2 Significant Findings

CAMx predicted future year ozone reductions on most days of the summer season in Doña Ana County. The ozone reductions are consistent with significant reductions in ozone precursor emissions (NOx and VOC) in the area around Doña Ana County, particularly from the on-road mobile sector.

3.9.3 Milestones and Deliverables

- Power Point Presentation on future year air quality modeling (Completed 5/31/2016)

3.10 Task 10: Modeled Attainment Test

3.10.1 Task Summary

The objective of this task was to conduct a model attainment test using the U.S. EPA Model Attainment Test Software (MATS)[8] to estimate future design values (DVFs), relative response factors (RRFs), and unmonitored area analysis (UAA) for the SNMOS 12 and 4-km modeling domains. We used MATS version 2.6.1. to estimate DVFs and RRFs with the EPA default MATS configuration. In addition to the EPA defaults, we tested two different MATS configuration options to quantify how they impacted the attainment test results. Based on analysis conducted in Task 6, we also conducted an alternative MATS analysis that used the top 10 modeled 8-hour ozone days for days in which CAMx had a normalized mean bias < 10%. We

[8] https://www3.epa.gov/scram001/modelingapps_mats.htm

created plots of all the MATS simulations and prepared a Power Point presentation of the results.

Under this task we compared ten years of design values at the Doña Ana County monitors and recent projections from the EPA to the SNMOS 2025 design values. Figure 3-28 compares the official ozone design values at each of the Doña Ana County monitors from 2006 to 2015. This plot illustrates that 2011 was the lowest reported year for several of the sites. The plot also compares the 2011 DVCs, EPA modeling 2017 DVFs, and SNMOS 2025 DVFs for the Doña Ana County monitors. While the 2025 DVFs appear consistent with the EPA 2017 modeling, it is important to note that as the SNMOS projections were made from 2011, they may be biased low because they are based off of an historically low concentration base year.

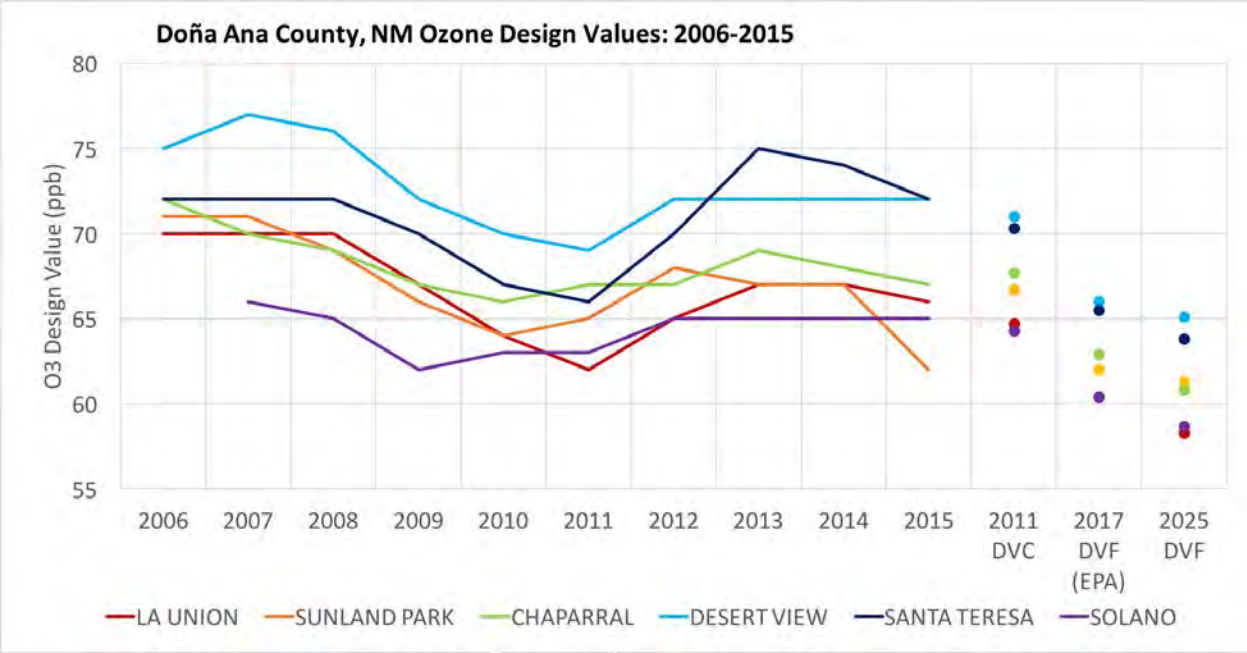


Figure 3-28. Annual ozone design values and a comparison of DVFs for EPA 2017 and SNMOS 2025 modeling.

Using the EPA default MATS configuration, we demonstrated that all of the monitors in the SNMOS 12-km domain, including all of the sites in Doña Ana County, are projected to be in attainment of the 2015 NAAQS for 8-hour ozone (70 ppb) in 2025 (Figure 3-29).

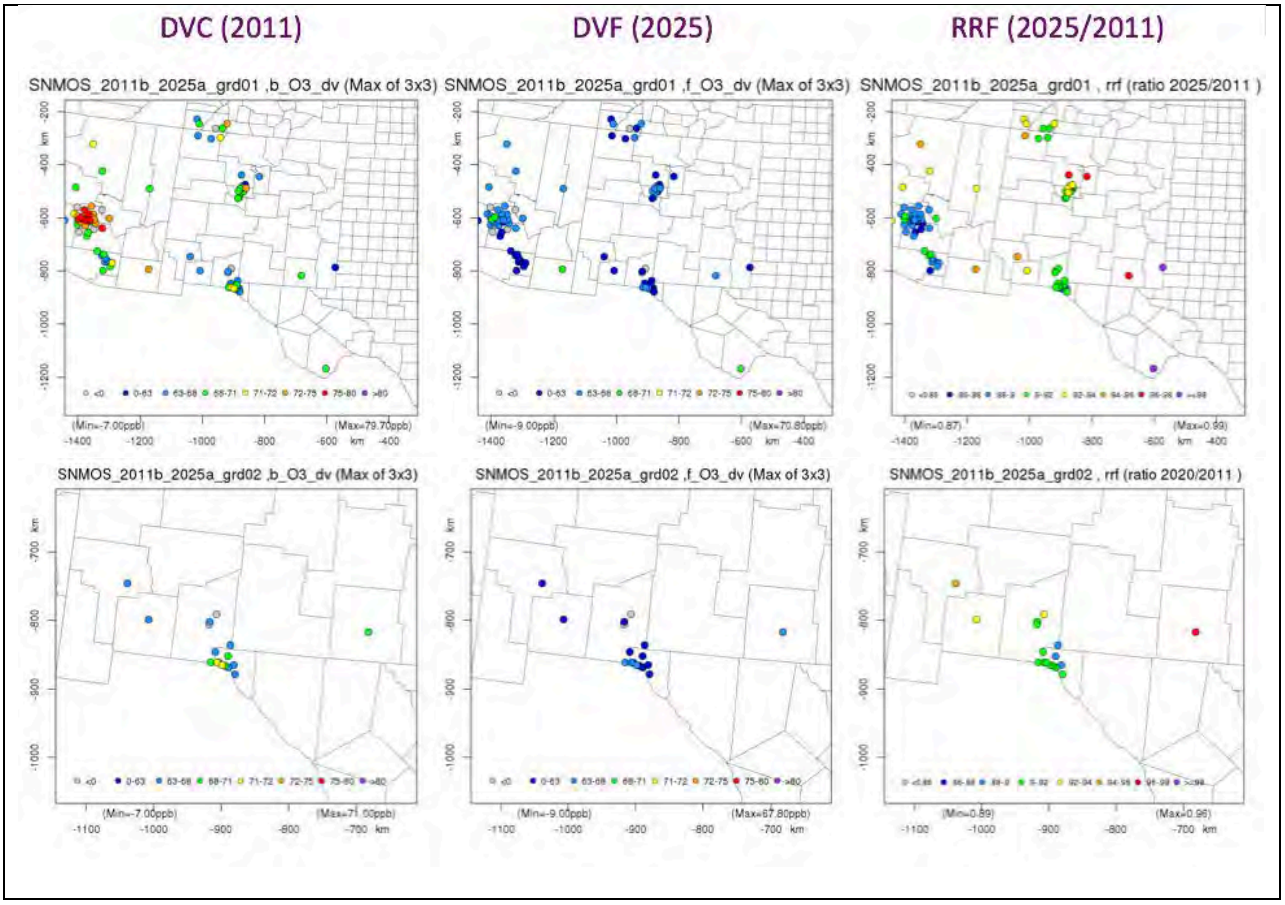


Figure 3-29. SNMOS 12-km (top) 4-km (bottom) domain MATS results.

In order to evaluate the sensitivity of the calculated DVFs to the MATS configuration and to biases in the CAMx ozone model, we conducted the following MATS sensitivity experiments:

- Spatial Matrix Experiment: test the impact of the size of the spatial matrix surrounding each monitor. MATS finds the maximum concentration from a matrix of modeled grid cells surrounding a monitor in the RRF calculation. We changed the EPA default from a 3x3 matrix to a 7x7 matrix.

- Temporal Averaging Experiment: test the impact of using fewer averaging days. Current EPA guidance uses the top 10 modeled daily maximum 8-hour average ozone in the RRF calculation. We tested the impact of using the top 5 modeled days.

- Model Performance Filter Experiment: test the impact of using only model days where the bias < 10%. We filtered the base year CAMx results to select the top 10 modeled days from only those days in which the Normalized Mean Bias was <= 10%. As this experiment required a separate MATS run for each monitor, we only used it for the Doña Ana County monitors in the 4-km modeling domain.

All of the experiments that we tested had little impact on the future year attainment status for the Doña Ana County monitors; they all continued to project attainment of the NAAQS. While the ozone bias filtering changed the DVF predictions by up to a few percent and resulted in a mix of higher and lower DVFs at the Doña Ana County monitors relative to the EPA default MATS configuration, none of the DVFs were greater than 65 ppb (Table 3-9).

Table 3-9. Low model bias MATS configuration 4-km domain results

Site ID	DVC	DVF (Base)	DVF (Bias < 10%)	RRF (Base)	RRF (Bias < 10%)	Site Name
350130008	64.7	58.3	60.2	0.9026	0.9306	LA UNION
350130017	66.7	61.3	60.9	0.9195	0.9136	SUNLAND PARK
350130020	67.7	60.8	62.9	0.8985	0.9293	CHAPARRAL
350130021	71	65.1	64.5	0.9183	0.9092	DESERT VIEW
350130022	70.3	63.8	64.3	0.9086	0.9158	SANTA TERESA
350130023	64.3	58.7	59.5	0.9136	0.9263	750 N.SOLANO DRIVE

The unmonitored area analysis that we conducted showed that all but a few cells in the 4-km domain will be in attainment in 2025 (Figure 3-30). The nonattainment cells in northern Grant County resulted from poor model performance related to a wildfire plume.

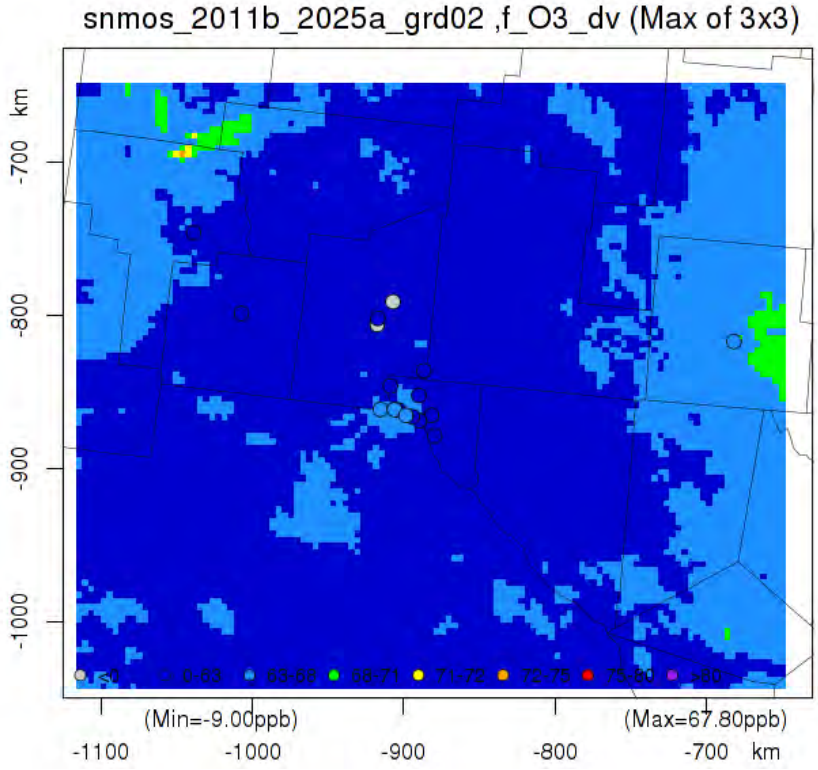


Figure 3-30. MATS unmonitored area analysis for 2025.

Additional details about the future year ozone projections using MATS is available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016b).

3.10.2 Significant Findings

All of the Doña Ana County monitors are projected to be in attainment of the 2015 ozone NAAQS in 2025 (Table 3-10). We ran a series of experiments that showed despite fairly large changes to the EPA default MATS configuration, the projections of the future year attainment status did not significantly change.

Table 3-10. SNMOS 4-km CAMx modeling DVFs and RRFs

Site ID	DVC	DVF	RRF	County	Site Name
350130008	64.7	58.3	0.9026	Dona Ana	LA UNION
350130017	66.7	61.3	0.9195	Dona Ana	SUNLAND PARK
350130019	-7	-9	0.9239	Dona Ana	LAS CRUCES WELL STATION #41;HOLMAN ROAD
350130020	67.7	60.8	0.8985	Dona Ana	CHAPARRAL
350130021	71	65.1	0.9183	Dona Ana	DESERT VIEW
350130022	70.3	63.8	0.9086	Dona Ana	SANTA TERESA
350130023	64.3	58.7	0.9136	Dona Ana	750 N.SOLANO DRIVE
350131012	-7	-9	0.9198	Dona Ana	HOLIDAY INN
350151005	70.3	67.8	0.9646	Eddy	HOLLAND ST;SE OF WATER TANK;CARLSBAD;NM
350171003	65	62	0.955	Grant	CHINO BLVD NR HURLEY PARK; HURLEY;NM
350290003	63	58.6	0.9311	Luna	310 AIRPORT ROAD; DEMING; NM 88030
481410029	65	58.4	0.8996	El Paso	10834 IVANHOE; IVANHOE FIRE STATION
481410037	71	65.2	0.9186	El Paso	RIM RD. NEAR HAWTHORNE NEXT TO UT POLICE
481410044	69	62.7	0.9098	El Paso	800 S. SAN MARCIAL STREET
481410055	66.3	60.1	0.9069	El Paso	650 R.E. THOMASON LOOP
481410057	66	59.8	0.9071	El Paso	201 S. NEVAREZ RD.
481410058	69.3	61.7	0.8917	El Paso	5050 A YVETTE DRIVE

3.10.3 Milestones and Deliverables

- Power Point Presentation on future year ozone projections (5/31/2016)

3.11 Task 11: Future Year Emissions Sensitivity/Control Modeling

3.11.1 Task Summary

The objective of this task was to conduct CAMx sensitivity modeling to evaluate the impacts of emissions reductions on attainment of the ozone NAAQS. We ran two CAMx sensitivity simulations to quantify the impacts of emissions from anthropogenic sources in Mexico and from U.S. on-road mobile sources on ozone concentrations at monitors in Doña Ana County. We used MATS to estimate the changes in the design values and RRFs resulting from the sensitivity simulations. We created model evaluation plots comparing the base CAMx and sensitivity results and bubble plots of the results from the MATS simulations. We summarized this task and presented some of the key figures in a Power Point presentation.

