



Technical Support Document (TSD): Preparation of Emissions Inventories for the 2019 North American Emissions Modeling Platform

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Technical Support Document (TSD) Preparation of Emissions Inventories for the 2019 North American
Emissions Modeling Platform

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

Authors:

Alison Eyth (EPA/OAR)

Jeff Vukovich (EPA/OAR)

Caroline Farkas (EPA/OAR)

Janice Godfrey (EPA/OAR)

Karl Seltzer (EPA/OAR)

TABLE OF CONTENTS

LIST OF TABLES.....	VII
LIST OF FIGURES.....	IX
LIST OF APPENDICES.....	X
ACRONYMS.....	XI
1 INTRODUCTION	14
2 EMISSIONS INVENTORIES AND APPROACHES.....	16
2.1 POINT SOURCES (PTEGU, PT_OILGAS, PTNONIPM, AIRPORTS)	20
2.1.1 EGU sector (<i>ptegu</i>)	22
2.1.2 Point source oil and gas sector (<i>pt_oilgas</i>).....	23
2.1.3 Non-IPM sector (<i>ptnonipm</i>)	26
2.1.4 Aircraft and ground support equipment (<i>airports</i>).....	25
2.2 NONPOINT SOURCES (AFDUST, FERTILIZER, LIVESTOCK, NP_OILGAS, RWC, NP_SOLVENTS, NONPT)	27
2.2.1 Area fugitive dust sector (<i>afdust</i>)	27
2.2.2 Agricultural Livestock (<i>livestock</i>)	34
2.2.3 Agricultural Fertilizer (<i>fertilizer</i>).....	35
2.2.4 Nonpoint Oil and Gas Sector (<i>np_oilgas</i>).....	38
2.2.5 Residential Wood Combustion (<i>rw</i>).....	39
2.2.6 Solvents (<i>np_solvents</i>)	40
2.2.7 Nonpoint (<i>nonpt</i>)	42
2.3 ONROAD MOBILE SOURCES (ONROAD)	43
2.3.1 Inventory Development using SMOKE-MOVES	44
2.3.2 Onroad Activity Data Development	46
2.3.3 MOVES Emission Factor Table Development	48
2.3.4 Onroad California Inventory Development (<i>onroad_ca</i>).....	51
2.4 NONROAD MOBILE SOURCES (CMV, RAIL, NONROAD)	52
2.4.1 Category 1, Category 2 Commercial Marine Vessels (<i>cmv_c1c2</i>).....	52
2.4.2 Category 3 Commercial Marine Vessels (<i>cmv_c3</i>)	57
2.4.3 Railway Locomotives (<i>rail</i>)	60
2.4.4 Nonroad Mobile Equipment (<i>nonroad</i>)	65
2.5 FIRES (PTFIRE-RX, PTFIRE-WILD, PTAGFIRE)	68
2.5.1 Wild and Prescribed Fires (<i>ptfire-rx</i> , <i>ptfire-wild</i>).....	68
2.5.2 Point source Agriculture Fires (<i>ptagfire</i>).....	74
2.6 BIOGENIC SOURCES (BEIS).....	76
2.7 SOURCES OUTSIDE OF THE UNITED STATES.....	77
2.7.1 Point Sources in Canada and Mexico (<i>othpt</i> , <i>canada_ag</i> , <i>canada_og2D</i>)	78
2.7.2 Fugitive Dust Sources in Canada (<i>othafdust</i> , <i>othptdust</i>)	78
2.7.3 Nonpoint and Nonroad Sources in Canada and Mexico (<i>othar</i>).....	79
2.7.4 Onroad Sources in Canada and Mexico (<i>onroad_can</i> , <i>onroad_mex</i>).....	79
2.7.5 Fires in Canada and Mexico (<i>ptfire_othna</i>).....	79
2.7.6 Ocean Chlorine, Ocean Sea Salt, and Volcanic Mercury	79
3 EMISSIONS MODELING	81
3.1 EMISSIONS MODELING OVERVIEW	81
3.2 CHEMICAL SPECIATION	84
3.2.1 VOC speciation	93
3.2.1.1 County specific profile combinations	96
3.2.1.2 Additional sector specific considerations for integrating HAP emissions from inventories into speciation	97
3.2.1.3 Oil and gas-related speciation profiles	99
3.2.1.4 Mobile source related VOC speciation profiles	100
3.2.2 PM speciation.....	105
3.2.2.1 Mobile source related PM2.5 speciation profiles	107
3.2.2.2 Diesel PM	108

3.2.3	<i>NO_x speciation</i>	108
3.2.4	<i>Creation of Sulfuric Acid Vapor (SULF)</i>	109
3.2.5	<i>Speciation of Metals and Mercury</i>	110
3.3	TEMPORAL ALLOCATION.....	112
3.3.1	<i>Use of FF10 format for finer than annual emissions</i>	113
3.3.2	<i>Temporal allocation for non-EGU sources (ptnonipm)</i>	114
3.3.3	<i>Electric Generating Utility temporal allocation (ptegu)</i>	114
3.3.4	<i>Airport Temporal allocation (airports)</i>	118
3.3.5	<i>Residential Wood Combustion Temporal allocation (rwc)</i>	121
3.3.6	<i>Agricultural Ammonia Temporal Profiles (livestock)</i>	125
3.3.7	<i>Oil and gas temporal allocation (np_oilgas)</i>	126
3.3.8	<i>Onroad mobile temporal allocation (onroad)</i>	126
3.3.9	<i>Nonroad mobile temporal allocation (nonroad)</i>	131
3.3.10	<i>Additional sector specific details (afdust, beis, cmv, rail, nonpt, ptnonipm, ptfire)</i>	132
3.4	SPATIAL ALLOCATION.....	134
3.4.1	<i>Spatial Surrogates for U.S. emissions</i>	135
3.4.2	<i>Allocation method for airport-related sources in the U.S.</i>	140
3.4.3	<i>Surrogates for Canada and Mexico emission inventories</i>	140
4	EMISSION SUMMARIES	145
5	REFERENCES	149

List of Tables

Table 2-1. Platform sectors used in the Emissions Modeling Process	17
Table 2-2. Point source oil and gas sector NAICS Codes	23
Table 2-3. Point source oil and gas sector emissions for 2017 and 2019	24
Table 2-4. SCCs for the airports sector	25
Table 2-5. Afdust sector SCCs	27
Table 2-6. Total impact of 2019 fugitive dust adjustments to unadjusted inventory	30
Table 2-7. SCCs for the livestock sector	34
Table 2-8. Source of input variables for EPIC	37
Table 2-9. Nonpoint oil and gas emissions for 2017 and 2019	38
Table 2-10. SCCs for the residential wood combustion sector	39
Table 2-11. Non-VCPy SCCs in the np_solvents sector	41
Table 2-12. MOVES vehicle (source) types	44
Table 2-13. Fraction of IHS Vehicle Populations to Retain	50
Table 2-14. SCCs for cmv_c1c2 sector	53
Table 2-15. Vessel groups in the cmv_c1c2 sector	55
Table 2-16. SCCs for cmv_c3 sector	58
Table 2-17. SCCs for the Rail Sector	60
Table 2-18. 2017-to-2019 projection factors for rail	60
Table 2-19. Alaska counties/census areas for which nonroad equipment sector-specific emissions were removed	68
Table 2-20. SCCs included in the ptfire sector for the 2019 platform	69
Table 2-21. SCCs included in the ptagfire sector	75
Table 2-22. Meteorological variables required by BEIS 3.7	76
Table 3-1. Key emissions modeling steps by sector	82
Table 3-2. Descriptions of the platform grids	83
Table 3-3. Emission model species produced for CB6R3AE7 for CMAQ	85
Table 3-4. Additional HAP Gaseous model species produced for CMAQ multipollutant specifically for toxics modeling (not used within CB6)	87
Table 3-5. Additional HAP Particulate* model species produced for CMAQ multipollutant modeling	88
Table 3-6. PAH/POM pollutant groups	88
Table 3-7. Integration status of naphthalene, benzene, acetaldehyde, formaldehyde and methanol (NBAFM) for each platform sector	95
Table 3-8. MOVES integrated species in M-profiles	98
Table 3-9. Basin/Region-specific profiles for oil and gas	99
Table 3-10. TOG MOVES-SMOKE Speciation for nonroad emissions	101
Table 3-11. Select mobile-related VOC profiles	102
Table 3-12. Onroad M-profiles	102
Table 3-13. MOVES process IDs	103
Table 3-14. MOVES Fuel subtype IDs	104
Table 3-15. MOVES regclass IDs	104
Table 3-16. Brake and tire PM2.5 profiles from Schauer (2006)	107
Table 3-17. Nonroad PM2.5 profiles	108
Table 3-18. NO _x speciation profiles	109
Table 3-19. Sulfate split factor computation	109
Table 3-20. SO ₂ speciation profiles	110
Table 3-21. Particle size speciation of Metals	110
Table 3-22. Speciation of Mercury	111

Table 3-23. Temporal settings used for the platform sectors in SMOKE	112
Table 3-24. U.S. Surrogates available for the 2019 modeling platforms	136
Table 3-25. Off-Network Mobile Source Surrogates	137
Table 3-26. Spatial Surrogates for Oil and Gas Sources	138
Table 3-27. Selected 2019 CAP emissions by sector for U.S. Surrogates (short tons in 12US1).....	138
Table 3-28. Canadian Spatial Surrogates	141
Table 3-29. 2019 CAPs Allocated to Mexican and Canadian Spatial Surrogates for 12US1 (short tons)	142
Table 4-1. National by-sector CAP emissions for the 2019 platform, 12US1 grid (tons/yr).....	146
Table 4-2. National by-sector VOC HAP emissions for the 2019 platform, 12US1 grid (tons/yr)	147
Table 4-3. National by-sector Diesel PM and metal emissions for the 2019 platform, 12US1 grid (tons/yr)	148

List of Figures

Figure 2-1. Impact of adjustments to fugitive dust emissions due to transport fraction, precipitation, and cumulative	33
Figure 2-2. “Bidi” modeling system used to compute emissions from fertilizer application	36
Figure 2-3. Map of Representative Counties.....	49
Figure 2-4. Areas of Transponder Data Request for 2019	54
Figure 2-5. 2017 US Railroad Traffic Density in Millions of Gross Tons per Route Mile (MGT).....	61
Figure 2-6. Class I Railroads in the United States.....	62
Figure 2-7. Class II and III Railroads in the United States ⁵	63
Figure 2-8. Amtrak Routes with Diesel-powered Passenger Trains	64
Figure 2-9. Processing flow for fire emission estimates in the 2019 inventory	72
Figure 2-10. Default fire type assignment by state and month where data are only from satellites.	73
Figure 2-11. Blue Sky Modeling Framework.....	74
Figure 3-1. Emissions modeling domain (12US1) and air quality modeling domain (12US2).....	84
Figure 3-2. Process of integrating NBAFM with VOC for use in VOC Speciation	95
Figure 3-3. Profiles composited for PM gas combustion related sources	106
Figure 3-4. Comparison of PM profiles used for Natural gas combustion related sources.....	106
Figure 3-5. Eliminating unmeasured spikes in CEMS data	115
Figure 3-6. Temporal Profile Input Unit Counts by Fuel and Peaking Unit Classification	116
Figure 3-7. Example Daily Temporal Profiles for the LADCO Region and the Gas Fuel Type	117
Figure 3-8. Example Diurnal Temporal Profiles for the MANE-VU Region and the Coal Fuel Type	117
Figure 3-9. Non-CEMS EGU Temporal Profile Application Counts	118
Figure 3-10. Diurnal Profile for all Airport SCCs.....	119
Figure 3-11. Weekly profile for all Airport SCCs.....	120
Figure 3-12. Monthly Profile for all Airport SCCs	120
Figure 3-13. Alaska Seaplane Profile.....	121
Figure 3-14. Example of RWC temporal allocation in 2007 using a 50 versus 60 °F threshold	122
Figure 3-15. RWC diurnal temporal profile	123
Figure 3-16. Data used to produce a diurnal profile for hydronic heaters	124
Figure 3-17. Day-of-week temporal profiles for hydronic heaters and recreational RWC.....	124
Figure 3-18. Annual-to-month temporal profiles for hydronic heaters and recreational RWC	125
Figure 3-19. Example of animal NH ₃ emissions temporal allocation approach (daily total emissions).....	126
Figure 3-20. Example of temporal variability of NO _x emissions	127
Figure 3-21. Sample onroad diurnal profiles for Fulton County, GA.....	128
Figure 3-22. Methods to Populate Onroad Speeds and Temporal Profiles by Road Type	129
Figure 3-23. Regions for computing Region Average Speeds and Temporal Profiles	130
Figure 3-24. Example of Temporal Profiles for Combination Trucks	131
Figure 3-25. Example Nonroad Day-of-week Temporal Profiles	132
Figure 3-26. Example Nonroad Diurnal Temporal Profiles	132
Figure 3-27. Agricultural burning diurnal temporal profile	133
Figure 3-28. Prescribed and Wildfire diurnal temporal profiles	134

List of Appendices

Appendix A: CB6 Assignment for Species

Appendix B: Appendix B: Profiles (other than onroad) that are new or revised in SPECIATE versions 4.5 and later that were used in the 2016 and later platforms

Appendix C: Mapping of Fuel Distribution SCCs to BTP, BPS and RBT

Acronyms

AADT	Annual average daily traffic
AE6	CMAQ Aerosol Module, version 6, introduced in CMAQ v5.0
AEO	Annual Energy Outlook
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AIS	Automated Identification System
APU	Auxiliary power unit
BEIS	Biogenic Emissions Inventory System
BELD	Biogenic Emissions Land use Database
BenMAP	Benefits Mapping and Analysis Program
BPS	Bulk Plant Storage
BSP	Blue Sky Pipeline
BTP	Bulk Terminal (Plant) to Pump
C1C2	Category 1 and 2 commercial marine vessels
C3	Category 3 (commercial marine vessels)
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
CB6	Version 6 of the Carbon Bond mechanism
CBM	Coal-bed methane
CDB	County database (input to MOVES model)
CEMS	Continuous Emissions Monitoring System
CISWI	Commercial and Industrial Solid Waste Incinerators
CMAQ	Community Multiscale Air Quality
CMV	Commercial Marine Vessel
CNG	Compressed natural gas
CO	Carbon monoxide
CONUS	Continental United States
CoST	Control Strategy Tool
CRC	Coordinating Research Council
CSAPR	Cross-State Air Pollution Rule
E0, E10, E85	0%, 10% and 85% Ethanol blend gasoline, respectively
ECA	Emissions Control Area
ECCC	Environment and Climate Change Canada
EF	Emission Factor
EGU	Electric Generating Units
EIA	Energy Information Administration
EIS	Emissions Inventory System
EPA	Environmental Protection Agency
EMFAC	EMission FACtor (California's onroad mobile model)
EPIC	Environmental Policy Integrated Climate modeling system
FAA	Federal Aviation Administration
FCCS	Fuel Characteristic Classification System
FEST-C	Fertilizer Emission Scenario Tool for CMAQ
FF10	Flat File 2010