We prepared the emissions and ran CAMx for two sensitivity simulations to test the impacts of key emissions sources on ozone concentrations in Doña Ana County. With the exception of the emissions changes in the designed sensitivity, all of the other CAMx inputs and configuration

remained the same as the base CAMx simulation. We ran the sensitivities for the full SNMOS modeling period (April 15 – August 31, 2011) and for both the 12-km and 4-km modeling domains.

In the first sensitivity simulation we evaluated the impact of Mexico emissions sources on 2011 air quality by removing ("zero out") all of the anthropogenic emissions in Mexico (SNMOS simulation ID: NoMex). The concept of this simulation was to estimate the ozone levels in Doña Ana County minus the influence of sources in Mexico. In the second sensitivity simulation we evaluated the sensitivity of 2025 projected U.S. air quality to the magnitude of the future year on-road mobile emissions estimates. We doubled the 2025 U.S. on-road mobile emissions (SNMOS simulation ID: 2xUSOR) to determine the sensitivity of the future year design values to this emissions source category. The concept of this simulation was to consider if a less conservative on-road mobile source projection scenario would still lead to ozone NAAQS attainment for the Doña Ana County monitors.

The NoMex simulation estimated that 2011 MDA8 ozone reduced by an average of 5.1 ppb (range -3.7 to -6.3 ppb) for the modeling period across all Doña Ana County monitors (Figure 3-31). The same figure shows a time series of observed (black) and modeled MDA8 at the Desert View monitor. The time series also shows the systematic ozone reductions in the NoMex simulation (blue) relative to the base 2011 CAMx simulation (red). The MATS results in Table 3-11 show that all of the monitors in the 4-km modeling domain reach NAAQS attainment in 2011 in the NoMex simulation. The design value at the Desert View monitor (2011 design value: 71 ppb) decreased by 6.2 ppb to 64.8 ppb. The results of the NoMex simulation provide evidence that in 2011 the monitors in Doña Ana County would have been in attainment of the ozone NAAQS but for the influence of anthropogenic emissions in Mexico.

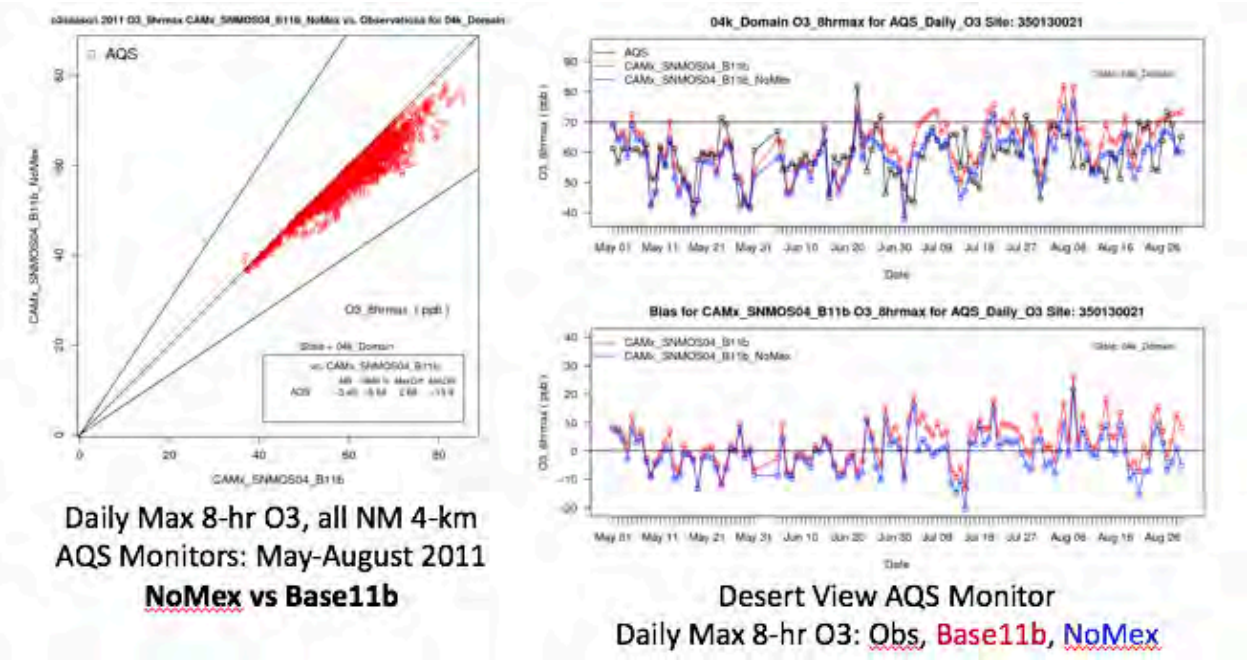


Figure 3-31. SNMOS 4-km domain 2011 zero out Mexico CAMx performance summary.

Table 3-11. SNMOS 4-km domain 2011 zero out Mexico MATS results

Site ID	DVC (2011)	DV No Mex (2011)	DV Diff	Site Name
350130008	64.7	59.6	-5.1	LA UNION
350130017	66.7	60.4	-6.3	SUNLAND PARK
350130020	67.7	63.3	-4.4	CHAPARRAL
350130021	71	64.8	-6.2	DESERT VIEW
350130022	70.3	65.2	-5.1	SANTA TERESA
350130023	64.3	60.6	-3.7	750 N.SOLANO DRIVE

The 2xUSOR simulation estimated that 2025 MDA8 ozone would increase by an average of 1.5 ppb (range: +1.3 to +1.6 ppb) for the modeling period across all Doña Ana County monitors. Despite doubling the 2025 emissions from on-road mobile sources (which contributed 70% of the anthropogenic NOx emissions in Doña Ana County), the projected air quality impacts were small. Table 3-12 shows that the DVFs for the Doña Ana County monitors were projected to increase by an average of 1.47 ppb and none of the monitors were predicted to be close to nonattainment of the 2015 ozone NAAQS (maximum 65.1 ppb at Desert View). The results of the 2xUSOR simulation demonstrate that a less conservative 2025 future year emissions scenario for U.S. on-road mobile sources than is currently estimated by MOVES will still lead to attainment of the 2015 ozone NAAQS for all monitors in Doña Ana County.

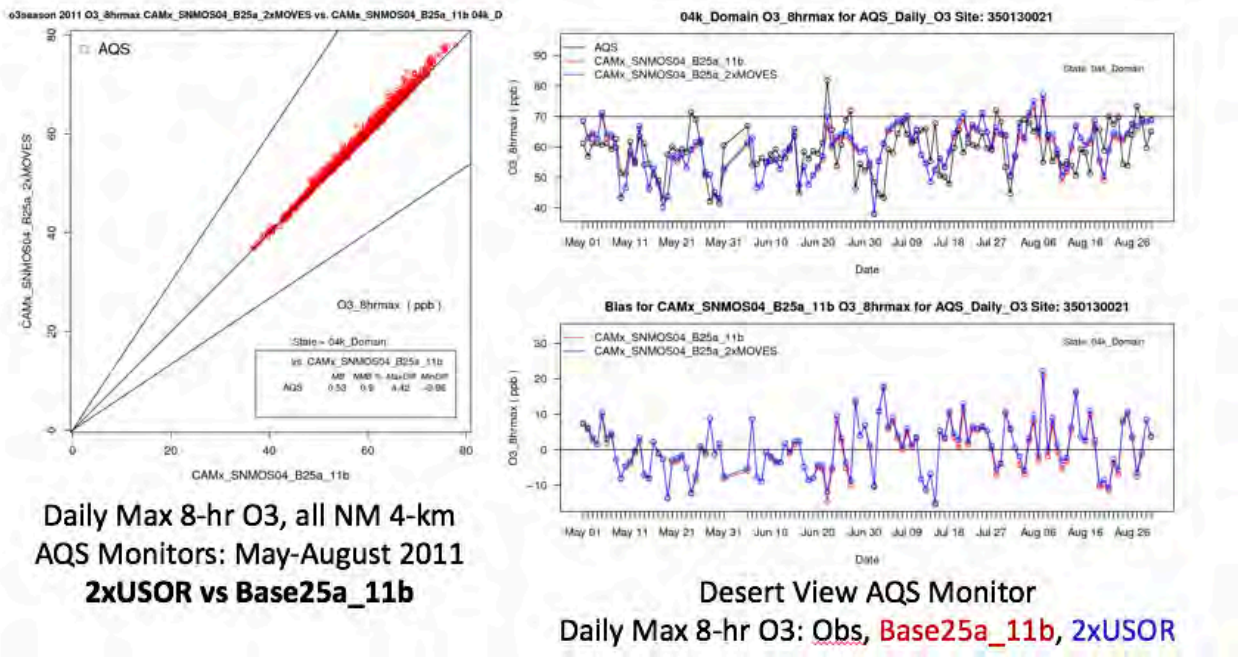


Figure 3-32. SNMOS 4-km domain 2025 double U.S. on-road emissions CAMx performance summary.

Table 3-12. SNMOS 4-km domain 2025 double U.S. on-road emissions MATS results

Site ID	DVC (2011)	DVF (2025)	DV 2xUSOR (2025)	DV Diff	RRF (2025)	RRF 2xUSOR (2025)	RRF % Change	Site Name
350130008	64.7	58.3	66.0	1.6	0.9026	0.9271	+2.71%	LA UNION
350130017	66.7	61.3	67.7	1.4	0.9195	0.9403	+2.26%	SUNLAND PARK
350130020	67.7	60.8	68.7	1.5	0.8985	0.9210	+2.50%	CHAPARRAL
350130021	71	65.1	71.9	1.5	0.9183	0.9388	+2.23%	DESERT VIEW
350130022	70.3	63.8	71.2	1.5	0.9086	0.9297	+2.32%	SANTA TERESA
350130023	64.3	58.7	65.2	1.3	0.9136	0.9341	+2.24%	750 N.SOLANO DRIVE

Additional details about the future year ozone projections using MATS are available in the final Power Point presentation for this task (UNC-IE and Ramboll Environ, 2016c).

3.11.2 Significant Findings

The results of the NoMex simulation provide evidence that in 2011 the monitors in Doña Ana County would have been in attainment of the ozone NAAQS but for the contribution of emissions from anthropogenic sources in Mexico. Despite doubling the 2025 emissions projections for U.S. on-road mobile sources, all of the monitors in Doña Ana County are projected to be well in attainment of the ozone NAAQS.

3.11.3 Milestones and Deliverables

- Power Point Presentation on future year air quality modeling (Completed 8/15/2016)

3.12 Task 12: Future Year Source Apportionment Modeling

3.12.1 Task Summary

The purpose of Task 12 was to conduct CAMx source apportionment simulations to better understand the source regions and source categories that contribute to elevated ozone concentrations in Doña Ana County and vicinity. These simulations will help set the ground work for the development of a potential State Implementation Plan (SIP) to demonstrate attainment of the ozone NAAQS. CAMx source apportionment modeling will be used to provide a complete accounting of the contributions of all sources delineated by the defined Source Groups that contribute to ozone concentrations at the Doña Ana monitoring sites and throughout the 12/4 km modeling domain.

Ozone is formed in the atmosphere by reactions of NOx and VOC in the presence of sunlight. Once formed, ozone persists and can be transported by prevailing winds. The Ozone Source Apportionment Tool (OSAT) in CAMx uses tracers to keep track of ozone production and transport (Yarwood et al., 1996; Ramboll Environ, 2015). The OSAT algorithm performs source attribution of ozone within a CAMx simulation, i.e., it provides a quantitative accounting of where ozone originated for any and all locations in the CAMx simulation. Within photochemical models like CAMx, ozone can originate from the initial conditions, the boundary conditions and emissions of ozone precursors (NOx and VOC). The OSAT method allows the emission inventory to be disaggregated to geographic regions and/or source categories for purposes of source apportionment. This allows an assessment of the role of transported ozone and precursors in

contributing to ozone episodes in Doña Ana County. The methodology is designed so that all ozone and precursor concentrations are attributed among the selected source groupings at all times. Thus, for all receptor locations and times, ozone (or ozone precursor concentrations) predicted by CAMx is attributed among the source groupings.

Source Groups are typically defined as the intersection between source regions (e.g., states) and source categories (e.g., on-road mobile sources). For the CAMx 12/4 source apportionment simulation defined four Source Regions and seven Source Categories as follows (Figure 3-33):

Source Regions (4):

- New Mexico
- Texas
- Mexico
- Arizona and remainder of other states in the 12-km domain

Source Categories (8):

- Natural (biogenics and lighting NOx)
- On-Road Mobile
- Non-Road Mobile
- Oil and Gas (point and non-point)
- Electrical Generating Unit (EGU) Point
- Non-EGU Point
- Open Land Fires (wildfire, prescribed, and agricultural burning)
- Remainder Anthropogenic.

Initial concentrations (IC) and boundary condition (BC) are always included as Source Groups, so that there were a total of 30 Source Groups (30 = 4 x 7 + 2) for the source apportionment modeling. The BCs represent the contribution from transport from outside of the 12/4 km SNMOS domain. This includes transport from sources in the remainder of U.S. outside the 12/4 km domain, international transport, and the natural global ozone background including stratospheric ozone intrusions. The boundary conditions as defined for the SNMOS includes contributions from additional sources of emissions relative to the North American background (NAB)[9] or the U.S. background (USB)[10].

[9] North American Background Ozone (NAB) is defined by the U.S. EPA to be as the ozone levels that would exist in the absence of continental North American (i.e., Canadian, U.S., and Mexican) anthropogenic emissions

[10] U.S. background (USB) ozone is defined by the U.S. EPA to be any ozone formed from sources or processes other than U.S. manmade emissions of NOx, VOC, methane and CO. USB ozone does not include intrastate or interstate transport of manmade ozone or ozone precursors.

Figure 3-33. 12/4 km domain source regions used in source apportionment modeling.

We performed the source apportionment simulation using both the 2011 and 2025 emissions in order to:

- Obtain the contributions of Mexico to 2011 ozone design values and demonstrate that, without anthropogenic emissions from Mexico, Doña Ana County would have attained the ozone NAAQS;
- Calculate 2025 ozone projections removing the contributions of fires that have high uncertainties as well as year-to-year variations.
- Determine changes in contributions between 2011 and 2025 to explain the reductions in Doña Ana County design values and provide a rough estimate of ozone levels if the emission reductions are not as large as projected.
  - For example, the reductions in ozone due to on-road mobile sources were examined to determine what the 2025 ozone design values would be if we obtained a lower level of emission reductions.
- Provide an accounting of ozone contributions in 2025 that can be used to identify those sources that contribute the most to ozone levels in Doña Ana County.

We ran the CAMx model on the SNMOS 12/4 km grids using ozone source apportionment for April–August 2011 and 2025. CAMx was configured as in the SNMOS 2011 Base Case modeling (Table 3-7). 2011 calendar dates were used for the 2025 run. The modeling setup was identical

to that used in the Task 11 Sensitivity Modeling except for the use of the use of the CAMx source apportionment tools and the unperturbed Base Case emission inventory for 2025. The 2025 Base Case emission inventory is described in Section 3.8.

We used EPA's MATS together with the CAMx OSAT results for 2011 and 2025 to calculate design values for 2025 and carry out the following analyses:

- Determine the source regions and source categories that contribute to elevated ozone concentrations in Doña Ana County and vicinity
- Obtain the contributions of Mexico emissions to 2011 ozone design values (DVs)
- Calculate 2025 ozone DVs without the contributions of fire emissions

We followed current EPA guidance on the use of MATS. The DVF calculation used the maximum concentration from a matrix 3 x 3 matrix (9 cells) of modeled grid cells surrounding each monitor. In the RRF calculation for each monitor in the 4-km grid, we used the top 10 modeled days (10 days with the highest modeled MDA8 ozone). We used a 70 ppb threshold and set the minimum number of days at or above the threshold to one day.

To calculate the contribution of each source group to each monitor's ozone design value, we first ran MATS with the full CAMx output for the base year ($CAMx\_total_{2011}$) and the future year ($CAMx\_total_{2025}$) and calculated the future year design value (DVF_{2025}) for each monitor using following EPA Guidance:

$$DVF_{2025} = \frac{CAMx\_total_{2025}}{CAMx\_total_{2011}} \times DVC_{2011}$$

where DVC_{2011} is the base year design value based on observed ozone. Next, we subtracted the ozone contribution from the i^{th} source group (for example, New Mexico on-road mobile emissions) ($SrcGrpContrib^{i}_{2025}$) from the full model output ($CAMx\_total_{2025}$) and reran MATS without contribution from the i^{th} source group.

$$DVF^{i}_{2025} = \frac{CAMx\_total_{2025} - SrcGrpContrib^{i}_{2025}}{CAMx\_total_{2011}} \times DVC_{2011}$$

The incremental contribution to the 2025 DVF from the i^{th} source group is

$$\Delta DVF^{i}_{2025} = DVF_{2025} - DVF^{i}_{2025}.$$

We define the DVF for the year 2011 to be:

$$DVF^{i}_{2011} = \frac{CAMx\_total_{2011} - SrcGrpContrib^{i}_{2011}}{CAMx\_total_{2011}} \times DVC_{2011}$$

so that the contribution to the 2011 current year design value from source group i is

$$\Delta DVC^{i}_{2011} = DVC_{2011} - DVF^{i}_{2011}.$$

3.12.1.1 OSAT Results

In this section, we present results of the OSAT analysis. We begin with detailed source apportionment results for the Desert View monitor. Results for this monitor were similar to those for the other Doña Ana monitors, so we focus on Desert View only for the sake of brevity and because it is the only Doña Ana County monitor with a DVC_{2011} that exceeds the 2015 NAAQS of 70 ppb. Results for the other Doña Ana County monitors may be found in the Task 12 Summary PowerPoint presentation.

We used the source apportionment results to assess the importance of transport in determining ozone design values at Doña Ana monitors. We reviewed the effect of boundary conditions and transport from within the 12-km domain, but outside New Mexico. The results for the Desert View monitor are shown in Figure 3-34 and Figure 3-35. The DVC_{2011} for Desert View is 71.0 ppb and the DVF_{2025} is 65.1 ppb. The contribution from each of the 12/4 km domain source regions for both years is shown in the stacked bar charts.

The BC contribution includes the effects of sources within the U.S. (e.g., Los Angeles and Phoenix) as well as sources outside the US (Asia, regions of Mexico outside the 12/4 km grid) and the stratospheric contribution. The contribution to the Desert View DVC_{2011} and DVF_{2025} from the12-km BC contribution is far larger than those of regions within the 12-km domain and decreases from 54 ppb in 2011 to 50 ppb in 2025. The total contribution from transport is indicated by the red brackets in Figure 3-34 and includes the BC contribution as well as contributions from Mexico, Texas and the Other 12 km region that includes parts of Colorado, Oklahoma, Kansas, Utah and Arizona. In 2011, transport contributed 68.6 ppb to the Desert View design value of 71.0 ppb, while New Mexico emissions sources contributed 2.4 ppb. In 2025, transport contributed 63.5 ppb to the design value of 65.1 ppb and New Mexico sources contributed 1.6 ppb.

The New Mexico contribution to the Desert View DVC_{2011} and DVF_{2025} is smaller than the Texas and Mexico contributions in both 2011 and 2025. In 2011, New Mexico emissions sources contributed 2.4 ppb to the Desert View design value while Texas contributed 6.9 ppb and Mexico contributed 7.6 ppb. In 2025, New Mexico emissions sources contributed 1.6 ppb to the Desert View design value while Texas contributed 5.0 ppb and Mexico contributed 7.8 ppb.

The reduction in the Desert View DVF_{2025} is driven by the decrease in BCs from 54 ppb to 50 ppb and in reductions contributions from New Mexico (2.4 ppb to 1.6 ppb), Texas (6.9 ppb to 5.0 ppb). The contribution from Mexico, on the other hand, increases slightly from 7.6 ppb to 7.8 ppb.

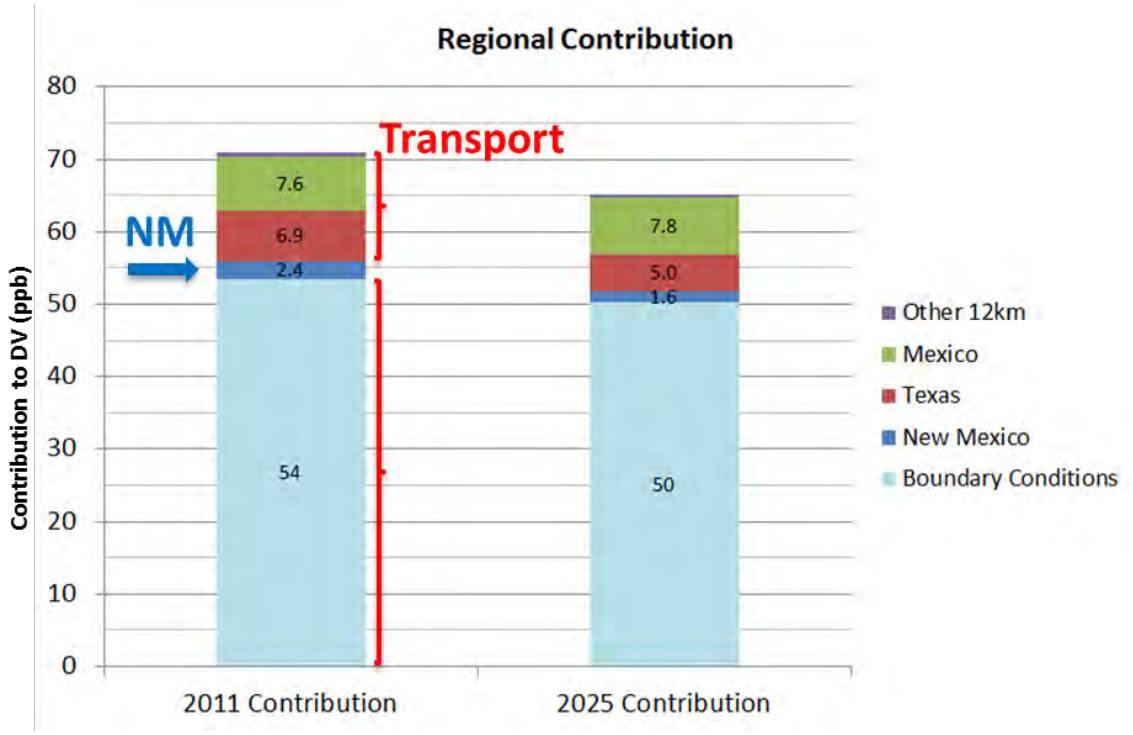


Figure 3-34. Contribution from source regions shown in Figure 3-33 and 12-km grid boundary conditions to 2011 and 2025 design values at the Desert View monitor. The contribution from New Mexico is shown in darker blue and the contribution from all sources outside New Mexico ("Transport") is indicated by the red bracket.

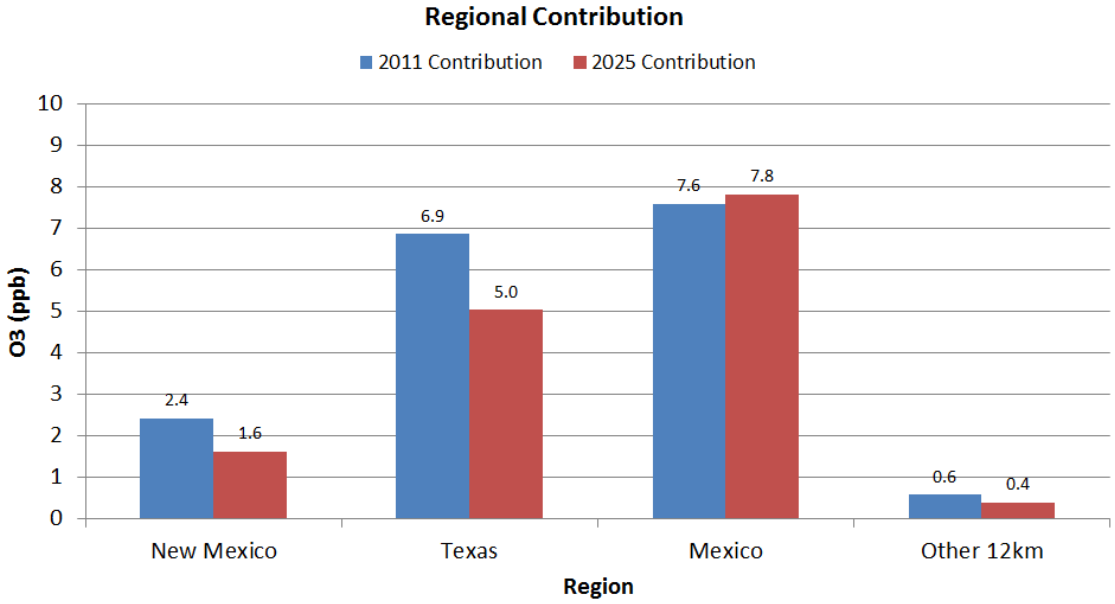


Figure 3-35. Contribution from source regions shown in Figure 3-33 to 2011 and 2025 design values at the Desert View monitor.

Figure 3-36 shows the contributions to the Desert View design values from the different emissions source categories. The largest contributions to the Desert View DVC_{2011} are from on-road mobile sources, natural sources, EGUs and non-road mobiles emissions. By 2025, the contribution of on-road mobile emissions decreases, but on-road mobile still contributes the most of any emissions source category to the Desert View design value. Natural emissions are the next largest contributor in 2025, followed by EGU and non-EGU point sources.

Figure 3-37 shows the top five contributing source groups to the DVC_{2011} at Desert View ranked by the value of their 2011 contribution alongside their 2025 contribution. The largest contributions to the Desert View DVC_{2011} are from Texas and Mexico on-road emissions and Mexico EGU and natural emissions. The largest 2025 contributions are from Mexico EGU and non-EGU point sources and on-road emissions from Texas and Mexico. Reductions in Texas, New Mexico and Mexico on-road contributions are responsible for much of the ozone decrease in the Desert View design value from 2011 to 2025.

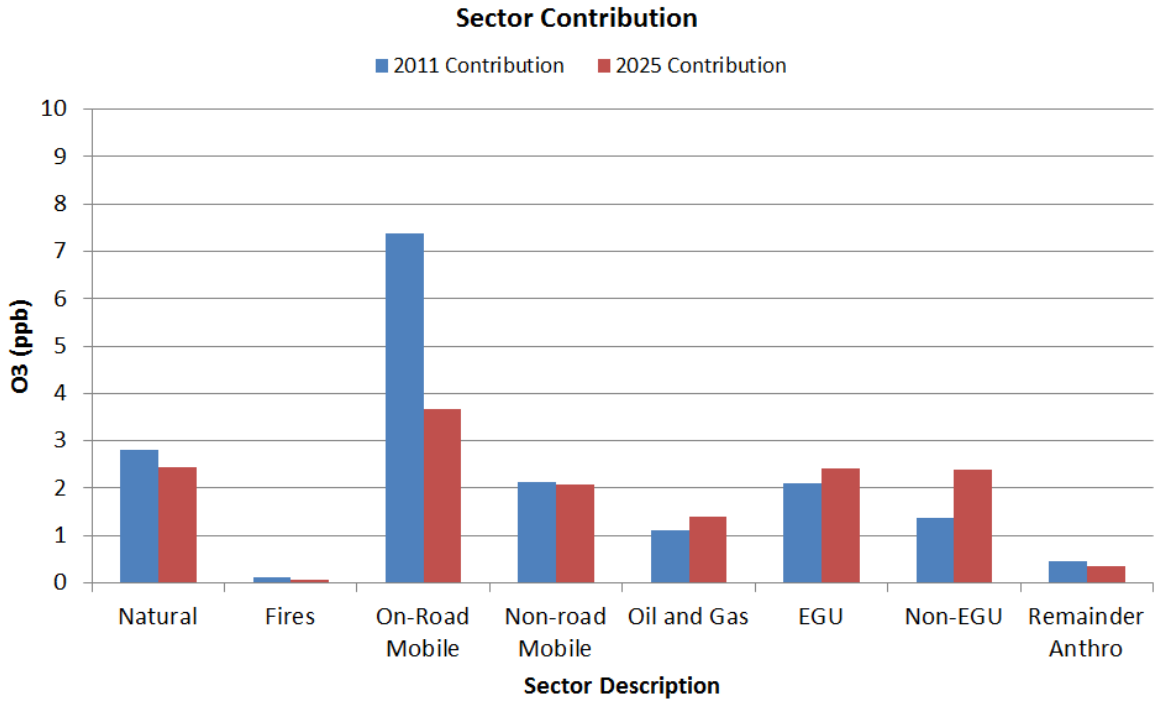


Figure 3-36. Contribution from emissions source categories to 2011 and 2025 design values at the Desert View monitor.