FINN	Fire Inventory from the National Center for Atmospheric Research
FIPS	Federal Information Processing Standards
FHWA	Federal Highway Administration
HAP	Hazardous Air Pollutant
HMS	Hazard Mapping System
HPMS	Highway Performance Monitoring System
ICI	Industrial/Commercial/Institutional (boilers and process heaters)
I/M	Inspection and Maintenance
IMO	International Marine Organization
IPM	Integrated Planning Model
LADCO	Lake Michigan Air Directors Consortium
LDV	Light-Duty Vehicle
LPG	Liquified 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
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
MTBE	Methyl tert-butyl ether
MWC	Municipal waste combustor
MY	Model year
NAAQS	National Ambient Air Quality Standards
NAICS	North American Industry Classification System
NBAFM	Naphthalene, Benzene, Acetaldehyde, Formaldehyde and Methanol
NCAR	National Center for Atmospheric Research
NEEDS	National Electric Energy Database System
NEI	National Emission Inventory
NESCAUM	Northeast States for Coordinated Air Use Management
NH₃	Ammonia
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NONROAD	OTAQ's model for estimation of nonroad mobile emissions
NO_x	Nitrogen oxides
NSPS	New Source Performance Standards
OHH	Outdoor Hydronic Heater
ONI	Off network idling
OTAQ	EPA's Office of Transportation and Air Quality
ORIS	Office of Regulatory Information System
ORD	EPA's Office of Research and Development
OSAT	Ozone Source Apportionment Technology
pcSOA	Potential combustion Secondary Organic Aerosol
PFC	Portable Fuel Container
PM_{2.5}	Particulate matter less than or equal to 2.5 microns
PM₁₀	Particulate matter less than or equal to 10 microns
POA	Primary Organic Aerosol
ppm	Parts per million

ppmv	Parts per million by volume
PSAT	Particulate Matter Source Apportionment Technology
RACT	Reasonably Available Control Technology
RBT	Refinery to Bulk Terminal
RIA	Regulatory Impact Analysis
RICE	Reciprocating Internal Combustion Engine
RWC	Residential Wood Combustion
RPD	Rate-per-vehicle (emission mode used in SMOKE-MOVES)
RPH	Rate-per-hour for hoteling (emission mode used in SMOKE-MOVES)
RPHO	Rate-per-hour for off-network idling (emission mode used in SMOKE-MOVES)
RPP	Rate-per-profile (emission mode used in SMOKE-MOVES)
RPS	Rate-per-start (emission mode used in SMOKE-MOVES)
RPV	Rate-per-vehicle (emission mode used in SMOKE-MOVES)
RVP	Reid Vapor Pressure
SCC	Source Classification Code
SMARTFIRE2	Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2
SMOKE	Sparse Matrix Operator Kernel Emissions
SO₂	Sulfur dioxide
SOA	Secondary Organic Aerosol
SIP	State Implementation Plan
SPDPRO	Hourly Speed Profiles for weekday versus weekend
S/L/T	state, local, and tribal
TAF	Terminal Area Forecast
TCEQ	Texas Commission on Environmental Quality
TOG	Total Organic Gas
TSD	Technical support document
USDA	United States Department of Agriculture
VIIRS	Visible Infrared Imaging Radiometer Suite
VOC	Volatile organic compounds
VMT	Vehicle miles traveled
VPOP	Vehicle Population
WRAP	Western Regional Air Partnership
WRF	Weather Research and Forecasting Model
2014NEIv2	2014 National Emissions Inventory (NEI), version 2

1 Introduction

The U.S. Environmental Protection Agency (EPA) developed an air quality modeling platform for air toxics and criteria air pollutants that represents the year 2019. The platform is based on the 2017 National Emissions Inventory (2017 NEI) published in January 2021 (EPA, 2021) along with other data specific to the year 2019. 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. This document focuses on the emissions modeling component of the 2019 modeling platform, including the emission inventories, the ancillary data files, and the approaches used to transform inventories for use in air quality modeling.

The modeling platform includes all criteria air pollutants and precursors (CAPs), two groups of hazardous air pollutants (HAPs) and diesel particulate matter. The first group of HAPs are those explicitly used by the chemical mechanism in the Community Multiscale Air Quality (CMAQ) model (Appel, 2018) for ozone/particulate matter (PM): chlorine (Cl), hydrogen chloride (HCl), benzene, acetaldehyde, formaldehyde, methanol, naphthalene (the last five are also abbreviated as NBAFM in subsequent sections of the document). The second group of HAPs consists of 52 HAPs or HAP groups (such as polycyclic aromatic hydrocarbon groups) that are included in CMAQ for the purposes of air quality modeling for a HAP+CAP platform.

Emissions were prepared for the Community Multiscale Air Quality (CMAQ) model (<https://www.epa.gov/cmaq>) version 5.3.2¹, which was used to model ozone (O₃) particulate matter (PM), and HAPs. CMAQ requires hourly and gridded emissions of the following inventory pollutants: carbon monoxide (CO), nitrogen oxides (NO_x), volatile organic compounds (VOC), sulfur dioxide (SO₂), ammonia (NH₃), particulate matter less than or equal to 10 microns (PM₁₀), and individual component species for particulate matter less than or equal to 2.5 microns (PM_{2.5}). In addition, the Carbon Bond mechanism version 6 (CB6) with chlorine chemistry within CMAQ allows for explicit treatment of the VOC HAPs naphthalene, benzene, acetaldehyde, formaldehyde and methanol (NBAFM), includes anthropogenic HAP emissions of HCl and Cl, and can model additional HAPs as described in Section 3. The short abbreviation for the modeling case name was “2019ge”, where 2019 is the year modeled, g represents that it was based on the 2017 NEI, and e represents that it was the fifth version of a 2017 NEI-based platform.

Emissions were also prepared for an air dispersion modeling system: American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) (EPA, 2018). AERMOD was run for all NEI HAPs (about 130 more than covered by CMAQ) across all 50 states, Puerto Rico and the Virgin Islands (EPA, 2022). This TSD focuses on the CMAQ aspects of the modeling platform.

The effort to create the emission inputs for this study included development of emission inventories to represent emissions during the year of 2019, along with application of emissions modeling tools to convert the inventories into the format and resolution needed by CMAQ and AERMOD.

The emissions modeling platform includes point sources, nonpoint sources, commercial marine vessels (CMV), onroad and nonroad mobile sources, biogenic emissions and fires for the U.S., Canada, and

¹ CMAQ version 5.3.2: <https://doi.org/10.5281/zenodo.4081737>; <https://www.epa.gov/cmaq/cmaq-models-0>. CMAQ v5.3.2 is also available from the Community Modeling and Analysis System (CMAS) at: <http://www.cmascenter.org>.

Mexico. Some platform categories use more disaggregated data than are made available in the NEI. For example, in the platform, onroad mobile source emissions are represented as hourly emissions by vehicle type, fuel type process and road type while the NEI emissions are aggregated to vehicle type/fuel type totals and annual temporal resolution. Emissions from Canada and Mexico are used in the CMAQ modeling but are not part of the NEI. Year-specific emissions were used for fires, biogenic sources, fertilizer, point sources, and onroad and nonroad mobile sources. Where available, continuous emission monitoring system (CEMS) data were used for electric generating unit (EGU) emissions. Most of the remaining emission inventories were adjusted to represent 2019, primarily using 2017-specific emissions as a starting point.

The primary emissions modeling tool used to create the CMAQ model-ready emissions was the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system. SMOKE version 4.8.1 was used to create CMAQ-ready emissions files for a 12-km grid covering the continental U.S. Additional information about SMOKE is available from <http://www.emascenter.org/smoke>.

The gridded meteorological model used to provide input data for the emissions modeling was developed using the Weather Research and Forecasting Model (WRF, <https://ral.ucar.edu/solutions/products/weather-research-and-forecasting-model-wrf>) version 3.8, 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 was run for 2019 over a domain covering the continental U.S. at a 12km resolution with 35 vertical layers. The run for this platform included high resolution sea surface temperature data from the Group for High Resolution Sea Surface Temperature (GHRSSST) (see <https://www.ghrsst.org/>) and is given the EPA meteorological case abbreviation “19k.” The full case abbreviation includes this suffix following the emissions portion of the case name to fully specify the abbreviation of the case as “2019ge_cb6_19k.”

Following the emissions modeling steps to prepare emissions for CMAQ and AERMOD, both models were run for the modeling domain covering the Continental United States. CMAQ outputs provide the overall mass, chemistry and formation for specific hazardous air pollutants (HAPs) formed secondarily in the atmosphere (e.g., formaldehyde, acetaldehyde and acrolein), whereas AERMOD provides spatial granularity and more detailed source attribution. CMAQ also provided the biogenic and fire concentrations, as these sources are not run in AERMOD. Special steps were taken to estimate secondary HAPs, fire and biogenic emissions in these areas. The outputs from CMAQ and AERMOD were combined to provide spatially refined concentration estimates for HAPs, from which estimates of cancer and non-cancer risk were derived. Information about the emissions and associated data files for this platform are available from this section of the air emissions modeling website <https://www.epa.gov/air-emissions-modeling/2019-emissions-modeling-platform>.

This document contains five sections and several appendices. Section 2 describes the emission inventories input to SMOKE. Section 3 describes the emissions modeling and the ancillary files used to process the emission inventories into air quality model-ready inputs. Data summaries are provided in Section 4. Section 5 provides references. The Appendices provide additional details about specific technical methods or data.

2 Emissions Inventories and Approaches

This section describes the emissions inventories created for input to SMOKE, which are based on the January 2021 version of the 2017 NEI along with the point source inventory for 2019 and other year 2019-specific data. The NEI includes five main data categories: a) nonpoint (formerly called “stationary area”) sources; b) point sources; c) nonroad mobile sources; d) onroad mobile sources; and e) fires. For CAPs, the NEI data are largely compiled from data submitted by state, local and tribal (S/L/T) agencies. HAP emissions data are often augmented by EPA when they are not voluntarily submitted to the NEI by S/L/T agencies. The NEI was compiled using the Emissions Inventory System (EIS). EIS includes hundreds of automated QA checks to improve data quality, and it also supports release point (stack) coordinates separately from facility coordinates. EPA collaboration with S/L/T agencies helped prevent duplication between point and nonpoint source categories such as industrial boilers. The 2017 NEI Technical Support Document describes in detail the development of the 2017 emission inventories and is available at <https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd> (EPA, 2021).

The full NEI including all emissions source categories is developed every three years, with 2017 being the most recent year represented with a full NEI. S/L/T agencies are required to submit large point sources to the NEI in interim years, including the year 2019. Where available, point source data representing 2019 were used for this study. Point sources in the 2017 NEI that did not have data submitted for the year 2019 and that were not marked as closed were pulled forward from the 2017 NEI into the 2019 point source inventory. The SMARTFIRE2 system and the BlueSky Pipeline (<https://github.com/pnwairfire/bluesky>) emissions modeling system were used to develop year 2019 fire emissions. SMARTFIRE2 categorizes all fires as either prescribed burning or wildfire categories, and the BlueSky Pipeline system includes fuel loading, consumption and emission factor estimates for both types of fires. Onroad and nonroad mobile source emissions were developed for this project for the year 2019 by running MOVES3 (<https://www.epa.gov/moves>).

With the exception of onroad, nonroad and fire emissions, Canadian emissions were based on the 2019 inventories developed for EPA’s Air Quality Time Series ([EQUATES](#)) project (Foley, 2020). For Mexico, year 2016 inventories were projected to 2019. The latest year for which Canada and Mexico inventories were provided was 2016, although the onroad and nonroad emissions were adjusted to represent the year 2019 and some additional adjustments to the Canadian emissions were made for EQUATES.

The emissions modeling process, performed using SMOKE v4.8.1, apportions the emissions inventories into the grid cells used by CMAQ and temporalizes the emissions into hourly values. In addition, the pollutants in the inventories (e.g., NO_x, PM and VOC) are split into the chemical species needed by CMAQ. For the purposes of preparing the CMAQ- ready emissions, the NEI emissions inventories by data category are split into emissions modeling platform “sectors”; and emissions from sources other than the NEI are added, such as the Canadian, Mexican, and offshore inventories. Emissions within the emissions modeling platform are separated into sectors for groups of related emissions source categories that are run through all of the SMOKE programs, except the final merge, independently from emissions categories in the other sectors. The final merge program called Mrggrid combines low-level sector-specific gridded, speciated and temporalized emissions to create the final CMAQ-ready emissions inputs. For biogenic and fertilizer emissions, the CMAQ model allows for these emissions to be included in the CMAQ-ready emissions inputs, or to be computed within CMAQ itself (the “inline” option). This study

uses the inline biogenic emissions option and the CMAQ bidirectional ammonia process for fertilizer emissions.

Table 2-1 presents the sectors in the emissions modeling platform used to develop the year 2019 emissions for this project. The sector abbreviations are provided in italics; these abbreviations are used in the SMOKE modeling scripts, the inventory file names, and throughout the remainder of this section.

Table 2-1. Platform sectors used in the Emissions Modeling Process

Platform Sector: <i>abbreviation</i>	NEI Data Category	Description and resolution of the data input to SMOKE
EGU units: <i>ptegu</i>	Point	2019 NEI point source EGUs, replaced with hourly Continuous Emissions Monitoring System (CEMS) values for NO _x and SO ₂ , and the remaining pollutants temporally allocated according to CEMS heat input where the units are matched to the NEI. Emissions for all sources not matched to CEMS data come from 2019 NEI point inventory. Annual resolution for sources not matched to CEMS data, hourly for CEMS sources. EGUs closed in 2019 are not part of the inventory.
Point source oil and gas: <i>pt_oilgas</i>	Point	2019 point sources that include oil and gas production emissions processes for facilities with North American Industry Classification System (NAICS) codes related to Oil and Gas Extraction, Natural Gas Distribution, Drilling Oil and Gas Wells, Support Activities for Oil and Gas Operations, Pipeline Transportation of Crude Oil, and Pipeline Transportation of Natural Gas. Includes U.S. offshore oil production. Production-related sources that did not have 2019 data were pulled forward from the 2017 NEI and adjusted to 2019. Annual resolution.
Aircraft and ground support equipment: <i>airports</i>	Point	2017 NEI point source emissions from airports, including aircraft and airport ground support emissions, adjusted to 2019 using Terminal Area Forecast (TAF) data. Airport-specific factors were used where available, state average factors were used for regional airports, and no change was made to military aircraft from 2017. Annual resolution.
Remaining non-EGU point: <i>ptnonipm</i>	Point	All 2019 NEI point source records not matched to the airports, ptegu, or pt_oilgas sectors. Closures were reviewed and implemented based on the most recent submissions to the Emissions Inventory System (EIS). Includes 2017 NEI rail yard emissions, adjusted to 2019 using same projection factors as the rail sector. Annual resolution.
Livestock: <i>livestock</i>	Nonpoint	2017 NEI nonpoint livestock emissions adjusted to 2019 using USDA survey data. Livestock includes ammonia and other pollutants (except PM _{2.5}). County and annual resolution.
Agricultural Fertilizer	Nonpoint	2019 agricultural fertilizer ammonia emissions computed inline within CMAQ.
Agricultural fires with point resolution: <i>ptagfire</i>	Nonpoint	Agricultural fire sources for year 2019 were developed by EPA as point and day-specific emissions. ² Only EPA-developed ag. fire data are used in this study, thus 2017 NEI state submissions are not included. Agricultural fires are in the nonpoint data category of the NEI, but in the modeling platform, they are treated as day-specific point sources. Updated HAP-augmentation factors were applied.

² Only EPA-developed agricultural fire data were included in this study; data submitted by states to the NEI were excluded.

Platform Sector: <i>abbreviation</i>	NEI Data Category	Description and resolution of the data input to SMOKE
Area fugitive dust: <i>afdust_adj</i>	Nonpoint	PM ₁₀ and PM _{2.5} fugitive dust sources from the 2017 NEI nonpoint inventory; including building construction, road construction, agricultural dust, and paved and unpaved road dust; with paved road dust adjusted to 2019 based on vehicle miles traveled (VMT). The emissions modeling system applies a transport fraction reduction and a zero-out based on 2019 gridded hourly meteorology (precipitation and snow/ice cover). Emissions are county and annual resolution.
Biogenic: <i>beis</i>	Nonpoint	Year 2019 emissions from biogenic sources. These were left out of the CMAQ-ready merged emissions, in favor of inline biogenic emissions produced during the CMAQ model run itself. Version 3.7 of the Biogenic Emissions Inventory System (BEIS) was used with Version 5 of the Biogenic Emissions Landuse Database (BELD5).
Category 1, 2 CMV: <i>cmv_c1c2</i>	Nonpoint	2019 Category 1 (C1) and Category 2 (C2), commercial marine vessel (CMV) emissions based on Automatic Identification System (AIS) data. Point and hourly resolution.
Category 3 CMV: <i>cmv_c3</i>	Nonpoint	2019 Category 3 (C3) commercial marine vessel (CMV) emissions based on AIS data. Point and hourly resolution.
Locomotives : <i>rail</i>	Nonpoint	Line haul rail locomotives emissions for year 2017, projected to 2019 using annual energy outlook (AEO) and additional factors supplied by ERTAC. County and annual resolution.
Nonpoint source oil and gas: <i>np_oilgas</i>	Nonpoint	Nonpoint 2017 NEI sources from oil and gas-related processes, projected to 2019 using based on U.S. Energy Information Administration (EIA) and Railroad Commission of Texas (TXRRC) historical production data. County and annual resolution.
Residential Wood Combustion: <i>rwc</i>	Nonpoint	2017 NEI nonpoint sources with residential wood combustion (RWC) processes were used as is, with no projection to represent 2019. County and annual resolution.
Solvents: <i>np_solvents</i>	Nonpoint	Emissions of solvents for the year 2019 (Seltzer, 2021). Includes household cleaners, personal care products, adhesives, architectural and aerosol coatings, printing inks, and pesticides. Annual and county resolution.
Remaining nonpoint: <i>nonpt</i>	Nonpoint	2017 NEI nonpoint sources not included in other platform sectors. No adjustments were made to represent 2019. County and annual resolution.
Nonroad: <i>nonroad</i>	Nonroad	2019 nonroad equipment emissions developed with MOVES3, including the updates made to spatial apportionment that were developed with the 2016v1 platform. MOVES3 was used for all states except California and Texas. California submitted their own emissions for the 2017 NEI that were adjusted to 2019 based on interpolations between 2017 and 2023. Texas provided 2017 and 2020 emissions which were interpolated to 2019. County and monthly resolution.
Onroad: <i>onroad</i>	Onroad	Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles. Includes the following emission processes: exhaust, extended idle, auxiliary power units, evaporative, permeation, refueling, vehicle starts, off network idling, long-haul truck hoteling, and brake and tire wear. Activity data were projected from 2017 to 2019 using factors developed using data from Federal Highway Administration and state departments of transportation. MOVES3 was run for 2019 to generate emission factors.

Platform Sector: <i>abbreviation</i>	NEI Data Category	Description and resolution of the data input to SMOKE
Onroad California: <i>onroad_ca_adj</i>	Onroad	California-provided 2017 CAP and metal HAP onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles based on Emission Factor (EMFAC) 2017, gridded and temporalized based on outputs from MOVES3. Volatile organic compound (VOC) HAP emissions derived from California-provided VOC emissions and MOVES-based speciation. 2019 was interpolated between 2017 and 2023 emissions from EMFAC2017.
Point source prescribed fires: <i>ptfire-rx</i>	Events	Point source day-specific prescribed fires for 2019 computed using SMARTFIRE 2 and BlueSky Pipeline. The ptfire emissions were run as two separate sectors: ptfire-rx (prescribed, including Flint Hills / grasslands) and ptfire-wild.
Point source wildfires: <i>ptfire-wild</i>	Events	Point source day-specific wildfires for 2019 computed using SMARTFIRE 2 and BlueSky Pipeline.
Non-US. Fires: <i>ptfire_othna</i>	N/A	Point source day-specific wildfires and agricultural fires outside of the U.S. for 2019 from v1.5 of the Fire INventory (FINN) from National Center for Atmospheric Research (NCAR, 2017 and Wiedinmyer, C., 2011) for Canada, Mexico, Caribbean, Central American, and other international fires.
Other Area Fugitive dust sources not from the NEI: <i>othafdust</i>	N/A	Area fugitive dust sources from Canada from EQUATES 2016 with transport fraction and snow/ice adjustments based on 2019 meteorological data. Annual and province resolution.
Other Point Fugitive dust sources not from the NEI: <i>othptdust</i>	N/A	Point source fugitive dust sources from Canada from EQUATES 2016 with transport fraction and snow/ice adjustments based on 2019 meteorological data. Annual and province resolution.
Other point sources not from the NEI: <i>othpt</i>	N/A	Canada and Mexico point source emissions from EQUATES 2016. Canada point sources were provided by ECCCC and Mexico point source emissions for 2016 were provided by SEMARNAT. Mexico sources were projected to 2019 based on national emissions trends from the Community Emissions Data System (CEDs). Annual and monthly resolution.
Other non-NEI nonpoint and nonroad: <i>othar</i>	N/A	For Canada except nonroad, EQUATES 2016. Projected Canada nonroad to 2019 based on US MOVES3 2019/2016 ratios. EQUATES 2016 Mexico (municipio resolution, provided by SEMARNAT) nonpoint and nonroad mobile inventories were projected to 2019 based on national emissions trends from the Community Emissions Data System (CEDs). Annual and monthly resolution.
Other non-NEI onroad sources: <i>onroad_can</i>	N/A	Monthly onroad mobile inventory for Canada from EQUATES 2016 projected to 2019 using US onroad trends. Separate trends applied to refueling (gas/diesel) and non-refueling (gas/diesel and LD/HD). Province resolution.
Other non-NEI onroad sources: <i>onroad_mex</i>	N/A	Monthly onroad mobile inventory from MOVES-Mexico (municipio resolution) for 2017, adjusted to 2019 using interpolation between 2017 and 2020.

Other natural emissions are also merged in with the above sectors, including ocean chlorine and sea salt. The ocean chlorine gas emission estimates are based on the build-up of molecular chlorine (Cl₂) concentrations in oceanic air masses (Bullock and Brehme, 2002).

Data at 12 km resolution were available and were not modified other than the name “CHLORINE” was changed to “CL2” because that is the name required by the CMAQ model.

The emission inventories in SMOKE input formats for the platform are available from EPA’s Air Emissions Modeling website: <https://www.epa.gov/air-emissions-modeling/2019-emissions-modeling-platform>. The platform informational text file indicates the particular zipped files associated with each platform sector. Some emissions data summaries are available with the data files for the 2019 platform. The types of reports include state summaries of inventory pollutants and model species by modeling platform sector and county annual totals by modeling platform sector.

2.1 Point sources (ptegu, pt_oilgas, ptnonipm, airports)

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 offshore oil platform (pt_oilgas sector) and CMV emissions (cmv_c1c2 and cmv_c3 sectors) are processed by SMOKE as point source inventories and are discussed later in this section. A complete NEI is developed every three years, with 2017 being the most recently finished complete NEI. A comprehensive description about the development of the 2017 NEI is available in the 2017 NEI TSD (EPA, 2021). Point inventories are also available in EIS for intermediate years such as 2019. In the intermediate point inventories, states are required to update larger sources with emissions for the interim year, while sources not updated by states for the interim year are either carried forward from the most recent triennial NEI or marked as closed and removed.

In preparation for modeling, the complete set of point sources in the NEI was exported from EIS for the year 2019 into the Flat File 2010 (FF10) format that is compatible with SMOKE (see <https://www.cmascenter.org/smoke/documentation/4.8.1/html/ch08s02s08.html>) and was then split into several sectors for modeling. The 20220325 version of the point FF10 file was used for the CMAQ and AERMOD modeling. In the flat file, sources without specific locations (i.e., the FIPS code ends in 777) were dropped and inventories for the other point source sectors were created from the remaining point sources. The point sectors are: EGUs (ptegu), point source oil and gas extraction-related sources (pt_oilgas), airport emissions (airports), and the remaining non-EGUs (ptnonipm). The EGU emissions were 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) and airport emissions (airports) were processed separately for summary tracking purposes and distinct projection techniques from the remaining non-EGU emissions (ptnonipm).

In some cases, data about facility or unit closures are entered into EIS after the inventory modeling inventory flat were reviewed and implemented based on the most recent submissions to EIS. Prior to processing through SMOKE, submitted closures were reviewed and if closed sources were found in the inventory, those were removed.

For the 2019 platform, an analysis of point source stack parameters (e.g., stack height, diameter, temperature, and velocity) was performed after some specific examples of unrealistic stack parameters as default values were noticed. The defaulted values were noticed in data submissions for the states of

Illinois, Louisiana, Michigan, Pennsylvania, Texas, and Wisconsin. Where these defaults were detected and deemed to be unreasonable for the specific process, the affected stack parameters were replaced by values from the currently available PSTK file that is input to SMOKE. PSTK contains default stack parameters by source classification code (SCC). These updates impacted the ptnonipm and pt_oilgas inventories.

The inventory pollutants processed through SMOKE for input to CMAQ for the ptegu, pt_oilgas, ptnonipm, and airports sectors included: CO, NO_x, VOC, SO₂, NH₃, PM₁₀, and PM_{2.5} and the following HAPs: HCl (pollutant code = 7647010), Cl (code = 7782505), and several dozen other HAPs listed in Section 3. NBAFM pollutants from the point sectors were utilized. For AERMOD, additional HAPS were included as described in the 2019 AirToxScreen TSD.

The ptnonipm, pt_oilgas, and airports sector emissions were provided to SMOKE as annual emissions. For sources in the ptegu sector that could be matched to 2019 CEMS data, hourly CEMS NO_x and SO₂ emissions for 2019 from EPA's Acid Rain Program were used rather than annual inventory emissions. For all other pollutants (e.g., VOC, PM_{2.5}, HCl), annual emissions were used as-is from the annual inventory but were allocated to hourly values using heat input from the CEMS data. For the unmatched units in the ptegu sector, annual emissions were allocated to daily values using IPM region- and pollutant-specific profiles, and similarly, region- and pollutant-specific diurnal profiles were applied to create hourly emissions.

The non-EGU stationary point source (ptnonipm) emissions were input to SMOKE as annual emissions. The full description of how the NEI emissions were developed is provided in the NEI documentation - a brief summary of their development follows:

- a. CAP and HAP data were provided by States, locals and tribes under the Air Emissions Reporting Rule (AERR) [the reporting size threshold is larger for inventory years between the triennial inventory years of 2011, 2014, 2017, ...].
- b. EPA corrected known issues and filled PM data gaps.
- c. EPA added HAP data from the Toxic Release Inventory (TRI) where corresponding data was not already provided by states/locals.
- d. EPA stored and applied matches of the point source units to units with CEMS data and also for all EGU units modeled by EPA's Integrated Planning Model (IPM).
- e. Data for airports and rail yards were incorporated.
- f. Off-shore platform data were added from the Bureau of Ocean Energy Management (BOEM).

The changes made to the NEI point sources prior to modeling with SMOKE are as follows:

- The tribal data, which do not use state/county Federal Information Processing Standards (FIPS) codes in the NEI, but rather use the tribal code, were assigned a state/county FIPS code of 88XXX, where XXX is the 3-digit tribal code in the NEI. This change was made because SMOKE requires all sources to have a state/county FIPS code.
- Sources that did not have specific counties assigned (i.e., the county code ends in 777) were not included in the modeling because it was only possible to know the state in which the sources

resided, but no more specific details related to the location of the sources were available.

Each of the point sectors is processed separately through SMOKE as described in the following subsections.

2.1.1 EGU sector (ptegu)

The ptegu sector contains emissions from EGUs in the 2019 point source inventory that could be matched to units found in the National Electric Energy Database System (NEEDS) v6 that is used by the Integrated Planning Model (IPM) to develop future year EGU emissions. It was necessary to put these EGUs into a separate sector in the platform because EGUs use different temporal profiles than other sources in the point sector and it is useful to segregate these emissions from the rest of the point sources to facilitate summaries of the data. Sources not matched to units found in NEEDS are placed into the pt_oilgas or ptnonipm sectors. For studies with future year cases, the sources in the ptegu sector are fully replaced with the emissions output from IPM. It is therefore important that the matching between the NEI and NEEDS database be as complete as possible because there can be double-counting of emissions in future year modeling scenarios if emissions for units are projected by IPM are not properly matched to the units in the point source inventory.

The 2019 ptegu emissions inventory is a subset of the point source flat file exported from the Emissions Inventory System (EIS). In the point source flat file, emission records for sources that have been matched to the NEEDS database have a value filled into the IPM_YN column based on the matches stored within EIS. Thus, unit-level emissions were split into a separate EGU flat file for units that have a populated (non-null) ipm_yn field. A populated ipm_yn field indicates that a match was found for the EIS unit in the NEEDS v6 database. Updates were made to the flat file output from EIS as described in the list below:

- ORIS facility and unit identifiers were updated based on additional matches in a cross-platform spreadsheet, based on state comments, and using the EIS alternate identifiers table as described later in this section.

Some units in the ptegu sector are matched to Continuous Emissions Monitoring System (CEMS) data via Office of Regulatory Information System (ORIS) facility codes and boiler IDs. For the matched units, the annual emissions of NO_x and SO₂ in the flat file are replaced with the hourly CEMS emissions in base year modeling. For other pollutants at matched units, the hourly CEMS heat input data are used to allocate the NEI annual emissions to hourly values. All stack parameters, stack locations, and Source Classification Codes (SCC) for these sources come from the flat file. If CEMS data exists for a unit, but the unit is not matched to the NEI, the CEMS data for that unit are 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 temporally allocated to hourly values.

EIS stores many matches from NEI units to the ORIS facility codes and boiler IDs used to reference the CEMS data. In the 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 are available at <http://ampd.epa.gov/ampd> near the bottom of the “Prepackaged Data” tab. Many smaller emitters in the CEMS program cannot be matched to the NEI due to inconsistencies in the way a unit is defined between the NEI and CEMS datasets, or due to uncertainties in source identification such as inconsistent plant names in the two data systems. In addition, the NEEDS database of units modeled by IPM includes many smaller emitting EGUs that do not have CEMS. Therefore, there will be more units in the ptegu sector than have CEMS data.

Matches from the NEI to ORIS codes and the NEEDS database were improved in the platform where applicable. In some cases, NEI units in EIS match to many CAMD units. In these cases, a new entry was made in the flat file with a “_M_” in the ipm_yn field of the flat file to indicate that there are “multiple” ORIS IDs that match that unit. This helps facilitate appropriate temporal allocation of the emissions by SMOKE. Temporal allocation for EGUs is discussed in more detail in the Ancillary Data section below.

The EGU flat file was split into two flat files: those that have unit-level matches to CEMS data using the oris_facility_code and oris_boiler_id fields and those that do not so that different temporal profiles could be applied. In addition, the hourly CEMS data were processed through v2.1 of the CEMCorrect tool to mitigate the impact of unmeasured values in the data.

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 North American Industry Classification System (NAICS) codes shown in Table 2-2. The emissions and other source characteristics in the pt_oilgas sector are submitted by states, while 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. The pt_oilgas sector includes emissions from offshore oil platforms. Where available, the point source emissions submitted as part of the 2019 NEI process were used.

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

NAICS	NAICS description
2111	Oil and Gas Extraction
211111	Crude Petroleum and Natural Gas Extraction
211112	Natural Gas Liquid Extraction
21112	Crude Petroleum Extraction
211120	Crude Petroleum Extraction
21113	Natural Gas Extraction
211130	Natural Gas Extraction
213111	Drilling Oil and Gas Wells
213112	Support Activities for Oil and Gas Operations
2212	Natural Gas Distribution
22121	Natural Gas Distribution
221210	Natural Gas Distribution
237120	Oil and Gas Pipeline and Related Structures Construction
4861	Pipeline Transportation of Crude Oil
48611	Pipeline Transportation of Crude Oil
486110	Pipeline Transportation of Crude Oil
4862	Pipeline Transportation of Natural Gas
48621	Pipeline Transportation of Natural Gas
486210	Pipeline Transportation of Natural Gas

For sources that otherwise would be pulled forward with 2017 emissions values because 2019-specific emissions were not available, projection factors by NAICS and state derived from historical production

data from EIA. The factors were applied to those 2017 sources to adjust the emissions to make them more representative of 2019. Texas historical production data by Texas Railroad district (<http://webapps.rrc.texas.gov/PDQ/generalReportAction.do>) were used to derive and apply district-specific factors instead of state-specific. State (plus TX Railroad Commission district) factors were applied to production-related NAICS. Transportation NAICS were projected using nationally derived production-related factors for oil and gas. All other NAICS were held constant from 2017 NEI. All Tribal data and offshore emissions were held constant from 2017 NEI. More information on the development of the 2017 NEI oil and gas emissions can be found in Section 4.17 of the 2017 NEI TSD. The point oil and gas emissions for 2017 and 2019 are shown in Table 2-3.