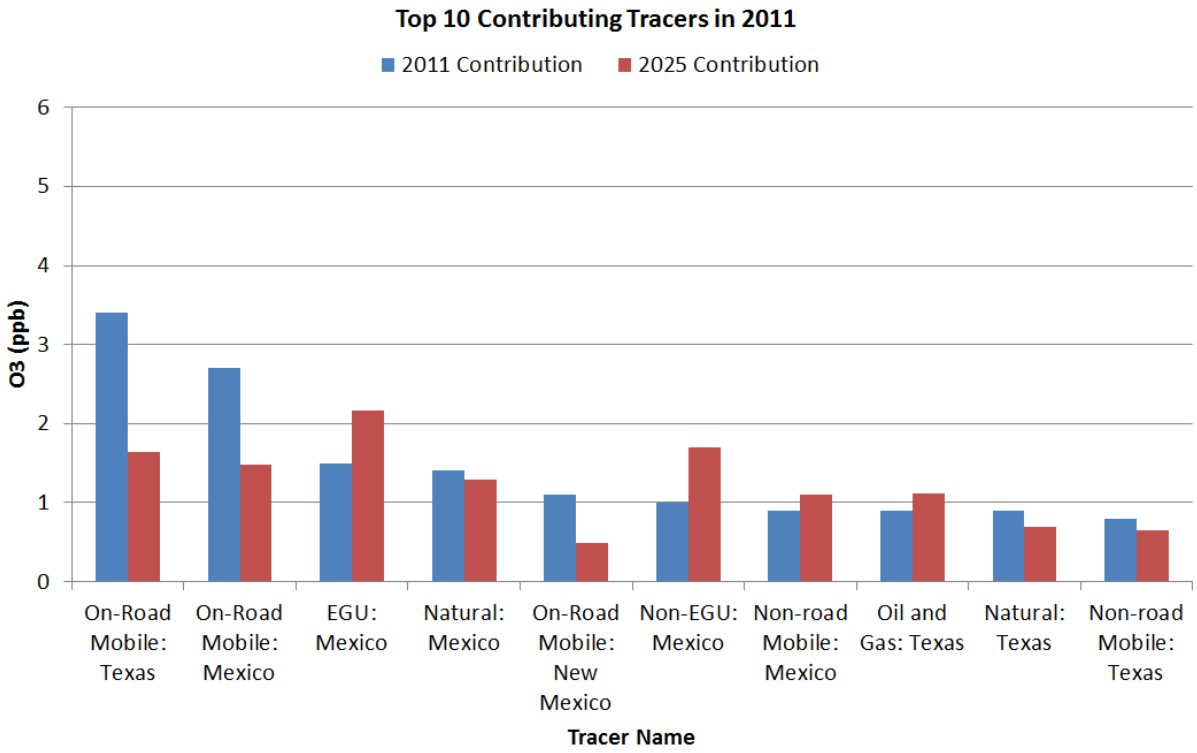


Figure 3-37. Contributions to the 2011 (blue) and 2025 (red) design values for the top ten contributing source groups in 2011 for the Desert View monitor. Source groups are ranked from left to right based on their contribution to the 2011 design values.

As noted above, results for the other Doña Ana County monitors are similar to those of Desert View and are available in the Task 12 PowerPoint. Next, we identify source groups that had the largest impact on Doña Ana County monitors. Figure 3-38 shows the frequency (as a count) with which each source group appears in the list of top five contributing source groups for the Doña Ana County monitors. We selected the top five source groups because contributions to design values tended to drop below 1 ppb for source groups outside the top five, so that focusing on the top five isolates the most important source groups. There were six Doña Ana County monitors active during this modeling episode (Figure 3-39), so that when the count for a source group is six (such as for natural emissions in Mexico in 2025) that source group was in the top five contributing source groups for all Doña Ana County monitors in that year.

Figure 3-37 shows that on-road, natural (Mexico) and EGU (Mexico) emissions appeared most frequently in the list of top five contributors to Doña Ana County monitor design values. All six Doña Ana County monitors had Texas on-road mobile sources appearing in the list of top five contributors in 2011. While New Mexico on-road mobile sources appeared in the list of the top five sources for five Doña Ana County monitors in 2011, reductions in on-road mobile emissions by 2025 meant that on-road mobile emissions from New Mexico appeared in the list of top five contributors for only one monitor (Solano) in 2025. Oil and gas emissions growth in the

Permian Basin is the cause of the increased frequency of appearance of Texas oil and gas sources in the list of top five contributors in 2025.

Mexico is the most frequently appearing source region, with emissions from Mexican natural sources, on-road mobile and EGU point sources appearing the most frequently in 2011 and Mexican natural emissions, on-road mobile sources and EGU and non-EGU point sources appearing most frequently in 2025. Next, we focus on the contribution from Mexico.

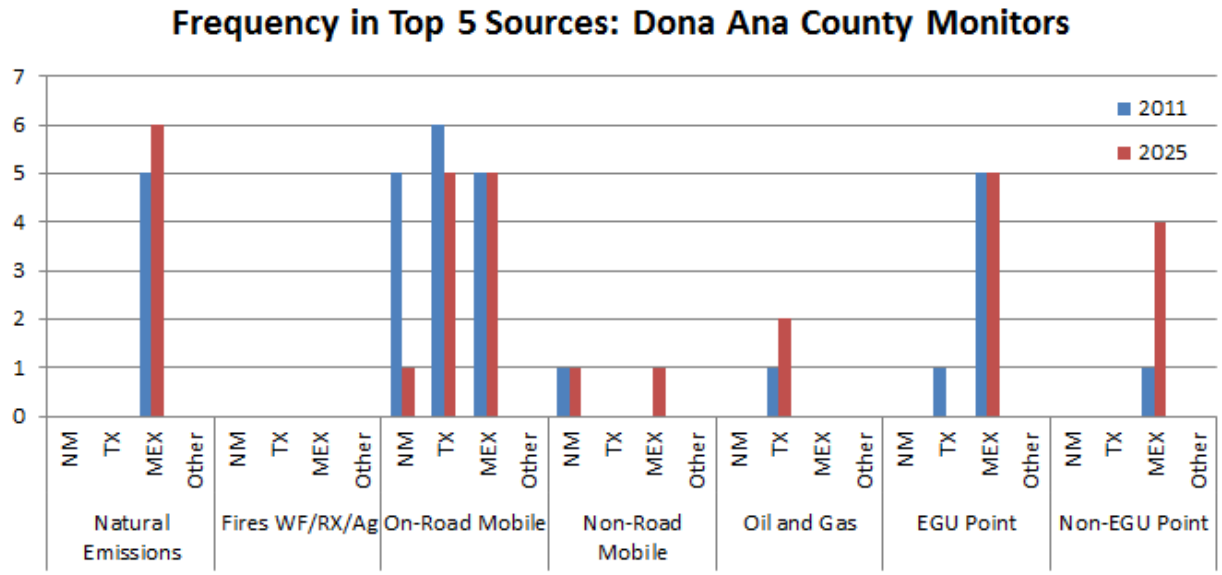


Figure 3-38. Frequency with which each source group appeared in the list of top five contributing source groups for the Doña Ana County monitors in 2011 and 2025.

Figure 3-40 shows the contributions to monitors within the 4-km domain due to emissions from Mexico along with a map of the monitors within and nearby Doña Ana County. The full map of monitors within the 4-km domain is shown in Figure 3-39. Contributions from Mexico emissions to 2011 and 2025 design values range from ~2-6 ppb at Doña Ana monitors and are similar in magnitude in 2011 and 2025. Monitors in New Mexico that are located near the U.S.-Mexico border (Desert View, Sunland Park) and El Paso monitors have larger contributions from Mexico emissions than monitors located further from the border (Carlsbad, Hurley). The contribution from Mexico emissions is significant and in 2011 is sufficiently large to affect the attainment status of the monitors. (See additional discussion below). The contribution from Mexico does not change substantially from 2011 to 2025; the contribution increases for some monitors (Sunland Park, El Paso UTEP) and decreases for other monitors (Santa Teresa, Ascarate Park).

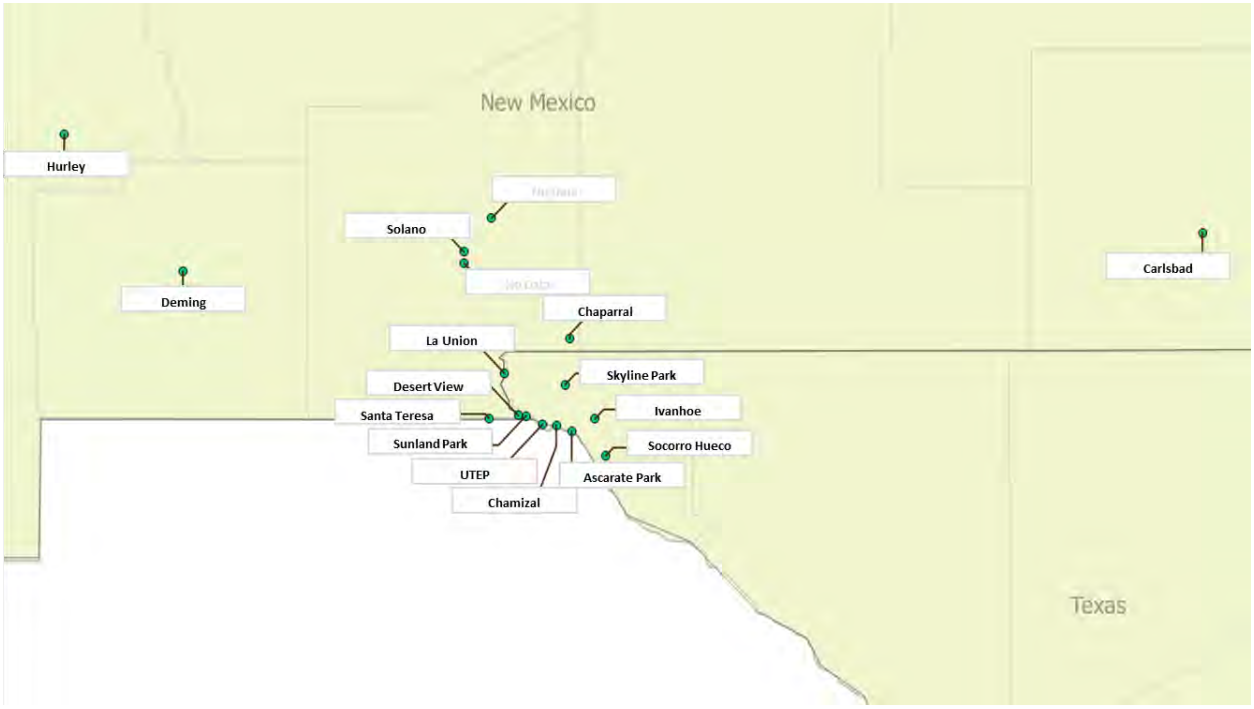


Figure 3-39. Map of ozone monitors within the SNMOS 4-km domain. Sites that were not active during the 2011 SNMOS modeling episode are indicated by "No Data".

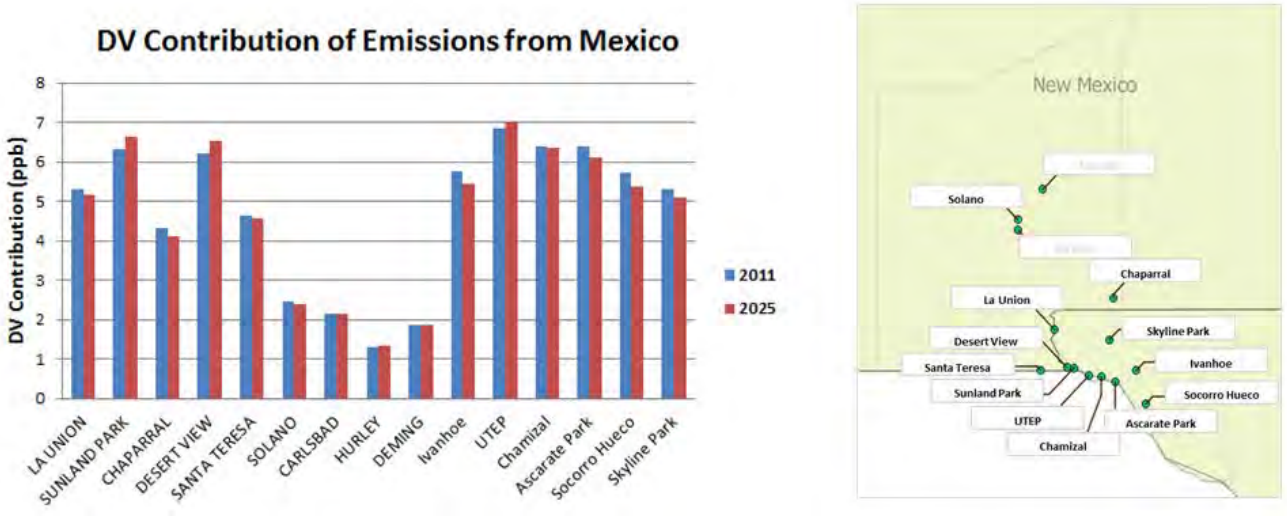


Figure 3-40. Left: contribution of Mexico anthropogenic emissions to 2011 and 2025 DVs for monitors in the 4-km grid. Right: map of ozone monitors within and nearby Doña Ana County.

The contribution to 4-km grid monitors from on-road mobile sources is shown in Figure 3-41. There are large (>7 ppb) 2011 contributions from on-road emissions to design values at Doña Ana and El Paso monitors. Decreases in U.S. and Mexico 2025 on-road mobile emissions relative to 2011 cause large decreases in the on-road mobile contribution in 2025 for all sites.