Table 2-3. Point source oil and gas sector emissions for 2017 and 2019

State	2017 NO _x	2019 NO _x	2019 – 2017 NO _x	2017 VOC	2019 VOC	2019-2017 VOC
Alabama	8,861	9,668	807	1,332	1,483	151
Alaska	39,424	38,248	-1,176	2,301	1,925	-376
Arizona	2,326	2,672	346	198	206	8
Arkansas	4,697	5,043	346	316	338	22
California	3,318	3,383	65	2,767	2,782	15
Colorado	14,209	16,748	2,539	15,102	17,815	2,713
Connecticut	172	101	-71	73	54	-19
Delaware	11	11	0	4	4	0
Florida	6,197	5,634	-563	678	657	-21
Georgia	3,163	3,179	16	463	458	-5
Idaho	1,131	1,412	281	34	42	8
Illinois	5,402	7,813	2,411	734	1,325	591
Indiana	3,540	2,513	-1,027	246	237	-9
Iowa	5,769	6,987	1,218	344	394	50
Kansas	23,622	25,984	2,362	2,634	3,250	616
Kentucky	9,673	9,269	-404	1,268	1,313	45
Louisiana	29,025	31,365	2,340	9,259	12,818	3,559
Maine	17	29	12	48	50	2
Maryland	206	220	14	14	66	52
Massachusetts	245	217	-28	56	44	-12
Michigan	10,933	13,840	2,907	1,431	1,378	-53
Minnesota	3,002	3,751	749	169	174	5
Mississippi	11,288	11,487	199	1,478	1,602	124
Missouri	3,544	5,056	1,512	176	236	60
Montana	1,321	815	-506	1,065	1,135	70
Nebraska	3,834	4,762	928	325	391	66
Nevada	195	262	67	32	32	0
New Jersey	216	181	-35	114	111	-3
New Mexico	15,002	16,337	1,335	4,979	5,152	173
New York	1,186	1,125	-61	340	337	-3
North Carolina	578	1,694	1,116	141	183	42

State	2017 NO _x	2019 NO _x	2019 – 2017 NO _x	2017 VOC	2019 VOC	2019-2017 VOC
North Dakota	4,511	4,648	137	1,316	2,594	1,278
Ohio	11,154	8,549	-2,605	1,381	1,523	142
Oklahoma	48,951	50,990	2,039	32,923	38,628	5,705
Oregon	684	855	171	58	72	14
Pennsylvania	5,193	4,708	-485	1,073	1,029	-44
Rhode Island	69	42	-27	39	14	-25
South Carolina	401	182	-219	156	119	-37
South Dakota	409	511	102	11	14	3
Tennessee	3,857	4,969	1,112	539	407	-132
Texas	51,558	53,856	2,298	21,058	22,973	1,915
Utah	1,938	2,211	273	686	722	36
Virginia	2,404	4,279	1,875	236	414	178
Washington	812	741	-71	41	45	4
West Virginia	8,891	8,705	-186	2,187	2,723	536
Wisconsin	545	348	-197	48	53	5
Wyoming	10,205	10,010	-195	15,736	15,888	152
Offshore to EEZ	49,962	49,962	0	38,833	38,833	0
Tribal Data	7,746	7,470	-276	2,030	2,047	17

2.1.3 Aircraft and ground support equipment (airports)

Emissions at airports were separated from other sources in the point inventory based on sources that have the facility source type of 100 (airports). The airports sector includes all aircraft types used for public, private, and military purposes and aircraft ground support equipment. The Federal Aviation Administration’s (FAA) Aviation Environmental Design Tool (AEDT) is used to estimate emissions for this sector. For 2017, Texas and California submitted aircraft emissions. Additional information about aircraft emission estimates can be found in section 3.2.2 of the 2017 NEI TSD. Data from the 2020 Terminal Area Forecast (TAF) were used to project 2017 NEI emissions to 2019. EPA used airport-specific factors where available. Regional airports were projected using state average factors. Military airports were unchanged from 2017. An update for the 2019 platform was that airport emissions were spread out into multiple 12km grid cells when the airport runways were determined to overlap multiple grid cells. Otherwise, airport emissions for a specific airport are confined to one air quality model grid cell. The SCCs included in the airport sector are shown in Table 2-4.

Table 2-4. SCCs for the airports sector

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2260008005	Mobile Sources	Off-highway Vehicle Gasoline	Airport Ground Support Equipment	2-Stroke Airport Ground Support Equipment
2265008005	Mobile Sources	Off-highway Vehicle Gasoline	Airport Ground Support Equipment	4-Stroke Airport Ground Support Equipment

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2267008005	Mobile Sources	Off-highway Vehicle LPG	Airport Ground Support Equipment	LPG Airport Ground Support Equipment
2268008005	Mobile Sources	Off-highway Vehicle CNG	Airport Ground Support Equipment	CNG Airport Ground Support Equipment
2270008005	Mobile Sources	Off-highway Vehicle Diesel	Airport Ground Support Equipment	Airport Ground Support Equipment
2275001000	Mobile Sources	Aircraft	Military Aircraft	Total
2275020000	Mobile Sources	Aircraft	Commercial Aircraft	Total: All Types
2275050011	Mobile Sources	Aircraft	General Aviation	Piston
2275050012	Mobile Sources	Aircraft	General Aviation	Turbine
2275060011	Mobile Sources	Aircraft	Air Taxi	Piston
2275060012	Mobile Sources	Aircraft	Air Taxi	Turbine
2275070000	Mobile Sources	Aircraft	Aircraft Auxiliary Power Units	Total
40600307	Chemical Evaporation	Transportation and Marketing of Petroleum Products	Gasoline Retail Operations – Stage I	Underground Tank: Breathing and Emptying
20200102	Internal Combustion Engines	Industrial	Distillate Oil (Diesel)	Reciprocating

2.1.4 Non-IPM sector (ptnonipm)

With some exceptions, the non-IPM (ptnonipm) sector contains the point sources that are not in the ptegu, pt_oilgas, or airports sectors. For the most part, the ptnonipm sector reflects the non-EGU emissions sources and rail yards. However, it is likely that some low-emitting EGUs not matched to units the NEEDS database or to CEMS data are in the ptnonipm sector.

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 NEI 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.

The ptnonipm sources (i.e., not EGUs and non -oil and gas sources) were used as-is from the 2019 NEI point inventory. Unlike in the 2018 platform, instead of removing solvent emissions from the ptnonipm sector, solvent emissions from point sources are instead removed from the np_solvents sector to prevent double counting, so that all point sources can be retained in the modeling as point sources rather than as area sources. The modeling was based on a version of the point flat file which included corrections to how the selection was implemented in EIS, updates from the state/local review, and updates specific to ethylene oxide. The np_solvents sector is described in more detail in Section 2.2.6.

Emissions from rail yards are included in the ptnonipm sector. Railyards were projected to 2019 from the 2017 NEI railyard inventory using factors derived from the Annual Energy Outlook 2018 (<https://www.eia.gov/outlooks/archive/aeo18/>).

2.2 Nonpoint sources (afdust, fertilizer, livestock, np_oilgas, rwc, np_solvents, nonpt)

This section describes the *stationary* nonpoint sources in the NEI nonpoint data category. Locomotives, C1 and C2 CMV, and C3 CMV are included in the NEI nonpoint data category but are mobile sources that are described in Section 2.4. The 2017 NEI TSD includes documentation for the nonpoint data.

Nonpoint tribal emissions submitted to the NEI 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 resolution used for this platform.

The following subsections describe how the sources in the NEI nonpoint inventory were separated into 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 PM₁₀ and PM_{2.5} emission estimates for nonpoint SCCs identified by EPA 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. Table 2-5 is a listing of the Source Classification Codes (SCCs) in the afdust sector.

Table 2-5. Afdust sector SCCs

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2275085000	Mobile Sources	Aircraft	Unpaved Airstrips	Total
2294000000	Mobile Sources	Paved Roads	All Paved Roads	Total: Fugitives
2296000000	Mobile Sources	Unpaved Roads	All Unpaved Roads	Total: Fugitives
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
2325000000	Industrial Processes	Mining and Quarrying: SIC 14	All Processes	Total
2325060000	Industrial Processes	Mining and Quarrying: SIC 10	Lead Ore Mining and Milling	Total

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2801000000	Miscellaneous Area Sources	Ag. Production - Crops	Agriculture – Crops	Total
2801000003	Miscellaneous Area Sources	Ag. Production - Crops	Agriculture – Crops	Tilling
2801000005	Miscellaneous Area Sources	Ag. Production - Crops	Agriculture – Crops	Harvesting
2801000007	Miscellaneous Area Sources	Ag. Production - Crops	Agriculture – Crops	Loading
2801000008	Miscellaneous Area Sources	Ag. Production - Crops	Agriculture - Crops	Transport
2805001000	Miscellaneous Area Sources	Ag. Production - Livestock	Beef cattle - finishing operations on feedlots (drylots)	Dust Kicked-up by Hooves (use 28-05-020, -001, -002, or -003 for Waste)
2805001100	Miscellaneous Area Sources	Ag. Production - Livestock	Beef cattle - finishing operations on feedlots (drylots)	Confinement
2805001200	Miscellaneous Area Sources	Agriculture Production – Livestock	Beef cattle - finishing operations on feedlots (drylots)	Manure handling and storage
2805001300	Miscellaneous Area Sources	Agriculture Production – Livestock	Beef cattle - finishing operations on feedlots (drylots)	Land application of manure
2805002000	Miscellaneous Area Sources	Ag. Production - Livestock	Beef cattle production composite	Not Elsewhere Classified
2805003100	Miscellaneous Area Sources	Ag. Production - Livestock	Beef cattle - finishing operations on pasture/range	Confinement
2805007100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with dry manure management systems	Confinement
2805007300	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with dry manure management systems	Land application of manure
2805008100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with wet manure management systems	Confinement
2805008200	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with wet manure management systems	Manure handling and storage
2805008300	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with wet manure management systems	Land application of manure
2805009100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production – broilers	Confinement
2805009200	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - broilers	Manure handling and storage
2805009300	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - broilers	Land application of manure
2805010100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - turkeys	Confinement
2805010200	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - turkeys	Manure handling and storage
2805010300	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - turkeys	Land application of manure
2805018000	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle composite	Not Elsewhere Classified
2805019100	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - flush dairy	Confinement
2805019200	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - flush dairy	Manure handling and storage

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2805019300	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - flush dairy	Land application of manure
2805020002	Miscellaneous Area Sources	Ag. Production - Livestock	Cattle and Calves Waste Emissions	Beef Cows
2805021100	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - scrape dairy	Confinement
2805021200	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - scrape dairy	Manure handling and storage
2805021300	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - scrape dairy	Land application of manure
2805022100	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - deep pit dairy	Confinement
2805022200	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - deep pit dairy	Manure handling and storage
2805022300	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - deep pit dairy	Land application of manure
2805023100	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - drylot/pasture dairy	Confinement
2805023200	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - drylot/pasture dairy	Manure handling and storage
2805023300	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle - drylot/pasture dairy	Land application of manure
2805025000	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production composite	Not Elsewhere Classified (see also 28-05-039, -047, -053)
2805030000	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry Waste Emissions	Not Elsewhere Classified (see also 28-05-007, -008, -009)
2805030007	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry Waste Emissions	Ducks
2805030008	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry Waste Emissions	Geese
2805035000	Miscellaneous Area Sources	Ag. Production - Livestock	Horses and Ponies Waste Emissions	Not Elsewhere Classified
2805039100	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production - operations with lagoons (unspecified animal age)	Confinement
2805039200	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production - operations with lagoons (unspecified animal age)	Manure handling and storage
2805039300	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production - operations with lagoons (unspecified animal age)	Land application of manure
2805040000	Miscellaneous Area Sources	Ag. Production - Livestock	Sheep and Lambs Waste Emissions	Total
2805045000	Miscellaneous Area Sources	Ag. Production - Livestock	Goats Waste Emissions	Not Elsewhere Classified
2805047100	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production - deep-pit house operations (unspecified animal age)	Confinement
2805047300	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production - deep-pit house operations (unspecified animal age)	Land application of manure

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2805053100	Miscellaneous Area Sources	Ag. Production – Livestock	Swine production - outdoor operations (unspecified animal age)	Confinement

Area Fugitive Dust Transport Fraction

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 using a script that applies land use-based gridded transport fractions based on landscape roughness, 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 (i.e., 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.

Paved road dust emissions were projected from the 2017 NEI (January 2021 version) to 2019 based on county-level VMT trends. All other afdust SCCs were held constant from the 2017 NEI. For the data compiled into the 2017 NEI, meteorological adjustments are applied to paved and unpaved road SCCs but not transport adjustments. This is because the modeling platform applies meteorological adjustments and transport adjustments based on unadjusted NEI values. For the 2019 platform, the meteorological adjustments that were applied (to paved and unpaved road SCCs) were backed out in order to reapply them in SMOKE. The FF10 that is run through SMOKE consists of 100% unadjusted emissions, and after SMOKE all afdust sources have both transport and meteorological adjustments applied according to year 2019 meteorology. The total impacts of the transport fraction and meteorological adjustments are shown in Table 2-6.

Table 2-6. Total impact of 2019 fugitive dust adjustments to unadjusted inventory

State	Unadjusted PM ₁₀	Unadjusted PM _{2.5}	Change in PM ₁₀	Change in PM _{2.5}	PM ₁₀ Reduction	PM _{2.5} Reduction
Alabama	305,723	41,233	-226,882	-30,594	74%	74%
Arizona	182,678	24,595	-70,907	-9,336	39%	38%
Arkansas	394,331	54,609	-298,345	-40,764	76%	75%
California	309,117	39,089	-142,624	-17,506	46%	45%
Colorado	282,549	41,231	-157,591	-22,073	56%	54%
Connecticut	24,371	4,017	-18,153	-3,008	74%	75%
Delaware	15,495	2,387	-8,946	-1,378	58%	58%
District of Columbia	2,917	411	-1,925	-272	66%	66%
Florida	401,015	56,239	-202,591	-28,525	51%	51%
Georgia	296,289	42,312	-221,610	-31,451	75%	74%

State	Unadjusted PM ₁₀	Unadjusted PM _{2.5}	Change in PM ₁₀	Change in PM _{2.5}	PM ₁₀ Reduction	PM _{2.5} Reduction
Idaho	567,238	65,579	-309,299	-34,601	55%	53%
Illinois	1,113,281	160,628	-795,705	-113,834	71%	71%
Indiana	145,852	27,266	-108,290	-20,364	74%	75%
Iowa	388,689	57,217	-288,740	-42,362	74%	74%
Kansas	671,034	89,491	-362,556	-47,414	54%	53%
Kentucky	177,719	29,040	-138,584	-22,580	78%	78%
Louisiana	180,636	27,639	-128,333	-19,570	71%	71%
Maine	71,411	8,760	-58,419	-7,182	82%	82%
Maryland	75,179	12,041	-47,908	-7,705	64%	64%
Massachusetts	62,941	9,664	-46,285	-7,022	74%	73%
Michigan	295,296	38,885	-215,083	-28,314	73%	73%
Minnesota	426,656	60,102	-311,323	-43,482	73%	72%
Mississippi	450,550	55,090	-343,086	-41,839	76%	76%
Missouri	1,345,973	159,831	-1,009,469	-119,626	75%	75%
Montana	503,803	66,808	-343,134	-44,300	68%	66%
Nebraska	518,897	71,883	-277,678	-37,564	54%	52%
Nevada	138,115	18,381	-54,526	-7,235	39%	39%
New Hampshire	20,851	4,383	-17,036	-3,570	82%	81%
New Jersey	33,085	6,207	-21,603	-3,997	65%	64%
New Mexico	213,114	26,553	-88,902	-11,014	42%	41%
New York	235,820	33,306	-183,374	-25,761	78%	77%
North Carolina	237,850	32,255	-171,865	-23,424	72%	73%
North Dakota	392,477	60,825	-269,361	-41,224	69%	68%
Ohio	273,742	42,761	-211,550	-33,102	77%	77%
Oklahoma	605,743	82,607	-335,543	-44,769	55%	54%
Oregon	611,291	68,882	-393,222	-43,504	64%	63%
Pennsylvania	136,536	24,510	-102,909	-18,752	75%	77%
Rhode Island	4,579	756	-3,100	-508	68%	67%
South Carolina	120,753	16,860	-85,074	-11,943	70%	71%
South Dakota	216,915	38,680	-148,482	-26,229	68%	68%
Tennessee	142,974	26,279	-106,647	-19,662	75%	75%
Texas	1,348,851	196,540	-702,631	-100,132	52%	51%
Utah	170,499	21,811	-99,452	-12,537	58%	57%
Vermont	76,845	8,552	-68,243	-7,582	89%	89%
Virginia	126,330	20,377	-99,572	-16,187	79%	79%
Washington	233,795	38,104	-118,973	-19,266	51%	51%
West Virginia	85,395	11,036	-76,326	-9,867	89%	89%
Wisconsin	184,730	31,429	-137,894	-23,449	75%	75%