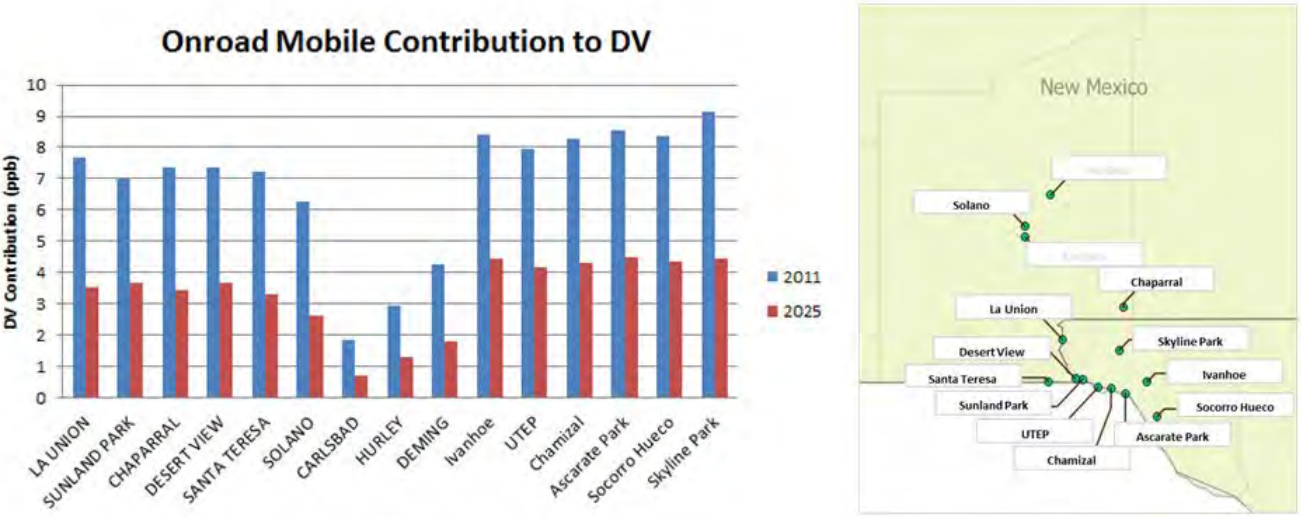


Figure 3-41. Left: contribution of on-road mobile emissions to 2011 and 2025 DVs for monitors in the 4-km grid. Right: map of ozone monitors within and nearby Doña Ana County.

Figure 3-42 shows the contribution of New Mexico anthropogenic emissions to design values of monitors in New Mexico. This represents the portion of the design values that are subject to

local control. On-road mobile emissions make the largest anthropogenic contribution to design values at most New Mexico monitors. The Solano monitor has the largest contribution from on-road mobile sources. This monitor is located within the Las Cruces urban area and is also close to Interstate I-15. The contribution from on-road mobile sources decreases in 2025 for all New Mexico monitors, consistent with the decrease in New Mexico on-road mobile emissions in 2025 relative to 2011.

Non-road mobile and oil and gas sources make next largest contributions, followed by EGU point sources. Oil and gas sources make the largest contribution at the Carlsbad monitor, which is the monitor located closest to the Permian Basin (Figure 3-39). The magnitude of the oil and gas impact increases in 2025 consistent with projected growth in emissions in the Permian Basin in 2025 relative to 2011 (Section 3.2.1).

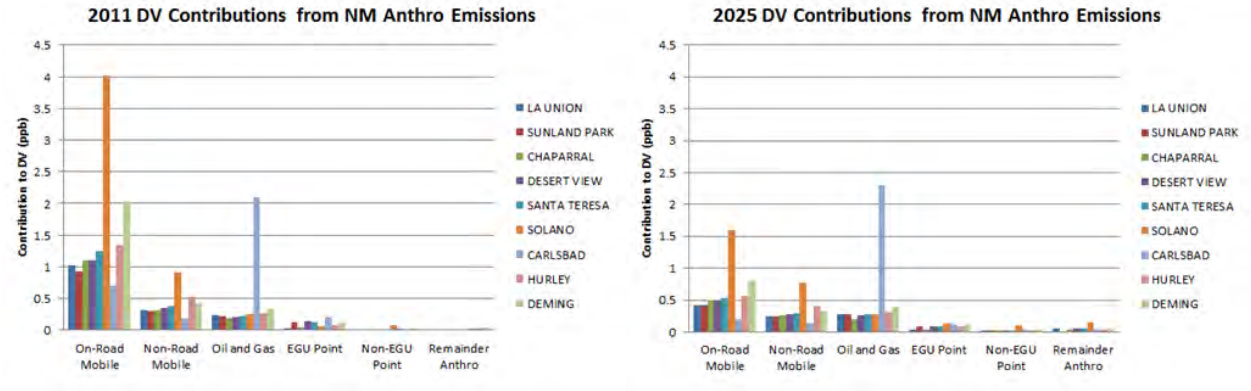


Figure 3-42. Contribution of New Mexico anthropogenic emissions to 2011 and 2025 design values for New Mexico monitors within the 4-km grid.

3.12.1.2 Contribution of Emissions from Mexico to Doña Ana County Ozone

We assessed the contribution of Mexico emissions to design values at Doña Ana monitors in 2011 and 2025 and compared the results with those of the Task 11 Sensitivity Test in which the ozone impacts of zeroing out Mexico anthropogenic emissions were quantified. This assessment is aimed at assessing whether a Section 179B "But For" test would be appropriate for Doña Ana monitors.

Section 179B of the Clean Air Act addresses impacts on U.S. air quality due to transport of pollution from outside the U.S. Section 179B provides relief from some requirements for areas that would be able to meet the NAAQS "but for" ozone impacts of emissions from another country. In preparing a Section 179B demonstration, an air agency must show that the area would attain the NAAQS but for the ozone contribution from outside the U.S. In Table 3-13, the contributions from Mexico anthropogenic emissions ("Mexico Anthro Contribution") to 2011 design values from the Task 12 source apportionment modeling as well as the Task 11 sensitivity modeling are shown. For the source apportionment results, the Mexico Anthro Contribution ranges between 1.3-6.8 ppb for monitors in the 4-km grid. Contributions to Dona Ana monitor design values from Mexico emissions range from ~2-6 ppb at Doña Ana monitors

and are similar in 2011 and 2025. Subtracting the Mexico Anthro Contribution from the 2011 DVC yields the 2011 DV NoMexAnthro, the value of the 2011 DVC at the monitor when the contribution from Mexico anthropogenic emissions is removed. When the ozone contribution from Mexico anthropogenic emissions is subtracted, the Desert View 2011 DVC drops from 71 ppb, which exceeds the 70 ppb NAAQS, to 64.8 ppb, which attains the 70 ppb NAAQS. Table 3-13 indicates that but for the contribution of emissions from Mexico, the Desert View monitor would have attained the 70 ppb NAAQS in 2011. The same is true for the UTEP monitor in El Paso; the UTEP monitor's 2011 design value drops from 71 ppb to 64.2 ppb when the contribution from Mexican anthropogenic emissions is removed.Table 3-13 indicates that monitors closer to the U.S.-Mexico border have a larger Mexico contribution (e.g., El Paso monitors) than monitors which are more distant from the border (Carlsbad, Deming).

Table 3-13. Ozone contribution to 2011 DVs from Mexico anthropogenic emissions (Mexico Anthro Contribution) for all monitors in the 4-km grid. Results are shown for the sensitivity test (Task 11) and source apportionment (Task 12) analyses. Orange shading of the 2011 DVC indicates that the DVC exceeds the 2015 ozone NAAQS of 70 ppb. Yellow shading indicates 70 ppb < DVC < 71 ppb.

Site ID	Observed	CAMx Source Apportionment		CAMx Sensitivity Test		County	Site Name
	2011 DVC	2011 DV NoMexAnthro	Mexico Anthro Contribution	2011 DV NoMexAnthro	Mexico Anthro Contribution		
350130008	64.7	59.4	5.3	59.6	5.1	Dona Ana	LA UNION
350130017	66.7	60.4	6.3	60.4	6.3	Dona Ana	SUNLAND PARK
350130020	67.7	63.4	4.3	63.3	4.4	Dona Ana	CHAPARRAL
350130021	71	64.8	6.2	64.8	6.2	Dona Ana	DESERT VIEW
350130022	70.3	65.7	4.6	65.2	5.1	Dona Ana	SANTA TERESA
350130023	64.3	61.8	2.5	60.6	3.7	Dona Ana	750 N.SOLANO DRIVE
350151005	70.3	68.2	2.1	65.2	5.1	Eddy	CARLSBAD
350171003	65	63.7	1.3	62.2	2.8	Grant	HURLEY
350290003	63	61.1	1.9	59.2	3.8	Luna	DEMING
481410029	65	59.3	5.7	59.5	5.5	El Paso	Ivanhoe
481410037	71	64.2	6.8	64.5	6.5	El Paso	UTEP
481410044	69	62.6	6.4	63.1	5.9	El Paso	Chamizal
481410055	66.3	59.9	6.4	60.4	5.9	El Paso	Ascarate Park
481410057	66	60.3	5.7	60.7	5.3	El Paso	Socorro Hueco
481410058	69.3	64	5.3	64.4	4.9	El Paso	Skyline Park

We compared the sensitivity and source apportionment results to see whether they are consistent in their estimates of the importance of the ozone contribution from Mexico. The Mexico Anthro Contribution is similar in magnitude in the source apportionment and the sensitivity testing results (Table 3-14).

Table 3-14. Contribution of Mexico emissions to 2011 DVs for Doña Ana County monitors (4-km grid results): comparison of CAMx zero out sensitivity test (Task 11) and source apportionment (Task 12) results.

	Average (ppb)	Maximum (ppb)	Minimum (ppb)
Sensitivity Test Results	5.1	6.3	3.7
Source Apportionment Results	4.9	6.3	2.5

The source apportionment and sensitivity test results are consistent in showing that Mexico emissions had a significant impact on Doña Ana County design values in 2011 and that the Desert View monitor would have attained the 70 ppb NAAQS but for the contribution of anthropogenic emissions from Mexico. The source apportionment results and the sensitivity test show similar maximum and average impacts and the sensitivity test has a higher minimum impact.

3.12.1.3 Contribution of Fire Emissions to Doña Ana County Ozone

In 2011, the southwestern U.S. had an active fire season, with a number of large fires occurring in the SNMOS 12-km domain. The CAMx modeling of 2011 showed intermittent large impacts from fire emissions. For example, on June 5, 2011, there were several large wildfires burning within the 12-km domain. In the left panel of Figure 3-43, there are areas of $PM_{2.5}$ emissions at the location of these fires, which were also apparent in satellite imagery for June 5 (Figure 3-13). The right hand panel of Figure 3-43 shows CAMx modeled 1-hour ozone for 0Z on June 5, and the plumes from the wildfire emissions in the left panel are apparent as regions of enhanced ozone. The Wallow Fire plume has modeled 1-hour ozone values exceeding 160 ppb, while ozone outside the plume ranges from ~50-70 ppb. The Wallow Fire plume passes over several ozone monitors in northern New Mexico and southern Colorado, but the monitors do not show enhanced ozone concentrations comparable to the modeled plume. The model overestimates ground level ozone impacts from the Wallow Fire plume as well as the other fires in the 12-km domain on June 5. This overestimate of fire plume ozone impacts was typical of SNMOS CAMx model performance.

The modeled ozone impacts of fires depend on accurate characterization of fire emissions and simulation of the transport, chemical transformation, and fate of emitted ozone precursors and the ozone that forms from them. Fire emissions contain uncertainties in both their magnitude and their chemical composition (e.g,. Wiedinmyer et al. 2011; Jaffe and Wigder, 2012). The chemical composition of the emissions plays a role in the photochemistry of the resulting fire plume and therefore the resulting ozone impact.

The chemistry of ozone production in fire plumes is an area of active research. Measurement campaigns in which aircraft made transects through fire plumes and measured ozone and other trace gases have produced a range of results regarding the magnitude of ozone production in fire plumes (e.g., Bertschi et al., 2004; Alvarado et al; 2010). Jaffe and Wigder (2012) note that there is not a clear relationship between the quantity of ozone precursor emissions released into the atmosphere and the ozone produced in the plume downwind of the fire. Wigder et al. (2013) hypothesize that plume rise and the altitude of subsequent plume transport can affect ozone production in the plume because temperatures are lower at higher altitudes. The interaction of fire plumes with anthropogenic emissions is not well understood. Singh et al. (2012) and Wigder et al. (2013) found enhanced ozone in fire plumes that mixed with air containing urban emissions. The presence of aerosols (smoke) in the fire plume can reduce the amount of sunlight available to initiate photochemistry, inhibiting ozone formation (e.g. Parrington et al., 2013).

Finally, in order to simulate the transport of ozone and precursors away from a fire, the meteorological model must successfully reproduce the true wind field and accurately represent vertical transport of emitted and secondary pollutants. Even if the photochemical accurately represents the amount of ozone and precursors in the fire plume, there will be bias in the modeled ground level ozone if transport and vertical mixing are not accurately simulated. In the SNMOS modeling, for example, it is possible that the modeled Wallow Fire plume affected the surface while in the real world, the fire plume passed over the monitor aloft without mixing down to the surface.

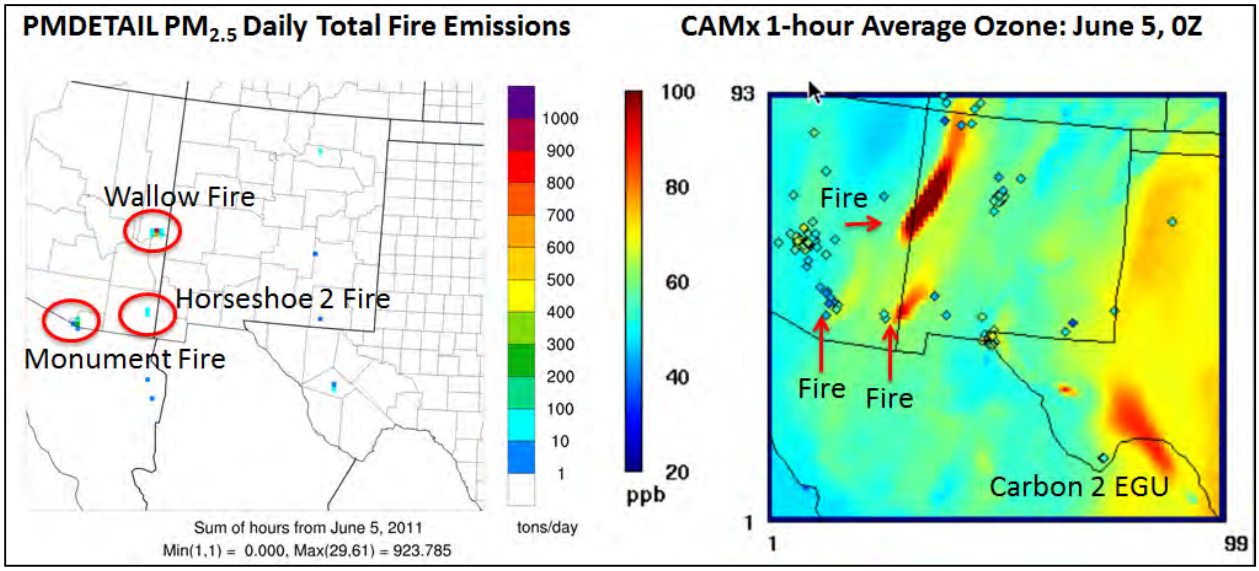


Figure 3-43. Fire emission ozone impacts on June 5, 2011. Left panel: PMDETAIL $PM_{2.5}$ emissions indicating the location of fires on June 5. Larger fires within the 12-km domain are circled in red. Right panel: CAMx 1-hour average modeled ozone for 0Z on June 5. Monitor locations are indicted by diamonds and the observed value for 0Z June 5 is indicated by the color within the diamond. The location of large fires and the ozone plume from the Carbon II Power Plant in Mexico are shown.