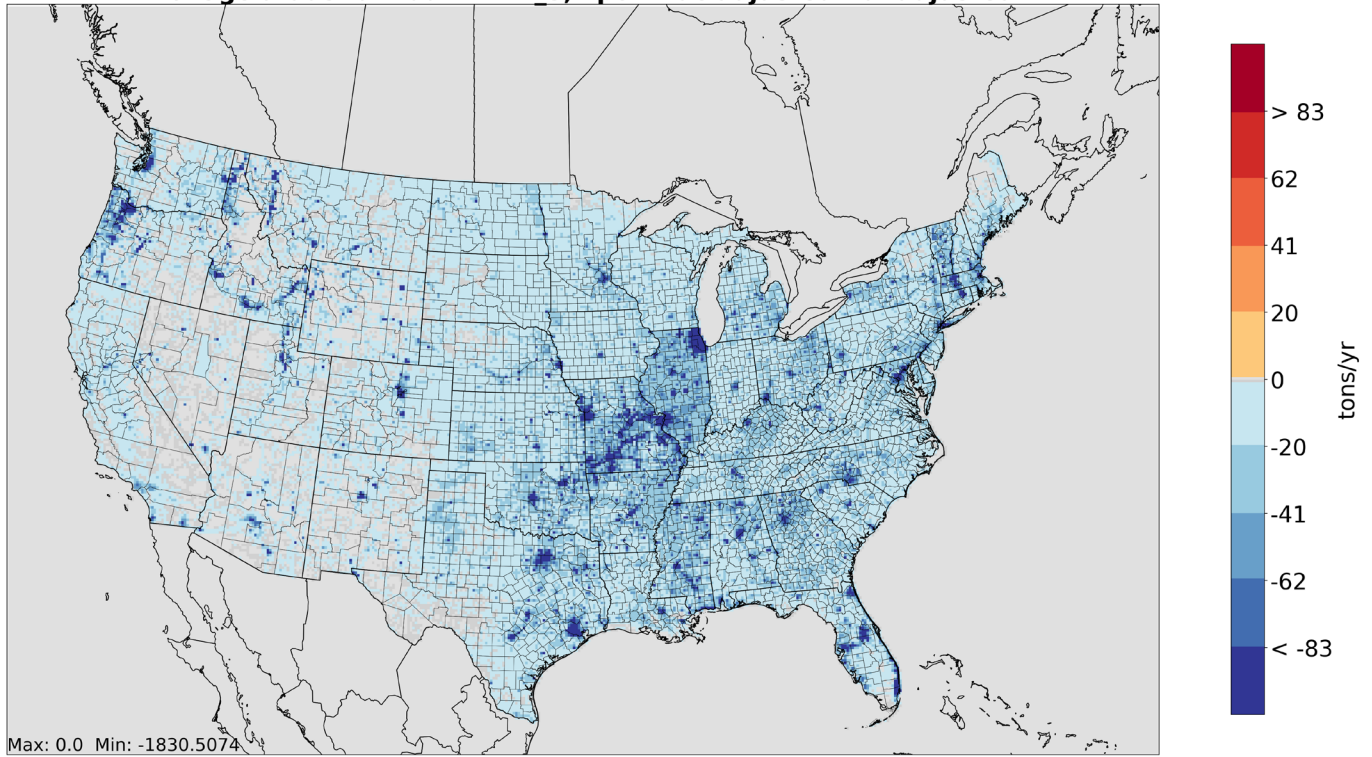
State	Unadjusted PM ₁₀	Unadjusted PM _{2.5}	Change in PM ₁₀	Change in PM _{2.5}	PM ₁₀ Reduction	PM _{2.5} Reduction
Wyoming	545,571	61,280	-343,987	-38,276	63%	62%
Domain Total (12km CONUS)	15,365,503	2,118,419	-9,973,736	-1,364,656	65%	64%
Alaska	107,903	11,775	N/A	N/A	N/A	N/A
Hawaii	18,276	2,389	N/A	N/A	N/A	N/A
Puerto Rico	1,133,401	150,742	N/A	N/A	N/A	N/A
Virgin Islands	1,777	245	N/A	N/A	N/A	N/A

For categories other than paved and unpaved roads, where states submitted afdust data, it was assumed that the state-submitted data were not met-adjusted and therefore the meteorological adjustments were applied. Thus, if states submitted data that were met-adjusted for sources other than paved and unpaved roads, these sources would have been adjusted for meteorology twice. Even with that possibility, air quality modeling shows that, in general, dust is frequently overestimated in the air quality modeling results.

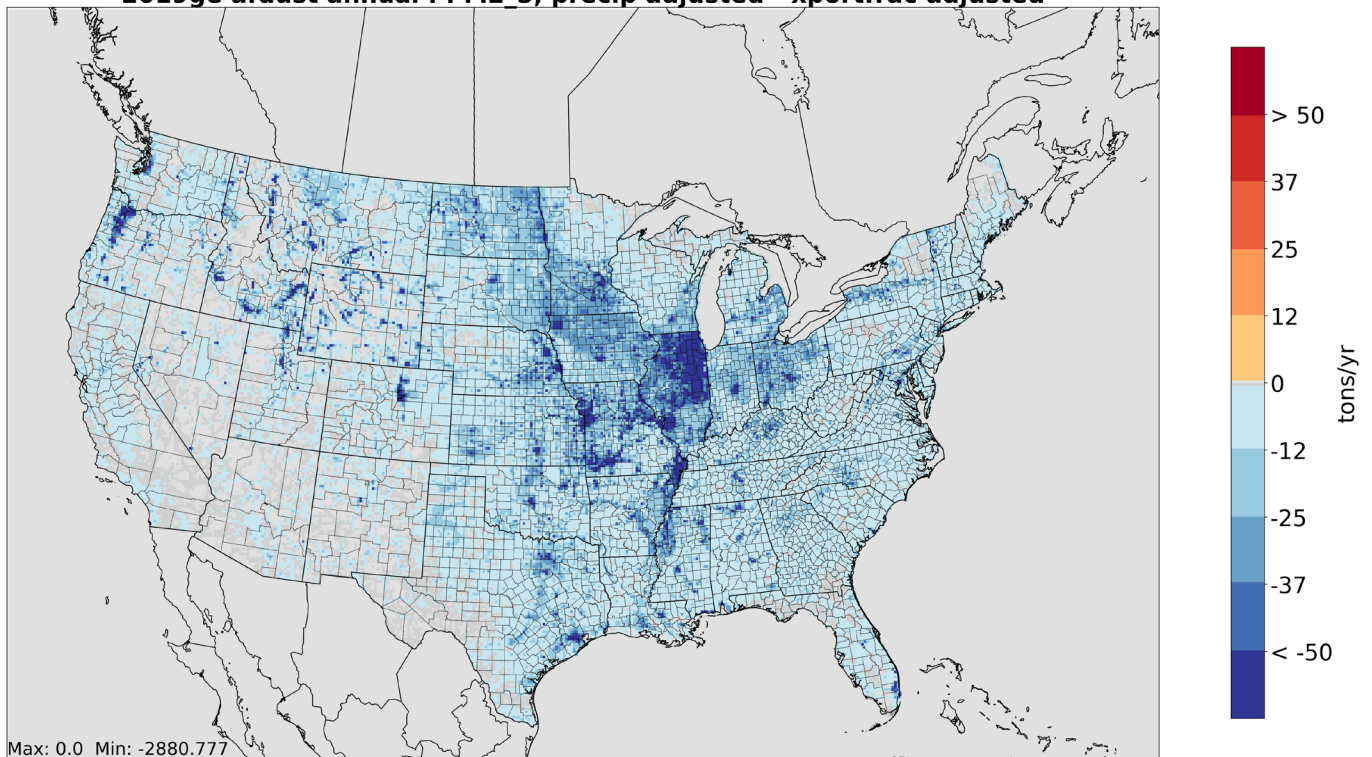
Figure 2-1 illustrates the impact of each step of the adjustment. The reductions due to the transport fraction adjustments alone are shown at the top of the figure. The reductions due to the precipitation adjustments alone are shown in the middle of the figure. The cumulative emission reductions after both transport fraction and meteorological adjustments are shown at the bottom of the figure. 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.

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

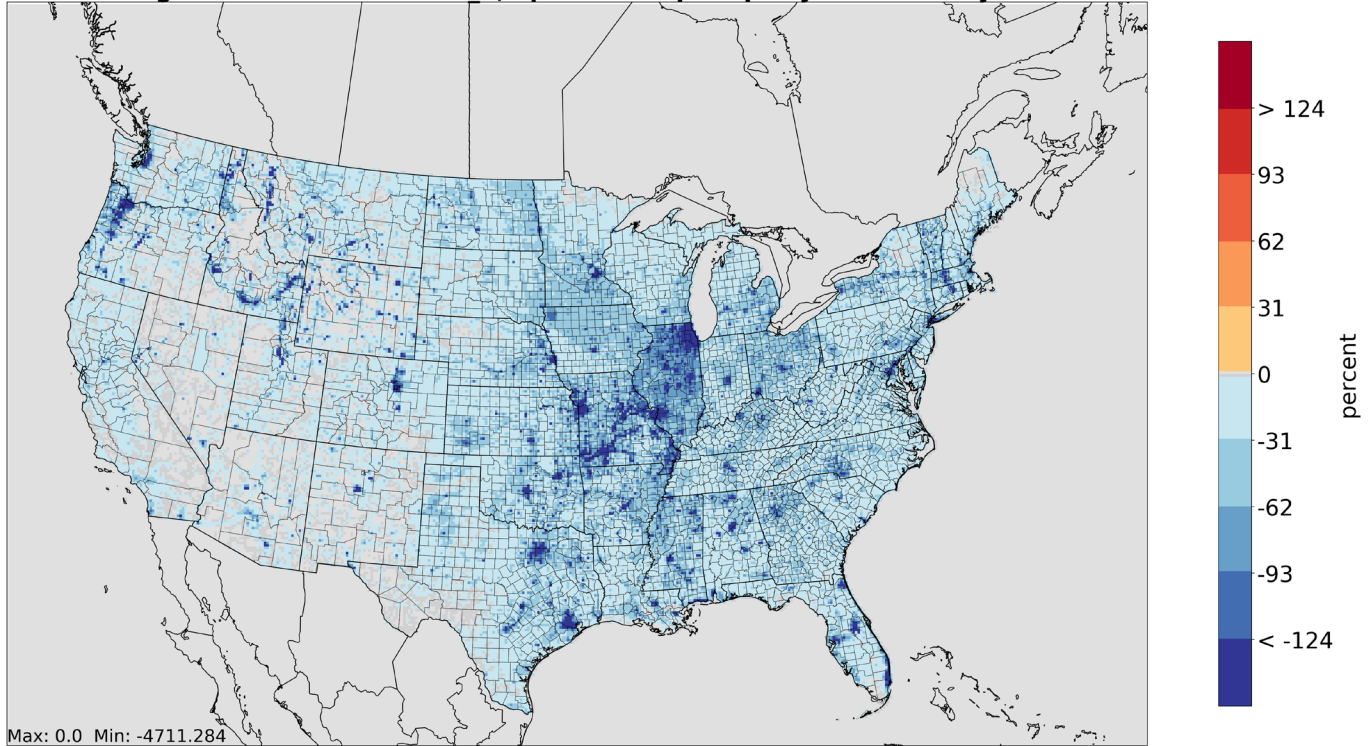
2019ge afdust annual : PM2_5, xportfrac adjusted - unadjusted



2019ge afdust annual : PM2_5, precip adjusted - xportfrac adjusted



2019ge afdust annual : PM2 5, xportfrac + precip adjusted - unadjusted



2.2.2 Agricultural Livestock (livestock)

The livestock SCCs are shown in Table 2-7. The livestock SCCs are related to beef and dairy cattle, poultry production and waste, swine production, waste from horses and ponies, and production and waste for sheep, lambs, and goats. The sector does not include quite all of the livestock NH₃ emissions, as there is a very small amount of NH₃ emissions from livestock in the ptnonipm inventory (as point sources). In addition to NH₃, the sector includes livestock emissions from all pollutants other than PM_{2.5}. PM_{2.5} from livestock are in the afdust sector.

Agricultural livestock emissions in the 2019 platform were projected from the 2017 NEI (January 2021 version), which is a mix of state-submitted data and EPA estimates. USDA Survey data for 2017 and 2019 was used to create projection factors (<https://quickstats.nass.usda.gov/>). Livestock emissions utilized improved animal population data. VOC livestock emissions, new for this sector, were estimated by multiplying a national VOC/NH₃ emissions ratio by the county NH₃ emissions. The 2017 NEI approach for livestock utilizes daily emission factors by animal and county from a model developed by Carnegie Mellon University (CMU) (Pinder, 2004, McQuilling, 2015) and 2017 U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) survey. Details on the approach are provided in Section 4.5 of the 2017 NEI TSD.

Table 2-7. SCCs for the livestock sector

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2805002000	Miscellaneous Area Sources	Ag. Production - Livestock	Beef cattle production composite	Not Elsewhere Classified

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2805007100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - layers with dry manure management systems	Confinement
2805009100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - broilers	Confinement
2805010100	Miscellaneous Area Sources	Ag. Production - Livestock	Poultry production - turkeys	Confinement
2805018000	Miscellaneous Area Sources	Ag. Production - Livestock	Dairy cattle composite	Not Elsewhere Classified
2805025000	Miscellaneous Area Sources	Ag. Production - Livestock	Swine production composite	Not Elsewhere Classified (see also 28-05-039, -047, -053)
2805035000	Miscellaneous Area Sources	Ag. Production - Livestock	Horses and Ponies Waste Emissions	Not Elsewhere Classified
2805040000	Miscellaneous Area Sources	Ag. Production - Livestock	Sheep and Lambs Waste Emissions	Total
2805045000	Miscellaneous Area Sources	Ag. Production - Livestock	Goats Waste Emissions	Not Elsewhere Classified

Agricultural livestock emissions in the 2019 platform are based on the 2017 NEI (January 2021 version), which is a mix of state-submitted data and EPA estimates. Livestock emissions utilized improved animal population data. VOC livestock emissions, new for this sector, were estimated by multiplying a national VOC/NH₃ emissions ratio by the county NH₃ emissions. The 2017 NEI approach for livestock utilizes daily emission factors by animal and county from a model developed by Carnegie Mellon University (CMU) (Pinder, 2004, McQuilling, 2015) and 2017 U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) survey. Details on the approach are provided in Section 4.5 of the 2017 NEI TSD.

For livestock, meteorological-based temporalization (described in Section 3.3.10) is used for month-to-day and day-to-hour temporalization. Monthly profiles for livestock are based on the daily data underlying the EPA estimates from 2014NEIv2.

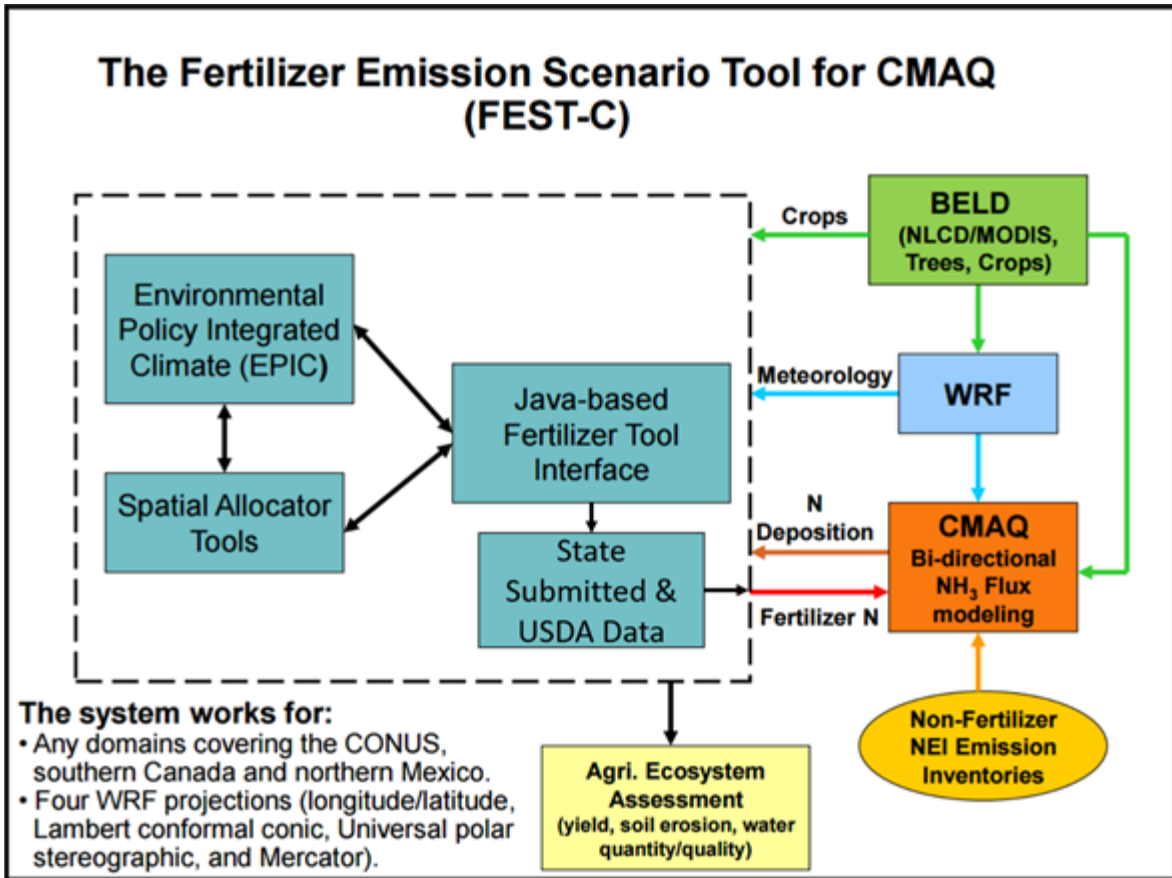
2.2.3 Agricultural Fertilizer (fertilizer)

As described in the 2017 NEI TSD, fertilizer emissions for 2017 are based on the FEST-C model (<https://www.cmascenter.org/fest-c/>). Unlike most of the other emissions that are input to the CMAQ model, fertilizer emissions are actually output from a run of CMAQ in bi-directional mode and summarized for inclusion with the rest of the emissions. The bidirectional version of CMAQ (v5.3) and the Fertilizer Emissions Scenario Tool for CMAQ FEST-C (v1.3) were used to estimate ammonia (NH₃) emissions from agricultural soils. The computed emissions were saved during the CMAQ run for the purposes of summaries and other model runs that did not use the bidirectional method.

FEST-C is the software program that processes land use and agricultural activity data to develop inputs for the CMAQ model when run with bidirectional exchange. FEST-C reads land use data from the Biogenic Emissions Landuse Dataset (BELD), meteorological variables from the Weather Research and Forecasting (WRF) model, and nitrogen deposition data from a previous or historical average CMAQ simulation. FEST-C, then uses the Environmental Policy Integrated Climate (EPIC) modeling system (<https://epicapex.tamu.edu/epic/>) to simulate the agricultural practices and soil biogeochemistry and provides information regarding fertilizer timing, composition, application method and amount.

An iterative calculation was applied to estimate fertilizer emissions. First, fertilizer application by crop type was estimated using FEST-C modeled data. Then CMAQ v5.3 was run with the Surface Tiled Aerosol and Gaseous Exchange (STAGE) deposition option with bidirectional exchange to estimate fertilizer and biogenic NH₃ emissions.

Figure 2-2. “Bidi” modeling system used to compute emissions from fertilizer application



Fertilizer Activity Data

The following activity parameters were input into the EPIC model:

- Grid cell meteorological variables from WRF
- Initial soil profiles/soil selection
- Presence of 21 major crops: irrigated and rain fed hay, alfalfa, grass, barley, beans, grain corn, silage corn, cotton, oats, peanuts, potatoes, rice, rye, grain sorghum, silage sorghum, soybeans, spring wheat, winter wheat, canola, and other crops (e.g., lettuce, tomatoes, etc.)
- Fertilizer sales to establish the type/composition of nutrients applied
- Management scenarios for the 10 USDA production regions. These include irrigation, tile drainage, intervals between forage harvest, fertilizer application method (injected versus surface applied), and equipment commonly used in these production regions.

The WRF meteorological model was used to provide grid cell meteorological parameters for year 2017 using a national 12-km rectangular grid covering the continental U.S. The meteorological parameters in Table 2-8 were used as EPIC model inputs.

Table 2-8. Source of input variables for EPIC

EPIC input variable	Variable Source
Daily Total Radiation (MJ/m ²)	WRF
Daily Maximum 2-m Temperature (C)	WRF
Daily minimum 2-m temperature (C)	WRF
Daily Total Precipitation (mm)	WRF
Daily Average Relative Humidity (unitless)	WRF
Daily Average 10-m Wind Speed (m s ⁻¹)	WRF
Daily Total Wet Deposition Oxidized N (g/ha)	CMAQ
Daily Total Wet Deposition Reduced N (g/ha)	CMAQ
Daily Total Dry Deposition Oxidized N (g/ha)	CMAQ
Daily Total Dry Deposition Reduced N (g/ha)	CMAQ
Daily Total Wet Deposition Organic N (g/ha)	CMAQ

Initial soil nutrient and pH conditions in EPIC were based on the 1992 USDA Soil Conservation Service (CSC) Soils-5 survey. The EPIC model then was run for 25 years using current fertilization and agricultural cropping techniques to estimate soil nutrient content and pH for the 2017 EPIC/WRF/CMAQ simulation.

The presence of crops in each model grid cell was determined using USDA Census of Agriculture data (2012) and USGS National Land Cover data (2011). These two data sources were used to compute the fraction of agricultural land in a model grid cell and the mix of crops grown on that land.

Fertilizer sales data and the 6-month period in which they were sold were extracted from the 2014 Association of American Plant Food Control Officials (AAPFCO, <http://www.aapfco.org/publications.html>). AAPFCO data were used to identify the composition (e.g., urea, nitrate, organic) of the fertilizer used, and the amount applied is estimated using the modeled crop demand. These data were useful in making a reasonable assignment of what kind of fertilizer is being applied to which crops.

Management activity data refers to data used to estimate representative crop management schemes. The USDA Agricultural Resource Management Survey (ARMS, https://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Ag_Resource_Management/) was used to provide management activity data. These data cover 10 USDA production regions and provide management schemes for irrigated and rain fed hay, alfalfa, grass, barley, beans, grain corn, silage corn, cotton, oats, peanuts, potatoes, rice, rye, grain sorghum, silage sorghum, soybeans, spring wheat, winter wheat, canola, and other crops (e.g., lettuce, tomatoes, etc.).

2.2.4 Nonpoint Oil and Gas Sector (np_oilgas)

The nonpoint oil and gas (np_oilgas) sector includes onshore and offshore oil and gas emissions. The EPA estimated emissions for all counties with 2019 oil and gas activity data with the Oil and Gas Tool. 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. Because of the importance of emissions from this sector, special consideration is given to the speciation, spatial allocation, and monthly temporalization of nonpoint oil and gas emissions, instead of relying on older, more generalized profiles.

The 2017NEI version of the Nonpoint Oil and Gas Emission Estimation Tool (i.e., the “tool”) was used to estimate emissions for 2019. Year 2019 oil and gas activity data was supplied to EPA by Enverus’ activity database (www.enverus.com) and from some state air agencies. The tool is an Access database that utilizes county-level activity data (e.g., oil production and well counts), operational characteristics (types and sizes of equipment), and emission factors to estimate emissions. The tool created a CSV-formatted emissions dataset covering all national nonpoint oil and gas emissions. This dataset was then converted to the FF10 format for use in SMOKE modeling. More details on the inputs for and running of the tool using year 2017 as an example are provided in the 2017 NEI TSD. Table 2-9 shows the nonpoint oil and gas NOx and VOC emissions for 2017 and 2019 by state.

Table 2-9. Nonpoint oil and gas emissions for 2017 and 2019

State	2017 NOx	2019 NOx	2019 – 2017 NOx	2017 VOC	2019 VOC	2019-2017 VOC
Alabama	3,415	4,129	714	8,981	10,826	1,845
Alaska	482	2,152	1,670	981	10,752	9,771
Arizona	9	12	3	47	35	-12
Arkansas	7,230	6,879	-351	8,950	7,821	-1,129
California	3,523	591	-2,932	25,808	30,607	4,799
Colorado	30,558	31,631	1,073	103,462	74,143	-29,319
Florida	17	23	6	737	673	-64
Idaho	9	6	-3	178	58	-120
Illinois	13,355	13,492	137	53,539	56,596	3,057
Indiana	4,208	2,608	-1,600	15,332	11,996	-3,336
Kansas	51,851	33,117	-18,734	96,242	69,658	-26,584
Kentucky	12,972	12,802	-170	37,210	36,515	-695
Louisiana	19,202	20,982	1,780	54,829	55,832	1,003
Maryland	0	0	0	0	1	1
Michigan	9,349	8,119	-1,230	16,991	14,937	-2,054
Mississippi	1,732	1,579	-153	9,771	9,099	-672
Missouri	539	457	-82	1,216	1,032	-184
Montana	2,446	2,684	238	31,081	32,793	1,712
Nebraska	356	378	22	2,337	2,383	46
Nevada	2	2	0	149	148	-1
New Mexico	38,065	43,059	4,994	154,849	209,578	54,729
New York	601	666	65	5,410	6,303	893

State	2017 NO _x	2019 NO _x	2019 – 2017 NO _x	2017 VOC	2019 VOC	2019-2017 VOC
North Dakota	17,626	26,248	8,622	362,287	469,426	107,139
Ohio	2,783	1,813	-970	19,540	16,130	-3,410
Oklahoma	50,221	43,681	-6,540	154,292	177,368	23,076
Oregon	14	12	-2	26	21	-5
Pennsylvania	40,779	48,685	7,906	109,104	136,552	27,448
South Dakota	110	110	0	1,676	1,550	-126
Tennessee	835	783	-52	2,796	2,619	-177
Texas	225,191	165,065	-60,126	894,796	911,109	16,313
Utah	13,130	8,034	-5,096	69,903	61,403	-8,500
Virginia	3,485	3,481	-4	8,569	9,508	939
West Virginia	25,775	21,631	-4,144	85,457	75,943	-9,514
Wyoming	19,750	17,454	-2,296	77,573	88,712	11,139

2.2.5 Residential Wood Combustion (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 chimeneas. 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 have to meet EPA emission standards and they are either catalytic or non-catalytic. As with the other nonpoint categories, a mix of S/L and EPA estimates were used. The EPA’s estimates use updated methodologies for activity data and some changes to emission factors. The source classification codes (SCCs) in the RWC sector are listed in Table 2-10.

The 2019 platform RWC emissions are unchanged from the data in the 2017 NEI. Some improvements to RWC emissions estimates were made for the 2017 NEI and were included in this study. The EPA, along with the Commission on Environmental Cooperation (CEC), the Northeast States for Coordinated Air Use Management (NESCAUM), and Abt Associates, conducted a national survey of wood-burning activity in 2019. The results of this survey were used to estimate county-level burning activity data. The activity data for RWC processes is the amount of wood burned in each county, which is based on data from the CEC survey on the fraction of homes in each county that use each wood-burning appliance and the average amount of wood burned in each appliance. These assumptions are used with the number of occupied homes in each county to estimate the total amount of wood burned in each county, in cords for cordwood appliances and tons for pellet appliances. Cords of wood are converted to tons using county-level density factors from the U.S. Forest Service. RWC emissions were calculated by multiplying the tons of wood burned by emissions factors. For more information on the development of the residential wood combustion emissions, see Section 4.15 of the 2017 NEI TSD

Table 2-10. SCCs for the residential wood combustion sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
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2104008100	Stationary Source Fuel Combustion	Residential	Wood	Fireplace: general
2104008210	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; non-EPA certified
2104008220	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; EPA certified; non-catalytic
2104008230	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; EPA certified; catalytic
2104008300	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, general
2104008310	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, non-EPA certified
2104008320	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, EPA certified, non-catalytic
2104008330	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, EPA certified, catalytic
2104008400	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: pellet-fired, general (freestanding or FP insert)
2104008510	Stationary Source Fuel Combustion	Residential	Wood	Furnace: Indoor, cordwood-fired, non-EPA certified
2104008530	Stationary Source Fuel Combustion	Residential	Wood	Furnace: Indoor, pellet-fired, general
2104008610	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: outdoor
2104008620	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: indoor
2104008630	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: pellet-fired
2104008700	Stationary Source Fuel Combustion	Residential	Wood	Outdoor wood burning device, NEC (fire-pits, chimeneas, etc)
2104009000	Stationary Source Fuel Combustion	Residential	Firelog	Total: All Combustor Types

2.2.6 Solvents (np_solvents)

The np_solvents sector is a diverse collection of emission sources whose emissions are driven by evaporation. Included in this sector are everyday items, such as cleaners, personal care products, adhesives, architectural and aerosol coatings, printing inks, and pesticides. These sources exclusively emit organic gases and feature origins spanning residential, commercial, institutional, and industrial settings. The organic gases that evaporate from these sources often fulfill other functions than acting as a traditional solvent (e.g., propellants, fragrances, emollients).

Here, emissions from this sector are derived using the volatile chemical products in python (VCPy) framework (Seltzer et al., 2021). The VCPy framework is based on the principle that the magnitude and speciation of organic emissions from this sector are directly related to (1) the mass of chemical products used, (2) the composition of these products, (3) the physiochemical properties of their constituents that govern volatilization, and (4) the timescale available for these constituents to evaporate. National product usage is preferentially estimated using economic statistics from the U.S. Census Bureau's Annual Survey

of Manufacturers (U.S. Census Bureau, 2019), commodity prices from the U.S. Department of Transportation’s 2012 Commodity Flow Survey (U.S. Department of Transportation, 2015) and the U.S. Census Bureau’s Paint and Allied Products Survey (U.S. Census Bureau, 2011), and producer price indices, which scale commodity prices to target years, are retrieved from the Federal Reserve Bank of St. Louis (U.S. Bureau of Labor Statistics, 2020). In circumstances where the aforementioned datasets are unavailable, default usage estimates are derived using functional solvent usage reported by a business research company (The Freedonia Group, 2016) or in sales reported in a California Air Resources Board (CARB) California-specific survey (CARB, 2019). The composition of products is estimated by generating composites from various CARB surveys from 2007 through 2019, along with profiles reported in the U.S. EPA’s SPECIATE database (EPA, 2019). The physiochemical properties of all organic components are generated from the quantitative structure-activity relationship model OPERA (Mansouri et al., 2018) and the characteristic evaporation timescale of each component is estimated using previously published methods (Khare and Gentner, 2018; Weschler and Nazaroff, 2008).