In the SNMOS source apportionment modeling, we treated fires separately from the rest of the natural emission inventory so their impacts could be tracked. We used source apportionment to quantify the effect of fire emissions on Doña Ana DVs in order to assess the uncertainty introduced into the design value analysis by the fire emissions modeling. Table 3-15 shows the future year 2025 design values (DVF) with and without the contribution from fire emissions for all monitors in the 4-km domain. The difference between these two DVFs is the impact of fire emissions on each monitor's design value. The impact of fire emissions on the 4-km grid monitor 2025 DVFs was < |0.5| ppb for all monitors. This indicates that fire emissions did not have a substantial effect on the design value results for monitors in the 4-km grid.

Table 3-15. Impact of fire emissions on 4-km grid monitor 2025 design value results.

Site ID	State	County	2011 DVC (ppb)	2025 Design Values (ppb)		Fire Impact on 2025 DVF (ppb)	Site Name
				DVF (without fires)	DVF (with fires)		
350130008	New Mexico	Dona Ana	64.7	58.3	58.3	0.006	LA UNION
350130017	New Mexico	Dona Ana	66.7	61.4	61.3	-0.007	SUNLAND PARK
350130020	New Mexico	Dona Ana	67.7	61.3	60.8	-0.439	CHAPARRAL
350130021	New Mexico	Dona Ana	71.0	65.1	65.1	-0.007	DESERT VIEW
350130022	New Mexico	Dona Ana	70.3	63.8	63.8	-0.007	SANTA TERESA
350130023	New Mexico	Dona Ana	64.3	58.6	58.7	0.108	SOLANO
350151005	New Mexico	Eddy	70.3	67.6	67.9	0.295	CARLSBAD
350171003	New Mexico	Grant	65.0	62.0	62.0	0.013	HURLEY
350290003	New Mexico	Luna	63.0	58.6	58.6	-0.038	DEMING
481410029	Texas	El Paso	65.0	58.4	58.4	0.006	Ivanhoe
481410037	Texas	El Paso	71.0	65.3	65.2	-0.163	UTEP
481410044	Texas	El Paso	69.0	62.5	62.7	0.158	Chamizal
481410055	Texas	El Paso	66.3	60.1	60.1	0.007	Ascarate Park
481410057	Texas	El Paso	58.7	59.8	59.8	0.000	Socorro Hueco
481410058	Texas	El Paso	69.3	62.1	61.7	-0.380	Skyline Park

The MATS design value analysis presented in Table 3-15 applies only to the monitoring sites within the 4-km domain. To determine whether fire emissions influenced ozone design values away from the monitoring sites, we performed a MATS Unmonitored Area Analysis (UAA). The UAA was performed by interpolating DVCs from monitoring sites to each grid cell in the modeling domain using the Voronoi Neighbor Averaging interpolation technique. The modeled ozone gradients are taken into account in the interpolation in order to reflect modeled higher and lower ozone areas in the interpolated DVC field. An unmonitored area analysis was performed that interpolated the 2011 DVCs across the modeling domain and performed ozone projections using the modeling results within each grid cell only. Figure 3-44 shows the results of the UAA for 2011 with the impacts of fire emissions included (left panel) and excluded (right panel). The difference of these two fields is shown in Figure 3-45. Figure 3-45 shows that larger fire impacts on design values (> 5 ppb) occurred away from monitoring sites within the 4-km domain downwind of 2011 fires. For example, the plume from the Horseshoe 2 Fire (Figure 3-43) in eastern Arizona extends into southwestern New Mexico and the ozone impacts of a number of other fires are apparent within the 4-km grid. Impacts away from the monitors exceeded 5 ppb in some of these plumes. Given the high bias seen in the CAMx simulated ozone downwind of fires in the 2011 model performance evaluation, these impacts may be overestimated and must be considered highly uncertain. However, because of the location of the fires in 2011 and wind patterns that caused plumes to miss the monitors in the 4-km domain, this uncertainty does not affect the design value results at the monitors. Results for the future year 2025 modeling are shown in Figure 3-46 and Figure 3-47and are similar to those of 2011.

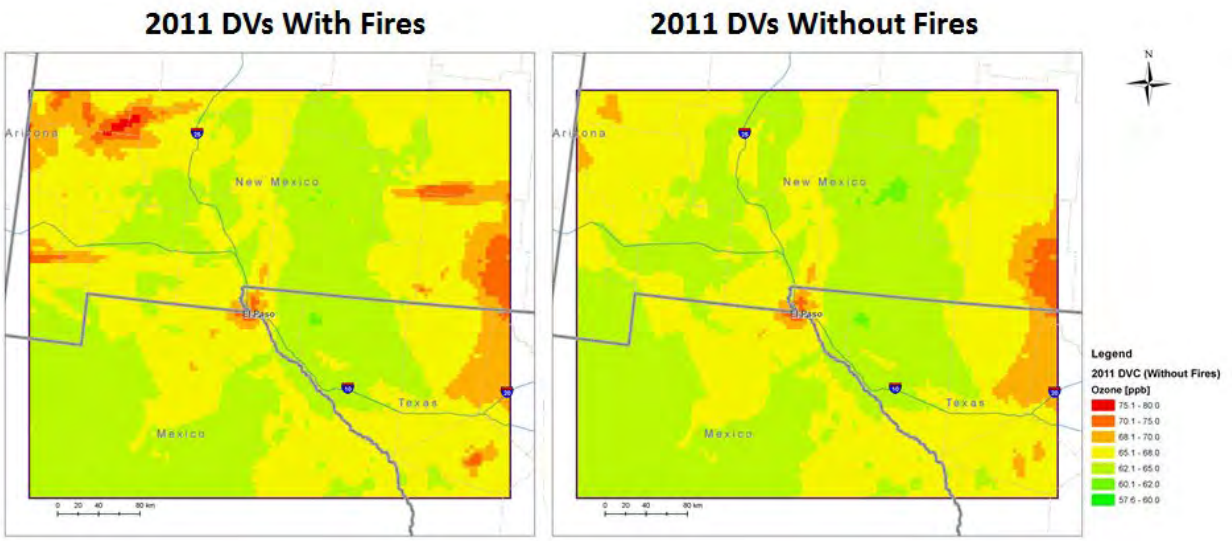


Figure 3-44. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis.

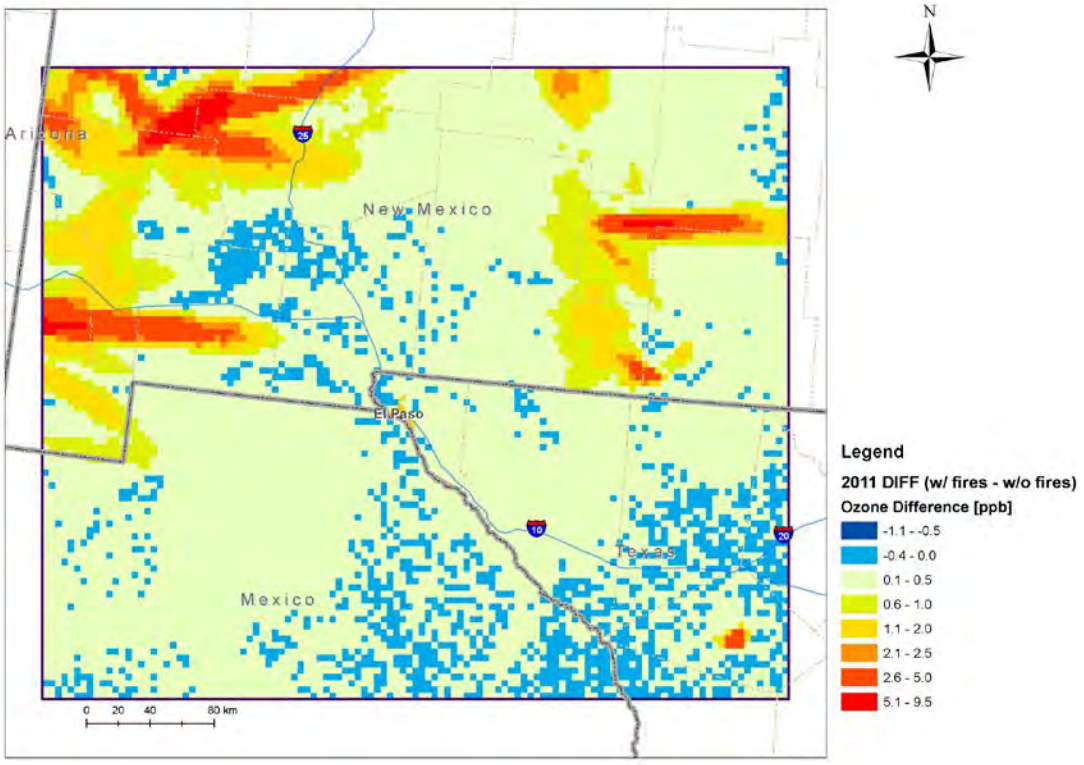


Figure 3-45. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis: DVC(with fire contribution) - DVC(without fire contribution).

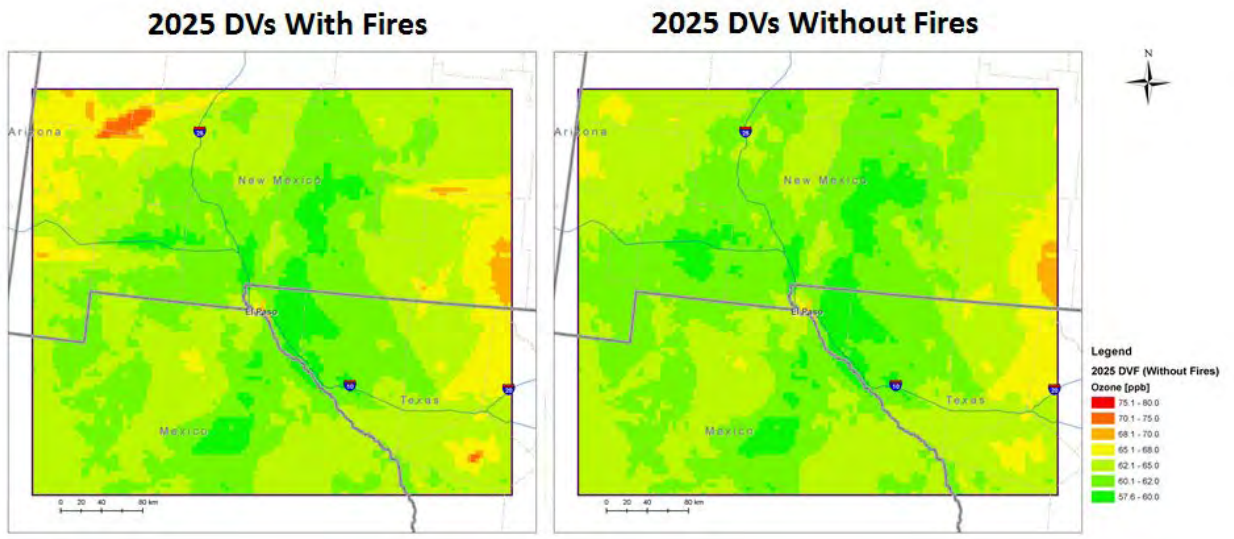


Figure 3-46. Impact of fire emissions on 4-km grid design value results: 2025 MATS Unmonitored Area Analysis.

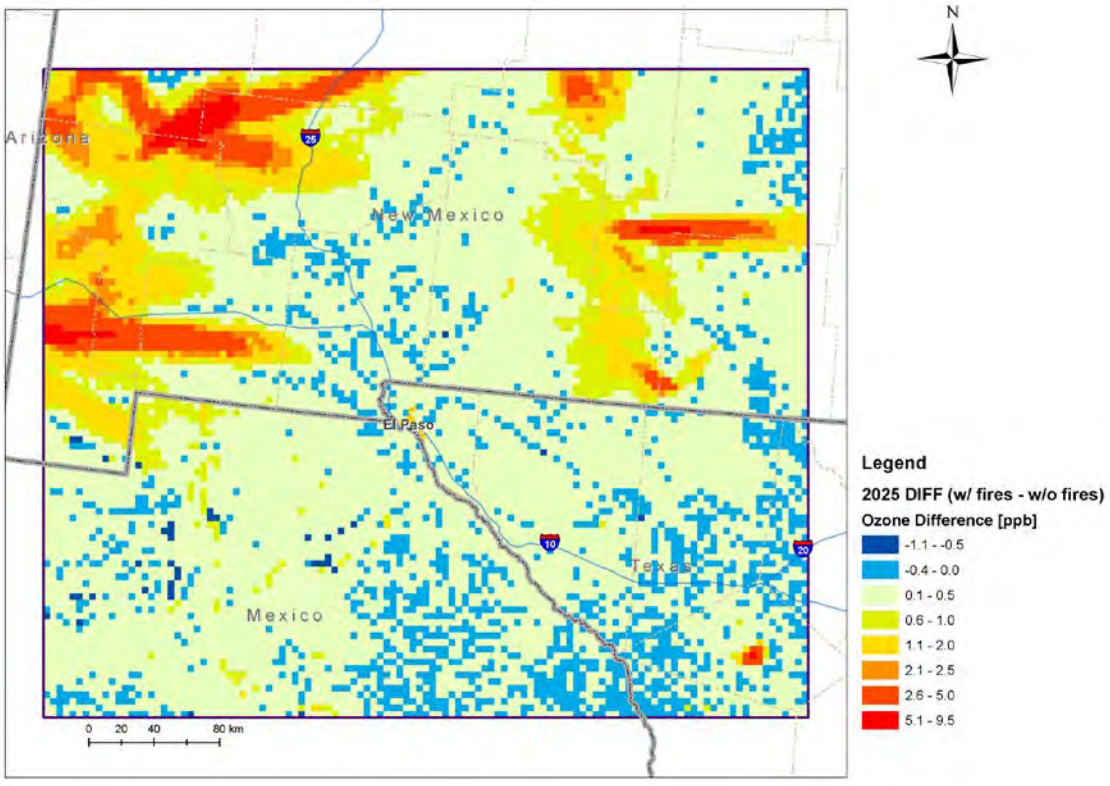


Figure 3-47. Impact of fire emissions on 4-km grid design value results: 2011 MATS Unmonitored Area Analysis: DVF(with fire contribution) - DVF(without fire contribution).