National-level emissions are then allocated to the county-level using several proxies. Most emissions are allocated using population as a spatial surrogate. This includes all cleaners, personal care products, adhesives, architectural coatings, and aerosol coatings. Industrial coatings, allied paint products, printing inks, and dry cleaning emissions are allocated using county-level employment statistics from the U.S. Census Bureau’s County Business Patterns (U.S. Census Bureau, 2019) and follow the same mapping scheme used in the U.S. EPA’s 2017 National Emissions Inventory (EPA, 2021). Agricultural pesticides are allocated using county-level agricultural pesticide use, as taken from the 2017 NEI.

The version of VCPy used for this platform includes additional product aggregations, variation in the VOC-content of products to reflect state-level area source rules relevant to the solvent sector, and the adoption of an indoor emissions pathway. To compute VCP emissions indoors, each product category is assigned an indoor usage fraction. All coating and industrial products are assigned a 50% indoor emission fraction, all pesticides and automotive aftermarket products are assigned a 0% indoor emission fraction, and all consumer and cleaning products are assigned a 100% indoor emission fraction. The lone exception are daily use personal care products, which are assumed to have a 50% indoor emission fraction. This indoor emission assignment enables the mass transfer coefficient to vary between indoor and outdoor conditions. Typically, the mass transfer coefficient indoors is smaller than the mass transfer coefficient outdoors due to more stagnant atmospheric conditions, and the newest version of the modeling framework reflects these dynamics. Indoor product usage utilizes a mass transfer coefficient of 5 m/hr, and the remaining outdoor portion is assigned a mass transfer coefficient of 30 m/hr (Weschler and Nazaroff, 2008; Khare and Gentner, 2018).

The np_solvents sector also includes emissions from the 2017 NEI not covered by VCPy. This includes some State, Locality, and Tribal emission submissions for other CAPs, such as CO, NOX, and PM2.5. In addition, there are some SCCs not covered by VCPy but included in the np_solvents sector. Here, emissions for all of these sources are taken from the 2017 NEI and these SCCs are listed in Table 2-11.

Table 2-11. Non-VCPy SCCs in the np_solvents sector

SCC	Description
2401050000	Solvent Utilization;Surface Coating;Miscellaneous Finished Metals: SIC 34 - (341 + 3498);Total: All Solvent Types
2440020000	Solvent Utilization;Miscellaneous Industrial;Adhesive (Industrial) Application;Total: All Solvent Types

SCC	Description
2461020000	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Asphalt Application: All Processes;Total: All Solvent Types
2461021000	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Cutback Asphalt;Total: All Solvent Types
2461022000	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Emulsified Asphalt;Total: All Solvent Types
2461023000	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Asphalt Roofing;Total: All Solvent Types
2461800001	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Pesticide Application: All Processes;Surface Application

Finally, since emissions from solvents occur from both point and nonpoint SCCs, point source subtraction is required to ensure emissions from this sector are not double-counted. Point source subtraction for this sector is performed at the county-level using uncontrolled point source emissions. As such, assumptions related to the control efficiency of the point sources must be made. In most some cases, metadata indicates that the point source emission estimates submitted to the NEI feature 80-90% control efficiencies. Therefore, uncontrolled point source emission calculations are calculated, as necessary, using the submitted point source emissions, engineering judgement, and an assumed control efficiency. If point source subtraction results in negative emissions, emissions will zero out emissions for that source category in that county. The mapping of nonpoint SCCs to point SCCs follows the same crosswalk implemented for the 2020 NEI.

2.2.7 Nonpoint (nonpt)

The 2019 platform nonpt sector inventory is mostly unchanged from the January 2021 version of the 2017 NEI. Stationary nonpoint sources that were not subdivided into the afdust, livestock, fertilizer, np_oilgas, rwc or np_solvents sectors were assigned to the “nonpt” sector. Locomotives and CMV mobile sources from the 2017 NEI nonpoint inventory are described with the mobile sources. The types of sources in the nonpt sector include:

- stationary source fuel combustion, including industrial, commercial, and residential and orchard heaters;
- chemical manufacturing;
- industrial processes such as commercial cooking, metal production, mineral processes, petroleum refining, wood products, fabricated metals, and refrigeration;
- 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; and
- miscellaneous area sources such as cremation, hospitals, lamp breakage, and automotive repair shops.

The nonpt sector includes emission estimates for Portable Fuel Containers (PFCs), also known as “gas cans.” The PFC inventory consists of five distinct sources of PFC emissions, further distinguished by residential or commercial use. The five sources are: (1) displacement of the vapor within the can; (2)

spillage of gasoline while filling the can; (3) spillage of gasoline during transport; (4) emissions due to evaporation (i.e., diurnal emissions); and (5) emissions due to permeation. Note that spillage and vapor displacement associated with using PFCs to refuel nonroad equipment are included in the nonroad inventory.

Volatile chemical product (aka solvent) SCCs were placed into the solvents sector. The EPA incorporated new methods to estimate emissions of VOC and associated HAPs from the solvents sector, for this 2019 modeling platform (See section 3.2.1 for details). The new methods result in improved emissions estimates for the nonpoint (county-wide) solvent emissions. The new emissions method results in improved VOC and HAP estimates for nonpoint categories of coatings, pesticides, adhesives and sealants, oil & gas exploration solvent use, dry cleaning, printing inks, cleaning products, personal care products, and other miscellaneous solvent uses.

2.3 Onroad Mobile sources (onroad)

Onroad mobile source include emissions from motorized vehicles operating 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 by the fuel they use, including 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 as they move along the roads). For more details on the approach and for a summary of the MOVES inputs submitted by states, see section 6.5.1 of the 2017 NEI TSD.

For the 2019 modeling platform, VMT were projected from 2017 to 2019 based mostly on Federal Highways administration (FHWA) annual VMT changes at the county level. In a few cases, state Department of Transportation (DOT) data were used instead of FHWA data. Other activity data (i.e., starts, on-network idling, VPOP, and hoteling) are projected by applying a ratio of 2017-based VMT/activity ratios to the 2019 VMT. In addition, a number of states submitted 2017-specific activity data for incorporation into this platform. Finally, a new MOVES run for 2019 was done using MOVES3.

Except for California, all onroad emissions are generated using the SMOKE-MOVES emissions modeling framework that leverages MOVES-generated emission factors (<https://www.epa.gov/moves>), county and SCC-specific activity data, and hourly 2019 meteorological data. Specifically, EPA used MOVES3 inputs for representative counties, vehicle miles traveled (VMT), vehicle population (VPOP), and hoteling hours 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 data available from meteorological modeling that are also used for air quality modeling. The onroad source classification codes (SCCs) in the modeling platform are more finely resolved than those in the National Emissions Inventory (NEI). The NEI SCCs distinguish vehicles and fuels. The SCCs used in the model platform also distinguish between emissions processes (i.e., off-network, on-network, and extended idle), and road types.

MOVES3 includes the following updates from MOVES2014b:

- Updated emission rates:
 - Updated heavy-duty (HD) diesel running emission rates based on manufacturer in-use testing data from hundreds of HD trucks
 - Updated HD gasoline and compressed natural gas (CNG) trucks
 - Updated light-duty (LD) emission rates for hydrocarbons (HC), CO, NO_x, and PM

- Includes updated fuel information
- Incorporates HD Phase 2 Greenhouse Gas (GHG) rule, allowing for finer distinctions among HD vehicles
- Accounts for glider vehicles that incorporate older engines into new vehicle chassis
- Accounts for off-network idling – emissions beyond the idling that is already considered in the MOVES drive cycle
- Includes revisions to inputs for hoteling
- Adds starts as a separate type of rate and activity data

2.3.1 Inventory Development using SMOKE-MOVES

Except for California, onroad emissions were computed with SMOKE-MOVES by multiplying specific types of vehicle activity data by the appropriate emission factors. This section includes discussions of the activity data and the emission factor development. The vehicles (aka source types) for which MOVES computes emissions are shown in Table 2-12. SMOKE-MOVES was run for specific modeling grids. Emissions for the contiguous U.S. states and Washington, D.C., were computed for a grid covering those areas. Emissions for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands, typically computed by running SMOKE-MOVES for distinct grids covering each of those regions, have not been processed for 2019.

Table 2-12. MOVES vehicle (source) types

MOVES vehicle type	Description	HPMS vehicle type
11	Motorcycle	10
21	Passenger Car	25
31	Passenger Truck	25
32	Light Commercial Truck	25
41	Intercity Bus	40
42	Transit Bus	40
43	School Bus	40
51	Refuse Truck	50
52	Single Unit Short-haul Truck	50
53	Single Unit Long-haul Truck	50
54	Motor Home	50
61	Combination Short-haul Truck	60
62	Combination Long-haul Truck	60

SMOKE-MOVES makes use of emission rate “lookup” tables generated by MOVES that 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 year 2019-specific emission factors by temperature and speed for a series of “representative counties,” to which every other county was mapped. The representative counties for which emission factors are generated are selected according to their state, elevation, fuels, age distribution, ramp fraction, and inspection and maintenance programs. Each county is then mapped to a representative county based on its similarity to the representative county with respect to those attributes. For this study, there are 294 representative counties in the continental U.S. and a total

of 332 including the non-CONUS areas. The representative counties that were used for the 2019 platform are the same as in the 2016 version 2 modeling platform, and very close to what was used in EPA's Air Quality Time Series (EQUATES) project for 2016/2017. The EPA added some additional representative counties to the set used for EQUATES to account for altitude and variations in I&M programs and fuels.

Once representative counties have been identified, emission factors are generated with MOVES for each representative county and for two "fuel months" – January to represent winter months, and July to represent summer months – due to the different types of fuels used. SMOKE selects the appropriate MOVES emissions rates for each county, hourly temperature, SCC, and speed bin and then multiplies the emission rate by appropriate activity data. For on-roadway emissions, vehicle miles travelled (VMT) is the activity data; off-network processes use vehicle population (VPOP), vehicle starts, and hours of off-network idling (ONI); and hoteling hours are used to develop emissions for extended idling of combination long-haul trucks. These calculations are 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 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, STARTS, off-network idling, 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 six processing streams that are merged together into the onroad sector emissions after each of the six streams have been processed:

- 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 VPOP activity data to compute off-network emissions from exhaust, evaporative, permeation, and refueling processes;
- rate-per-profile (RPS) uses STARTS activity data to compute off-network emissions from vehicles starts;
- rate-per-profile (RPP) uses VPOP activity data to compute off-network emissions from evaporative fuel vapor venting, including hot soak (immediately after a trip) and diurnal (vehicle parked for a long period) emissions;
- 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; and

- rate-per-hour off-network idling (RPHO) uses off network idling hours activity data to compute off-network idling emissions for all types of vehicles.

The onroad emissions inputs to MOVES for the 2019 platform are based on the 2017 NEI, described in more detail in Section 6 of the 2017 NEI TSD. These inputs include:

- Key parameters in the MOVES County databases (CDBs) including Low Emission Vehicle (LEV) table
- Fuel months
- Activity data (e.g., VMT, VPOP, speed, HOTELING)

Fuel months and other inputs were consistent with those in the 2017 NEI. Age distributions in the MOVES databases were adjusted to represent the year 2019. States that submitted activity data and development of the EPA default activity data sets for VMT, VPOP, and hoteling hours are described in detail in the 2017 NEI TSD and supporting documents. Hoteling hours activity are used to calculate emissions from extended idling and auxiliary power units (APUs) by combination long-haul trucks.

2.3.2 Onroad Activity Data Development

SMOKE-MOVES uses vehicle miles traveled (VMT), vehicle population (VPOP), vehicle starts, hours of off-network idling (ONI), and hours of hoteling, to calculate emissions. These datasets are collectively known as “activity data”. For each of these activity datasets, first a national dataset was developed; this national dataset is called the “EPA default” dataset. The default dataset started with the 2017 NEI activity data, which was supplemented with data submitted by state and local agencies. EPA default activity was used for California, but the emissions were scaled to California-supplied values during the emissions processing.

Vehicle Miles Traveled (VMT) and Vehicle Population (VPOP)

States that submitted activity data and development of the EPA default activity data sets for VMT, VPOP, and hoteling hours are described in detail in the 2017 NEI TSD (EPA, 2021) and supporting documents. For the 2019 modeling platform, VMT were projected from 2017 to 2019 based mostly on Federal Highways administration (FHWA) annual VMT changes at the county level. In Georgia, state Department of Transportation (DOT) data were used instead of FHWA data. In Oklahoma, human population trends were used for 2017 to 2018 and FHWA-based factors were used to project from 2018 to 2019.

Speed Activity (SPEED/SPDIST)

In SMOKE 4.7, SMOKE-MOVES was updated to use speed distributions similarly to how they are used when running MOVES in inventory mode. This new speed distribution file, called SPDIST, specifies the amount of time spent in each MOVES speed bin for each county, vehicle (aka source) type, road type, weekday/weekend, and hour of day. This file contains the same information at the same resolution as the Speed Distribution table used by MOVES but is reformatted for SMOKE. Using the SPDIST file results in a SMOKE emissions calculation that is more consistent with MOVES than the old hourly speed profile (SPDPRO) approach, because emission factors from all speed bins can be used, rather than interpolating between the two bins surrounding the single average speed value for each hour as is done with the SPDPRO approach.

As was the case with the previous SPDPRO approach, the SPEED inventory that includes a single overall average speed for each county, SCC, and month, must still be read in by the SMOKE program Smkinven. SMOKE requires the SPEED dataset to exist even when speed distribution data are available, even though only the speed distribution data affects the selection of emission factors. The SPEED and SPDIST for 2017NEI are based on a combination of the CRC A-100 (CRC, 2017) project data and 2017 NEI MOVES CDBs.

Hoteling Hours (HOTELING)

Hoteling hours were capped by county at a theoretical maximum and any excess hours of the maximum were reduced. For calculating reductions, a dataset of truck stop parking space availability was used, which includes a total number of parking spaces per county. This same dataset is used to develop the spatial surrogate for allocating county-total hoteling emissions to model grid cells. The parking space dataset includes several recent updates based on new truck stops opening and other new information. There are 8,760 hours in the year 2019; therefore, the maximum number of possible hoteling hours in a particular county is equal to 8,760 * the number of parking spaces in that county. Hoteling hours were capped at that theoretical maximum value for 2017 in all counties, with some exceptions.

Because the truck stop parking space dataset may be incomplete in some areas, and trucks may sometimes idle in areas other than designated spaces, it was assumed that every county has at least 12 parking spaces, even if fewer parking spaces are found in the parking space dataset. Therefore, hoteling hours are never reduced below 105,408 hours for the year in any county. If the unreduced hoteling hours were already below that maximum, the hours were left unchanged; in other words, hoteling activity are never increased as a result of this analysis. Four states requested that no reductions be applied to the hoteling activity based on parking space availability: CO, ME, NJ, and NY. For these states, reductions based on parking space availability were not applied.

The final step related to hoteling activity is to split county totals into separate values for extended idling (SCC 2202620153) and Auxiliary Power Units (APUs) (SCC 2202620191). For 2019 modeling with MOVES3, a 6.9% APU split is used nationwide, meaning that during 6.9% of the hoteling hours auxiliary power units are assumed to be running.

Starts

Onroad “start” emissions are the instantaneous exhaust emissions that occur at the engine start (e.g., due to the fuel rich conditions in the cylinder to initiate combustion) as well as the additional running exhaust emissions that occur because the engine and emission control systems have not yet stabilized at the running operating temperature. Operationally, start emissions are defined as the difference in emissions between an exhaust emissions test with an ambient temperature start and the same test with the engine and emission control systems already at operating temperature. As such, the units for start emission rates are instantaneous grams/start.