3.12.1.4 Source Apportionment Visualization Tools Overview

The SNMOS modeling results were loaded into a web-based Source Apportionment Visualization Tool (SA Vis Tool) on the Intermountain West Data Warehouse website (**http://views.cira.colostate.edu/tsdw/**). Documentation of the source apportionment results may be found in the SNMOS wiki on the IWDW website[11] (Figure 3-48).

Figure 3-48. IWDW web page.

The SNMOS ozone design value source apportionment modeling analysis is available in an interactive Excel spreadsheet that can be accessed through a link in the SNMOS wiki page. To display the Source Group contributions to 2011 and 2025 MDA8 ozone concentrations, the user can access the SNMOS 2011 and 2025 SA Vis Tool through the SNMOS wiki. The SA Vis Tools generate pie charts of 2011 and 2025 ozone contributions by Source Region, Source Category or both (i.e., Source Groups) for monitoring sites within the SNMOS 4-km modeling domain. The SA Vis Tools can be used to display base (2011) and future (2025) year MDA8 SA results. The SA Vis Tools provide source apportionment results as well as information on CAMx model performance by monitor and by date.

[11] http://vibe.cira.colostate.edu/wiki/wiki/9131/southern-new-mexico-ozone-study-snmos-2011-and-2025-ozone-source-apportionm

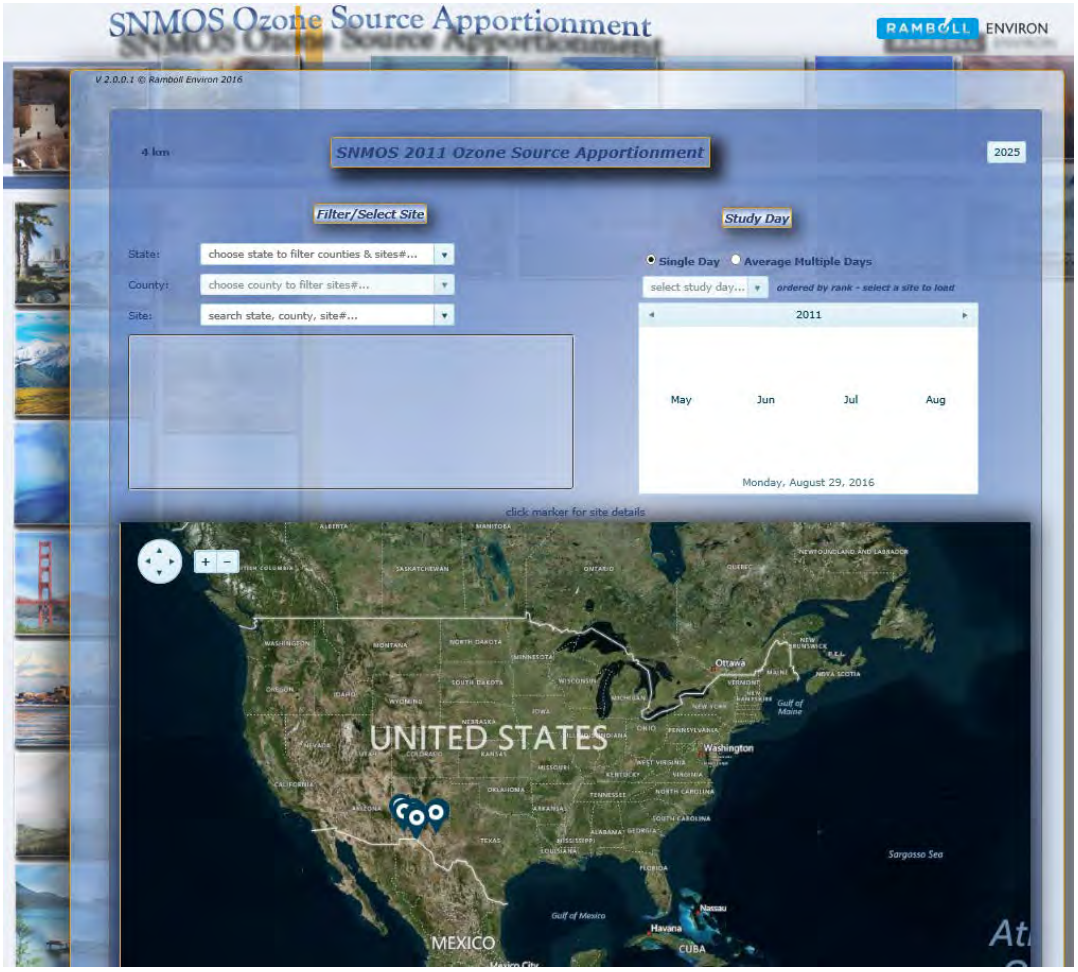


Figure 3-49. SNMOS SA Vis Tools website.

3.12.2 Significant Findings

Transport plays an important role in determining ozone levels in Doña Ana County. For Doña Ana County monitors, the 12-km grid boundary conditions were the largest contributor of ozone; this is a typical result for a regional modeling study. The contribution of New Mexico emissions to Doña Ana County monitor design values is smaller than the contributions of Texas and Mexico for all Doña Ana monitors except Solano, which has a large on-road mobile contribution from New Mexico on-road mobile emissions.

The source apportionment results indicate that the contribution of Mexico anthropogenic emissions to Doña Ana monitor 2011 design values ranges from 2.5 – 6.3 ppb with an average of 4.9 ppb. The source apportionment results confirm that all Doña Ana County ozone monitors, including Desert View, would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico.The source apportionment (Task 12) and Sensitivity Test (Task 11) model analyses are consistent in showing this result.

The emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2011 were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions from Mexico. In 2025, the emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.

Of all New Mexico anthropogenic emissions sources, on-road mobile emissions make the largest contribution to design values at Doña Ana monitors. New Mexico anthropogenic emission sources that contributed the most ozone to New Mexico monitors in the SNMOS 4-km grid were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants. Oil and gas emissions made the largest New Mexico anthropogenic contribution at the Carlsbad monitor due to its closer proximity to the Permian Basin. The impact of oil and gas sources increases in 2025 due to projected growth in Permian Basin emissions.

Fire emissions had a small (≤ |0.5| ppb) effect on 2011 and 2025 DVs at Doña Ana County monitors. These impacts are too small to affect the attainment status results for 2011 and 2025. The small magnitude of the impacts is due to location of monitors relative to 2011 fires and 2011 winds. Fire emissions had a larger effect on 2011 and 2025 DVs at grid cells elsewhere in the 4-km domain with the UAA showing design value impacts exceeding 5 ppb downwind of the fire locations.

3.12.3 Milestones and Deliverables

- Carry out SNMOS ozone source apportionment CAMx modeling of 2011 and 2025 (Completed July 18, 2016)
- PowerPoint presentation on ozone source apportionment modeling (Completed September 8, 2016)
- Wiki and SA Vis Tools Provide interactive spreadsheet source apportionment results on ozone DVs(Completed September 8, 2016)
- Provide SA Visualization Tool for 2011 and 2025 ozone contributions to MDA8 ozone at monitors (hosted on IWDW and available through wiki) (Completed September 8, 2016)

3.13 Task 13: Technical Support Document

3.13.1 Task Summary

A Technical Support Document that (TSD) that summarizes the SNMOS (this document) was prepared and submitted to the NMED.

3.13.2 Significant Findings

UNC-IE and Ramboll Environ prepared a draft TSD documenting Tasks 1-12 and submitted the draft TSD for review. The draft TSD will be updated to reflect comments received and a Response to Comments (RtC) document will be prepared and submitted along with the final AQTSD.

3.13.3 Milestones and Deliverables

- Draft Technical Support Document (TSD) (completed September 30, 2016)
- Final TSD (to completed by November 18, 2016)
- Response to Comments (RtC) document for NMED (to completed by November 18, 2016)
- Modeling data, RtC document, and final TSD posted on WAQS data warehouse (to completed by November 18, 2016)

4.0 SUMMARY OF FINDINGS AND RECOMMENDATIONS

In this section, we summarize the main findings of the SNMOS. We discuss the major sources of uncertainty noted during the study and provide recommendations for future work to reduce these uncertainties.

4.1 SNMOS Major Findings

- 2025 future year design value projections indicate that all Doña Ana County ozone monitors are expected to attain the 70 ppb ozone NAAQS in 2025.
  - The finding of attainment was not sensitive to the method used in the MATS design value projection procedure, the model's bias in simulating ozone, or to the modeling of fire emissions
  - The finding of attainment was robust under a sensitivity test in which projected reductions in on-road mobile emissions by 2025 were smaller than EPA MOVES model estimates
- The projected decreases in Doña Ana County ozone design values between 2011 and 2025 are mainly driven by projected reductions in on-road mobile source emissions.
- All Doña Ana County ozone monitors would have attained the 70 ppb ozone NAAQS in 2011 but for the ozone contribution due to anthropogenic emissions from Mexico.
- Emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2011 were: (1) on-road mobile emissions from Texas, Mexico and New Mexico; (2) power plant emissions from Mexico; and (3) natural emissions from Mexico.
- Emissions sources within the 12/4 km modeling domains that contributed the most ozone to Doña Ana County ozone monitors in 2025 were: (1) on-road mobile emissions from Texas and Mexico; (2) power plant non-power plant point source emissions from Mexico; and (3) natural emissions from Mexico.
- Ozone transport plays an important role in determining ozone levels in Doña Ana County. For Doña Ana County monitors, the 12-km grid boundary conditions were the largest contributor of ozone; this is a typical result for a regional modeling study. For all Doña Ana County monitors except Solano, the ozone contribution from Texas and Mexico was larger than that of New Mexico.
- New Mexico anthropogenic emission sources that contributed the most ozone to New Mexico monitors in the SNMOS 4-km grid were: (1) on-road mobile; (2) offroad mobile; (3) oil and gas; and (4) power plants.
- Oil and gas emissions are the largest New Mexico anthropogenic contribution at the Carlsbad monitor due to its closer proximity to the Permian Basin. The impact of oil and gas sources increases in 2025 due to projected growth in Permian Basin emissions.

4.2 Recommendations for Future Work

Based on our evaluation of model performance and the major uncertainties in the SNMOS, we make the following recommendations for future work.

4.2.1 WRF Meteorological Modeling

WRF meteorological model performance is a source of uncertainty in the SNMOS. While WRF performance was improved using the Multiscale (grid-aware) Kain-Fritsch cumulative cloud scheme, the model was still unable to consistently simulate precipitation, temperature and wind patterns related to the North American monsoon. This likely degraded the CAMx model's simulation of ozone in southern New Mexico.

Recommendation: Perform additional sensitivity testing to refine the WRF configuration with the aim of improving model performance in simulating temperatures, winds and precipitation improves during the months when the North American Monsoon is active.

4.2.2 Natural Emissions

Modeling of natural emissions (biogenics, fire and lightning) is an active area of scientific research, and the SNMOS emission inventories should be considered to have considerable uncertainty associated with them. In order to understand and possibly reduce this uncertainty, additional study of these emissions and their effect on Doña Ana County ozone should be undertaken.

In the MEGAN v2.1 biogenic inventory, there is a discontinuity in isoprene and monoterpene emissions at the U.S.-Mexico border with emissions larger in Mexico than in the U.S. for environments that appear from Google Earth imagery to have comparable vegetation cover.

Recommendation: Further investigation of differences in U.S. and Mexico MEGAN inputs should be undertaken to understand their origin and to ensure that the most accurate and consistent input data available are used as well as using the most up-to-date calculation methods to develop emissions on both sides of the border.

While modeling of fire emissions did not have a substantial effect on the design value analysis at Doña Ana County monitors, fires had impacts exceeding 5 ppb on design values for grid cells elsewhere in the modeling domain. In an episode in which fires are in different locations and wind patterns are different, fire emissions may have a large influence on Doña Ana County monitors and may introduce significant uncertainty, complicating air quality planning efforts.

Recommendation: Perform a detailed analysis of the fire emissions, their modeling, and the resulting CAMx air quality model simulation of the fire plume in order to better understand the reasons for CAMx overestimates of ozone at ground level monitoring sites during 2011.

LNOx emissions are intermittent, but can contribute to regional background ozone. In the SNMOS model performance evaluation, CAMx had a high bias during July and August and better

performance earlier in the episode, before the onset of the monsoon, when intense convection and associated lightning occur across the region.

Recommendation: Investigate the effect of LNOx emissions on modeled ozone by zeroing out the SNMOS LNOx emissions and comparing the resulting ozone with the 2011 model base case. If there is a significant effect on model performance (such as a reduction in model high bias in July and August), efforts should be made to improve the treatment of LNOx emissions in the Southern New Mexico ozone modeling. We recommend a review of current parameterizations for specifying LNOx emissions to determine whether an alternate approach would be beneficial and whether satellite data can be used to constrain LNOx emissions over Southern New Mexico and the surrounding region, including Mexico.

4.2.3 Anthropogenic Emissions

The SNMOS used the best available anthropogenic emission inventories for the region. However, uncertainties in these inventories may affect the SNMOS modeling results as well as future air quality planning efforts for Doña Ana County.

Much of the reduction in Doña Ana County design values between 2011 and 2025 is driven by reductions in on-road mobile emissions. Therefore, the projection of attainment of the NAAQS by 2025 for Doña Ana monitors depends on the accuracy of these estimates of on-road mobile emissions. In the SNMOS, we used EPA's NEI on-road mobile emission estimates, which were calculated using the MOVES model. Given the importance of on-road mobile emissions for air quality planning in Doña Ana County, we recommend further evaluation of the inventory.

Recommendation: Review the MOVES inputs and model configuration for the emissions modeling in the 2011 NEI platform with the goal of evaluating the likelihood of the modeled reductions in regional on-road mobile emissions between 2011 and 2025.

Anthropogenic emissions from Mexico are a source of uncertainty in the SNMOS modeling. The data used in the SNMOS were determined to be the most complete and accurate available information, but are based on 2008 data.

Recommendation: We recommend that the NMED continue to work with air quality planning partners in Mexico to ensure that the most complete and recent available emissions data available for Mexico are integrated into modeling efforts for Southern New Mexico.

New Mexico and Texas Counties within the Permian Basin showed increases in oil and gas emissions between 2011 and 2025, and the increased emissions were reflected in the increased ozone contribution from oil and gas sources in 2025. Oil and gas emissions in these counties were among the few U.S. source groups to show an increase in projected emissions in 2025 relative to 2011. Permian Basin emissions are based on 2014 AEO activity projections. Because the oil and gas industry undergoes rapid changes in response to fluctuations in pricing and domestic and foreign production, we recommend that the Permian Basin projections be revisited before any future modeling effort is carried out.

Recommendation: Update activity projections for the Permian Basin in advance of future ozone modeling efforts.

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Yarwood, G., H. Gookyoung, W.P.L. Carter, G.Z. Whitten, 2012. Environmental Chamber Experiments to Evaluate NOx Sinks and Recycling in Atmospheric Chemical Mechanisms. Final Report prepared for the Texas Air Quality Research Program, University of Texas, Austin, Texas (AQRP Project 10-042, 2) February, 2012. http://aqrp.ceer.utexas.edu/projectinfo%5C10-042%5C10-042%20Final%20Report.pdf.

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NMED
EXHIBIT 8

KERWIN C. SINGLETON

EDUCATION

Bachelor of Science, Chemical Engineering 1982 University of Missouri - Columbia

EXPERIENCE

New Mexico Environment Department Santa Fe, New Mexico August 2004 - Present

Planning Section Chief – Air Quality Bureau June 2018 – Present

The Planning Section of the Air Quality Bureau includes the Control Strategies, Dispersion Modeling, Emissions Inventory, and Small Business Assistance Programs. The control strategies section is responsible for preparing state implementation plan, policies, and regulations for air quality. The dispersion modeling and emission inventory section ensures that all air dispersion modeling analyses submitted to our agency are accurate and complete, assists major sources with the submittal of annual emissions inventories, and performs a quality control check of submitted data prior to certification and submittal to the US EPA. The Small Business Assistance Program assists small businesses in meeting air quality regulatory requirements.

Manager, Control Strategies - Air Quality Bureau July 2008 – June 2018

As the Manager of Control Strategies, managed a staff of environmental analysts for the development of air quality plans and regulations for the State of New Mexico, including providing guidance and assistance to staff to ensure that plans and regulations are successfully adopted by the Environmental Improvement Board; providing technical, fiscal, performance and administrative analysis on draft bills during the legislative session; and representing the Department at stakeholder meetings on issues related to air quality plans and rule development.

Environmental Scientist & Specialist – Advanced August 2004 - July 2008

As a permit writer, processed all assigned air quality permit applications (New Source Review, Prevention of Significant Deterioration, and Title V) to final action before or by regulatory deadlines in accordance with approved Department policies and standards and performed special projects to achieve the enhancement of the Bureau's goals.

Concept Technical Group Menomonee Falls, Wisconsin March 2003 - July 2004
Engineer

As a staff engineer, provided project-specific environmental support to the Johnson Controls Battery Group manufacturing sites and group headquarters, including preparation of air quality construction permit applications with detailed emissions calculations and supporting documentation; annual emission inventories; Toxic Release Inventory Form R reports; updating storm water management and contingency plans; and development of standardized environmental procedures.

RMT, Inc. Chicago, Illinois December 1994 - January 2003
Senior Project Manager/Operations Manager

As a Senior Project Manager, guided clients through the complexities of air pollution permitting, reporting and compliance in multiple states to minimize their regulatory burden and obtain permits according to schedule. As the Chicago Operations Manager, managed three staff engineers, identified and developing project opportunities for engineers to meet or exceed utilization goals, and provided training and workload leveling.

Johnson Controls Battery Group, Inc. Milwaukee, Wisconsin March 1992 - December 1994
Environmental Engineer

As an Environmental Engineer, maintained air quality compliance at thirteen lead-acid battery plants and successfully obtained air construction permits to support all new equipment installations and plant modifications.

Olin Corp. – Brass Group/Winchester Operations East Alton, Illinois June 1989 - March 1992
Senior Environmental Engineer
As a Senior Environmental Engineer, prepared and submitted all air pollution permit applications and annual emissions reports for the casting plant, brass mill and Winchester ammunition operations. Duties also included the development and implementation of an obsolete chemical identification project to minimize future liabilities; the investigation and categorization of the use of hazardous solvents and implementation of non-hazardous alternatives that resulted in the elimination of several waste streams and a reduction of waste management costs; and providing comprehensive environmental permitting and compliance assistance for satellite operations in Missouri and Ohio.

Missouri Department of Natural Resources St. Louis, MO July 1984 - June 1989
Environmental Engineer I/II
As an Environmental Engineer, conducted inspections of hazardous waste generators and treatment/storage/disposal Facilities in the St. Louis region for compliance with state and federal regulations, and represented the Department at industrial association meetings and seminars.

NMED
EXHIBIT 9

Ted Schooley
33 Pan de Vida
Santa Fe, NM 87508

505-984-8282 home
505-660-2349 cell
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Resume

Summary of Qualifications

- Registered Professional Engineer, State of Louisiana (Mechanical)
- 31 years successful experience in small and medium business management
- Experience in HR management including recruitment, development and retention of personnel
- Exceptional skills in engineering, business management, customer service and problem solving
- Computer Skills: Solid knowledge of Window software applications, various special purpose software programs (HTML web site design, 3D CAD, desktop publishing, graphics design, video editing, etc.), as well as customization of proprietary software

Management Flexibility and Accomplishments:

- **Entrepreneurial Skills**: Conceptualized, created, and managed **CompServCo**, a successful software development, marketing, and fulfillment company that produced a product MacCAD that won a "Top 100 Macintosh Products" award. CompServCo also won fulfillment contracts (packaging design, packaging, and shipping) for several other engineering software products. These contracts also included co-marketing efforts such as multi-product display ads in national magazines, technical support, packaging and national trade shows.
- **Marketing**: After a few years, CompServCo won the exclusive North American distributorship of a proprietary 3-D CAD kitchen design software product, Planit. To fulfill this contract, CompServCo spun off another software distributing company, **Planit USA**. In return for a lucrative distributing contract, CompServCo though Planit USA, capitalized the marketing and database development of Planit in the USA, and brought this new product from being unknown in this vertical market to a market leader within a few years. Sold the company in 1997.
- **Contract Negotiations**: 11 years experience in upper management level contract negotiations with major manufacturing firms in the United States, Canada, and Europe (including: Masco, Woodmode, Aristocraft, Craftmaid, and Merillat).
- **Sales & Marketing**: Over 17 years experience in marketing, sales, and customer service. Responsible for conceptualizing and coordinating a national marketing campaigns for several software products, including personally creating display ads, internet advertising (web site & e-mail campaigns), national trade shows (booth design and marketing focus), and negotiating co-marketing efforts. As VP Sale & Marketing, I grew a commercial print shop to win American Printing Magazine's "Top 50 Fastest Growing Printing Companies" award. I also put systems in place to diversify the sales base and move the company to web-based publishing.
- **Software Development**: Managed software programmers developing various products for CompServCo: MacCAD (3-D graphic engineering templates), Riddler (teaching software that incorporated text-graphics-sounds in a gaming style user interface), My Family Tree (genealogy software that mapped and produced a family book with text and photos), Planit Cut List (produced a cut list of panel parts and sizes from a list of kitchen cabinets).
- **Engineering: Space Shuttle External Tank**: As a facilities design engineer for Martin Marietta, under contract to NASA, building the External Tank for the Space Shuttle I designed and managed construction of a dust collection system for Thermal Protection System (TPS) machining facility, re-designed a faulty lifting hook and insertion mechanism that inserted an

umbrella-like washing probe into the interior of the liquid hydrogen portion of the space shuttle external tank, designed and oversaw the TPS application on an emergency basis on the dome of the LOX (liquid oxygen) tank of the External Tank used in the first Space Shuttle flight.

- **Engineering & Manufacturing Management**: Starting as an engineer at Dixie Manufacturing, I co-designed pneumatic instrumentation that sensed emergency conditions at the oil wellhead and shut down all operations using pneumatics only (no electricity or sparks to ignite fuel). After being promoted to General Manager, I was responsible for all aspects of production and marketing of the company's products. In my youth, I started a jewelry manufacturing business that successfully mass produced and marketed silver and gold jewelry before returning to school to obtain my engineering degree.
- **Environmental Regulatory Management**: Almost 12 years experience managing permitting programs (New Source Review, Technical Services Units) of the Air Quality Bureau, New Mexico Environment Department. I am now the Acting Permit Programs Manager for the Air Quality Bureau. In this capacity I am responsible for overseeing all aspects of the Air Permitting Programs for all applicable sources of air pollution in the State of New Mexico.

Work History

• 6/14 – Present	NMED, AQB Santa Fe, NM	Permit Programs Section Chief
• 6/01 – 6/14	NMED, AQB Santa Fe, NM	Minor Source/Tech Serv Manager
• 5/00 – 5/01	Pre-Paid Legal, Inc. Santa Fe, NM	Independent Associate Executive Director
• 6/97 – 5/00	TLC Printing & Copying, Inc Metairie, LA	VP Sales & Marketing
• 1/97 – 6/97	Sabbatical	USA, Europe, Asia
• 5/86 – 1/97	Planit USA Slidell, LA	Owner
• 7/84 – 1/97	CompServCo Slidell, LA	Owner
• 1/82 – 7/84	Dixie Manufacturing, Inc. Harvey, LA	General Manager
• 2/79 – 1/82	Martin Marietta Aerospace, Corp. Metairie, LA	Facilities Design Engineer
• 8/77 – 1/79	LSU at New Orleans New Orleans, LA	Student, engineering
• 2/74 – 7/77	Abraxas Jewelry Manufacturing New Orleans, LA	Owner

Education, Certifications:	Professional Engineer, Louisiana	Mechanical Engineering
	LSU, New Orleans	BS. Mechanical Engineering
	University of Texas at El Paso	BS. Math, Physics

Interests: Gardening, reading, jewelry making (certified gemologist), writing, sailing, and hiking.

NMED
EXHIBIT 10

525 Camino de Los Marquez
Santa Fe, New Mexico

Angela R. W. Raso

(505)476-4345
Angela.Raso@state.nm.us

Education

Purdue University, West Lafayette, IN **December 2018**
Doctor of Philosophy, Analytical chemistry
Dissertation: "Halogen Photochemistry and Emissions from the Arctic Snowpack"
Advisor Dr. Paul B. Shepson, Dr. Kerri A. Pratt (University of Michigan)

Whitman College, Walla Walla, WA **May 2012**
Bachelor of Arts, Chemistry. Mathematics minor.
Undergraduate Thesis: "Determining the Presence of Dense Non-Aqueous Phase Liquid (DNAPL) Pollutants in River Sediments"
Advisor Dr. Frank M. Dunnivant

Professional Experience

Dispersion Modeler, New Mexico Environment Department, Air Quality Bureau **September 2018 - Present**
- Evaluate facilities emissions for compliance with Ambient Air Quality Standards using dispersion models
- Assist with data analysis and evaluation related to emissions inventories
- Assist with special projects involving modeling and emissions inventories including; preparation for photochemical modeling, modeling for state implementation plans

Research Experience

Research Assistant, Purdue University **Fall 2012 – August 2018**
- Lead field work based research on gas phase oxidation processes in the Arctic to understand a complex environmental system
- Collaboratively design and perform atmospheric chemistry experiments in the Arctic including eddy covariance flux measurements
- Full process responsibility for analytical measurements in a remote Arctic environment
- Coordinate logistical needs to ensure successful Arctic fieldwork in Barrow, Alaska
- Manage instrumentation including a homebuilt chemical ionization mass spectrometer, and an ion chromatography / liquid chromatography system
- Mentor and train students to safely and effectively use instrumentation
- Conduct zero- and one- dimensional photochemical modeling to understand and contextualize the importance of measurements

Visiting Research Assistant, University of Michigan **Fall & Winter 2015**
- Collaboratively planned for a spring 2016 field study in Barrow, Alaska

User, Environmental Molecular Sciences Laboratory, **October 2015**
Pacific Northwest National Laboratory
- Acquired first ever measurements of iodide in Arctic snow using ion chromatography coupled with inductively coupled plasma mass spectrometry (IC-ICPMS)

Undergraduate Research Assistant, Whitman College **Fall 2010 –Spring 2012**
- Conducted research on dense non-aqueous phase liquids in mixed stream-bed media for detection at highly polluted sites using gas chromatography – electron capture detection

Teaching Experience

General Chemistry Adjunct, Santa Fe Community College **Spring & Fall 2019**
- Instructed General Chemistry Laboratories

Analytical Chemistry TA, Purdue Chemistry Department **Fall 2013**
- Instructed laboratory sessions for upper division chemistry students in a major required course

- Wrote and graded exam questions and graded written lab reports, giving important feedback to students

Fundamental General Chemistry TA, Purdue Chemistry Department **Spring 2013**

- Instructed laboratory and recitation for students with no previous chemistry courses to give a gentle introduction to important laboratory and scientific skills

General Chemistry for Engineers TA, Purdue Chemistry Department **Fall 2012**

- Instructed laboratory and recitation sessions to introduce freshman engineers and scientists to college level science courses.

Chemistry Tutor, Whitman Chemistry Department **2010 -2012**

- Demonstrated concepts and problem solving techniques for students from general, organic and analytical chemistry classes in an open "drop in" environment using a variety of teaching methods

Organic Chemistry Laboratory Assistant, Whitman Chemistry Department **Fall 2011**

- Supported students in an organic chemistry laboratory to ensure safe, time effective, and comprehensive completion of experiments

Quantitative Analysis Lab. Assistant, Whitman Chemistry Department **Fall 2011**

- Supported students in a data rich laboratory to introduce analytical methods to chemistry majors
- Corrected spreadsheet style lab reports to give important feedback to students

Tutor, Whitman College Academic Resource Center **2010-2012**

- Tutored general chemistry, organic chemistry, calculus I, calculus II and differential equations to support student understanding and grades

Publications and Presentations

- "Active Molecular Iodine Photochemistry in the Arctic" December 11, 2017. Oral Presentation, American Geophysical Union Meeting. New Orleans, La
- "Surface fluxes and recycling of molecular halogens above the snowpack" December 11, 2017. Poster, American Geophysical Union Meeting. New Orleans, La
- Raso, A. R. W., K. D. Custard, N. W. May, D. J. Tanner, M. K. Newburn, L. Walker, R. Moor, L. G. Huey, M. L. Alexander, P. B. Shepson, K. A. Pratt "Active Molecular Iodine Photochemistry in the Arctic" *Proceedings of the National Academy of Sciences 114(38) 10053-10058*
- Custard, K. D., A. R. W. Raso, K. A. Pratt, R. M. Staebler, and P. B. Shepson (2017) "Molecular halogen production in and flux measurements from tundra snow" *ACS earth and space chem. 1(3), 142-151*
- Raso, A.R.W., B. Elstrott, and F. M. Dunnivant, (2012) Envirolab: Simulations of Laboratory experiments in environmental chemistry [Computer Program]
- Available at http://people.whitman.edu/~dunnivfm/software.html
- "Mass transport and recycling of molecular halogens near the snowpack surface in Barrow (Utqiaġvik), Alaska" December 12, 2016. American Geophysical Union Fall Meeting. San Francisco, Ca.
- "The impact of Molecular iodine photochemistry in the Arctic" December 17, 2014. Poster, American Geophysical Union Fall Meeting. San Francisco, Ca.
- "Determining the presence of dense non-aqueous phase liquid (DNAPL) pollutants in river sediments" March 26, 2012. Poster, National Spring Meeting of the American Chemical Society. San Diego, Ca.