MOVES3 uses vehicle population information to sort the vehicle population into source bins defined by vehicle source type, fuel type (gas, diesel, etc.), regulatory class, model year and age. The model uses default data from instrumented vehicles (or user-provided values) to estimate the number of starts for each source bin and to allocate them among eight operating mode bins defined by the amount of time parked (“soak time”) prior to the start. Thus, MOVES3 accounts for different amounts of cooling of the engine and emission control systems. Each source bin and operating mode has an associated g/start

emission rate. Start emissions are also adjusted to account for fuel characteristics, LD inspection and maintenance programs, and ambient temperatures.

$$2019 \text{ STARTS} = 2019 \text{ VMT} * (2017 \text{ STARTS} / 2017 \text{ VMT by county \& SCC6})$$

Off-network Idling Hours

After creating VMT inputs for SMOKE-MOVES, Off-network idle (ONI) activity data were also needed. ONI is defined in MOVES as time during which a vehicle engine is running idle and the vehicle is somewhere other than on the road, such as in a parking lot, a driveway, or at the side of the road. This engine activity contributes to total mobile source emissions but does not take place on the road network. Examples of ONI activity include:

- light duty passenger vehicles idling while waiting to pick up children at school or to pick up passengers at the airport or train station,
- single unit and combination trucks idling while loading or unloading cargo or making deliveries, and
- vehicles idling at drive-through restaurants.

Note that ONI does not include idling that occurs on the road, such as idling at traffic signals, stop signs, and in traffic—these emissions are included as part of the running and crankcase running exhaust processes on the other road types. ONI also does not include long-duration idling by long-haul combination trucks (hoteling/extended idle), as that type of long duration idling is accounted for in other MOVES processes.

ONI activity hours were calculated based on VMT. For each representative county, the ratio of ONI hours to onroad VMT (on all road types) was calculated using the MOVES ONI Tool by source type, fuel type, and month. These ratios are then multiplied by each county's total VMT (aggregated by source type, fuel type, and month) to get hours of ONI activity.

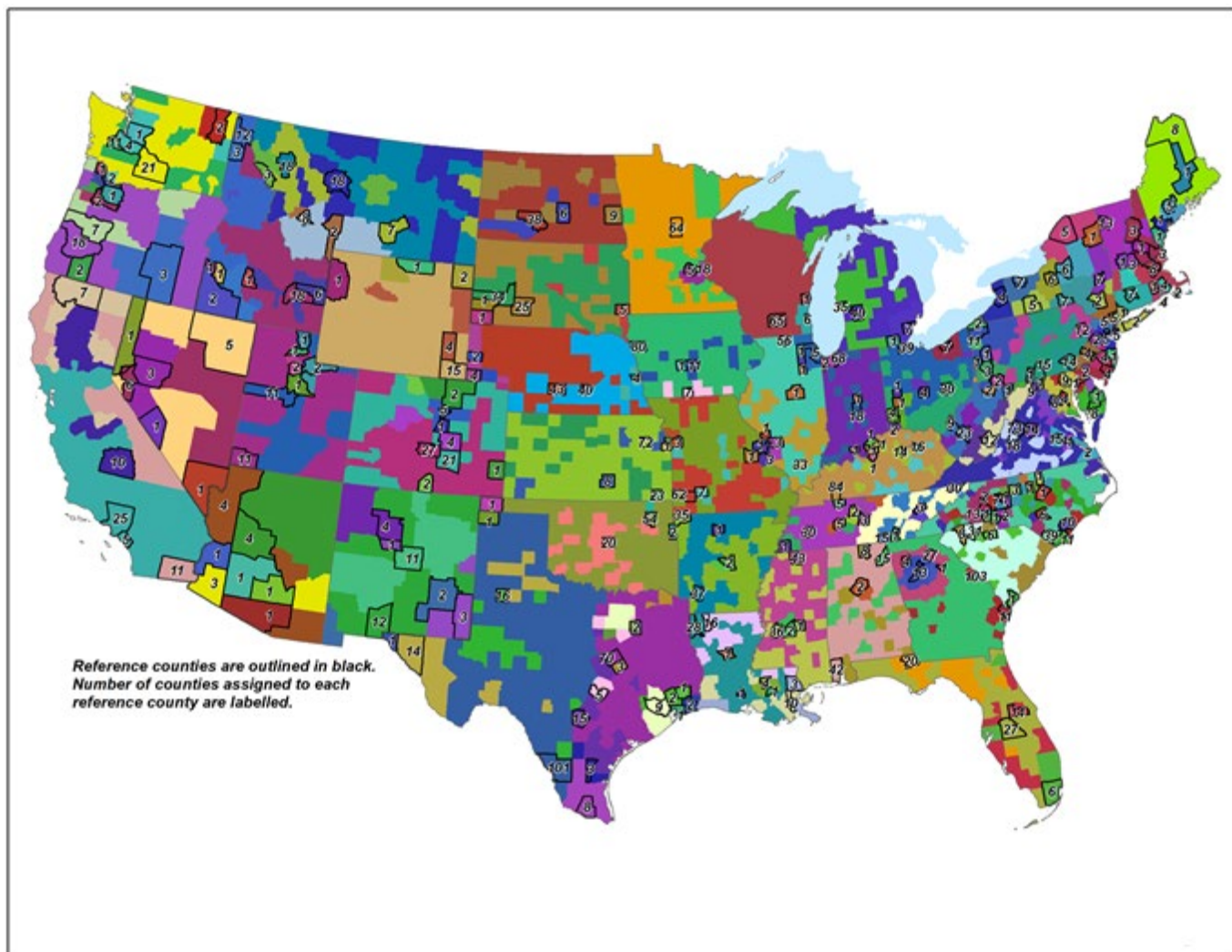
2.3.3 MOVES Emission Factor Table Development

MOVES3 was run in emission rate mode to create emission factor tables using CB6 speciation for 2019, for all representative counties and fuel months. The county databases used to run MOVES to develop the emission factor tables included the state-specific control measures such as the California LEV program, and fuels represented the year 2019. The range of temperatures run along with the average humidities used were specific to the year 2019. The remaining settings for the CDBs are documented in the 2017 NEI TSD. To create the emission factors, MOVES was run separately for each representative county and fuel month for each temperature bin needed for the calendar year 2019. The MOVES results were post-processed into CSV-formatted emission factor tables that can be read by SMOKE-MOVES. Additionally, MOVES was run for all counties in Alaska, Hawaii, and Virgin Islands, and for a single representative county in Puerto Rico.

The county databases CDBs used to run MOVES to develop the emission factor tables were those used for the 2017 NEI and therefore included any updated data provided and accepted for the 2017 NEI process. The 2017 NEI development included an extensive review of the various tables including speed distributions were performed. Where state speed profiles, speed distributions, and temporal profiles data were not accepted from S/L submissions, those data were obtained from the CRC A-100 study. Each

county in the continental U.S. was classified according to its state, altitude (high or low), fuel region, the presence of inspection and maintenance programs, the mean light-duty age, and the fraction of ramps. A binning algorithm was executed to identify “like” counties. The result was 294 representative counties for CONUS and 38 for Alaska, Hawaii, Puerto Rico, and the US Virgin Islands. The representative counties for CONUS, which were the same as those used in 2016v2 platform, are shown in Figure 2-3.

Figure 2-3. Map of Representative Counties



Age distributions are a key input to MOVES in determining emission rates. The age distributions for 2017 were updated based on vehicle registration data obtained from the CRC A-115 project (CRC, 2019), subject to reductions for older vehicles determined according to CRC A-115 methods but using additional age distribution data that became available as part of the 2017 NEI submitted input data. One of the findings of CRC project A-115 is that IHS data contain higher vehicle populations than state agency analyses of the same Department of Motor Vehicles data, and the discrepancies tend to increase with increasing vehicle age (i.e., there are more older vehicles in the IHS data).

For the 2017 NEI, EPA repeated the CRC’s assessment of IHS vs. state vehicles by age, but with updated information from the 2017 NEI and for more states. The 2017 light-duty vehicle (LDV) populations from

the CRC A-115 project were compared by model year to the populations submitted by state/local (S/L) agencies for the 2017 NEI. The comparisons by model year were used to develop adjustment factors that remove older age LDVs from the IHS dataset. Out of 31 S/L agencies that provided age distribution and vehicle population data for the 2017 NEI, sixteen agencies provided LDV population and age distributions with snapshot dates of January 2017, July 2017, or 2018. The other fifteen agencies had either unknown or older (back to 2013) data pull dates, so were compared to the 2017 IHS data. The vehicle populations by model year were compared with IHS data for each of the sixteen agencies for source type 21 (passenger cars) and for source type 31 plus 32 (light trucks) together. Prior to finalizing the activity data, the S/L agency populations of source type 21 and light trucks to match IHS car and light-duty truck splits by county so that vehicles of the same model and year were consistently classified into MOVES source types throughout the country. The IHS population of vehicles were found to be higher than the pooled state data by 6.5 percent for cars and 5.9 percent for light trucks.

To adjust for the additional vehicles in the IHS data, vehicle age distribution adjustment factors as one minus the fraction of vehicles to remove from IHS to equal the state data, with two exceptions: (1) the model year range 2006/2007 to 2017 receives no adjustment and (2) the model year 1987 receives a capped adjustment that equals the adjustment to 1988. Table 2-13 below shows the fraction of vehicles to keep by model year based on this analysis. The adjustments were applied to the 2017 IHS-based age distributions from CRC project A-115 prior to use in this 2017 platform. In addition, the age distributions to ensure the “tail” of the distribution corresponding to age 30 years and older vehicles did not exceed 20% of the fleet. After limiting the age distribution 30 and up bins, the age distributions were renormalized to ensure they summed to one (1). In addition, antique license plate vehicles were removed based on the registration summary from IHS. Nationally, the prevalence of antique plates is only 0.8 percent, but as high as 6 percent in some states (e.g., Mississippi).

Table 2-13. Fraction of IHS Vehicle Populations to Retain

Model Year	Cars	Light
pre-1989	0.675	0.769
1989	0.730	0.801
1990	0.732	0.839
1991	0.740	0.868
1992	0.742	0.867
1993	0.763	0.867
1994	0.787	0.842
1995	0.776	0.865
1996	0.790	0.881
1997	0.808	0.871
1998	0.819	0.870
1999	0.840	0.874
2000	0.838	0.896
2001	0.839	0.925
2002	0.864	0.921
2003	0.887	0.942
2004	0.926	0.953
2005	0.941	0.966
2006	1	0.987
2007-2017	1	1

In addition to removing the older and antique plate vehicles from the IHS data, 25 counties found to be outliers because their fleet age was significantly younger than in typical counties. The outlier review was limited to LDV source types 21, 31, and 32. Many rural counties have outliers for low-population source types such as Transit Bus and Refuse Truck due to small sample sizes, but these do not have much of an impact on the inventory overall and reflect sparse data in low-population areas and therefore do not require correction.

The most extreme examples of LDV outliers were Light Commercial Truck age distributions where over 50 percent of the population in the entire county is 0 and 1 years old. These sorts of young fleets can happen if the headquarters of a leasing or rental company is the owner/entity of a relatively large number of vehicles relative to the county-wide population. While the business owner of thousands of new vehicles may reside in a single county, the vehicles likely operate in broader areas without being registered where they drive. To avoid creating artificial low spots of LDV emissions in these outlier counties, data for all counties with more than 35% new vehicles were excluded from the final set of grouped age distributions that went into the CDBs.

The 2017 NEI age distributions were then grouped using a population-weighted average of the source type populations of each county in the representative county group, and were updated to represent the year 2019. The resulting end-product was age distributions for each of the 13 source types in each of the representative counties. The long-haul truck source types 53 (Single Unit) and 62 (Combination Unit) are based on a nationwide average due to the long-haul nature of their operation.

To create the emission factors, MOVES was run separately for each representative county and fuel month and for each temperature bin needed for calendar year 2019. The CDBs used to run MOVES include the state-specific control measures such as the California low emission vehicle (LEV) program, except that fuels were updated to represent calendar year 2019. In addition, the range of temperatures run along with the average humidities used were specific to the year 2019. The MOVES results were post-processed into CSV-formatted emission factor tables that can be read by SMOKE-MOVES.

2.3.4 Onroad California Inventory Development (onroad_ca)

California uses their own emission model, EMFAC, to develop onroad emissions inventories and provides those inventories to EPA. EMFAC uses emission inventory codes (EICs) to characterize the emission processes instead of SCCs. The EPA and California worked together to develop a code mapping to better match EMFAC's EICs to EPA MOVES' detailed set of SCCs that distinguish between off-network and on-network and brake and tire wear emissions. This detail is needed for modeling but not for the NEI. California provided set of emissions for 2023 as part of the 2016v1 platform development. EPA interpolated between 2017 and 2023 to calculate the 2019 onroad emissions for California. The California inventory had CAPs only and did not have NH₃ or refueling emissions. The EPA added NH₃ to the CARB inventory by using the state total NH₃ from MOVES and allocating it at the county level based on CO. California refueling emissions were computed by multiplying California refueling emissions from the 2017 NEI by projection factors developed by dividing county total refueling from the 2019 MOVES3 run by the county total refueling from the EQUATES 2017 run (which also used MOVES3). CARB VOCs were speciated to VOC HAPs using MOVES VOC speciation. All other HAPs (e.g., metals and PAHs) are from MOVES.

The California onroad mobile source 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 California-developed emissions, 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 based on SMOKE-MOVES results were:

- 1) Run CA using EPA inputs through SMOKE-MOVES to produce hourly emissions hereafter known as “EPA estimates.” These EPA estimates for CA are run in a separate sector called “onroad_ca.”
- 2) Calculate ratios between state-supplied emissions and EPA estimates. The ratios were calculated for each county/SCC/pollutant combination based on the California onroad emissions inventory. Unlike in previous platforms, the California data separated off and on-network emissions and extended idling. However, the on-network did not provide specific road types, and California’s emissions did not include information for vehicles fueled by E-85, so these differentiations were obtained using MOVES.
- 3) Create an adjustment factor file (CFPRO) that includes EPA-to-state estimate ratios.
- 4) Rerun CA 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, but have the temporal and spatial patterns reflecting the highly resolved meteorology and SMOKE-MOVES. After adjusting the emissions, this sector is called “onroad_ca_adj.” Note that in emission summaries, the emissions from the “onroad” and “onroad_ca_adj” sectors are summed and designated as the emissions for the onroad sector.

2.4 Nonroad Mobile sources (cmv, 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 Commercial Marine Vessels (cmv_c1c2)

The cmv_c1c2 sector contains Category 1 and 2 CMV emissions. Category 1 and 2 vessels use diesel fuel. Some examples of CMV sources included in cmv_c1c2 are fishing vessels, tug boats, and oil and gas platform support vessels. For more information on the CMV sources, see the supplemental documentation for 2020 NEI CMV³. C1 and C2 emissions that occur outside of state waters are not assigned to states. All CMV emissions in the cmv_c1c2 sector are treated as hourly gridded point sources with stack parameters that should result in them being placed in layer 1. The C1C2 CMV emissions were computed for 2019 using methods compatible with the 2020 NEI.

Sulfur dioxide (SO₂) emissions reflect rules that reduced sulfur emissions for CMV that took effect in the year 2015. The cmv_c1c2 inventory sector contains small to medium-size engine CMV emissions. Category 1 and Category 2 (C1C2) marine diesel engines typically range in size from about 700 to 11,000 hp. These engines are used to provide propulsion power on many kinds of vessels including tugboats, towboats, supply vessels, fishing vessels, and other commercial vessels in and around ports. They are also used as stand-alone generators for auxiliary electrical power on many types of vessels. Category 1 represents engines up to 7 liters per cylinder displacement. Category 2 includes engines from 7 to 30 liters per cylinder.

³ https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/nonpoint/CMV/

The cmv_c1c2 inventory sector contains sources that traverse state and federal waters along with emissions from surrounding areas of Canada, Mexico, and international waters. The cmv_c1c2 sources are modeled as point sources but using plume rise parameters that cause the emissions to be released in the ground layer of the air quality model.

The cmv_c1c2 sources within state waters are identified in the inventory with the Federal Information Processing Standard (FIPS) county code for the state and county in which the vessel is registered. The cmv_c1c2 sources that operate outside of state waters but within the Emissions Control Area (ECA) are encoded with a state FIPS code of 85. The ECA areas include parts of the Gulf of Mexico, and parts of the Atlantic and Pacific coasts. The cmv_c1c2 sources are categorized as operating either in-port or underway and as main and auxiliary engines are encoded using the SCCs listed in Table 2-14.

Table 2-14. SCCs for cmv_c1c2 sector

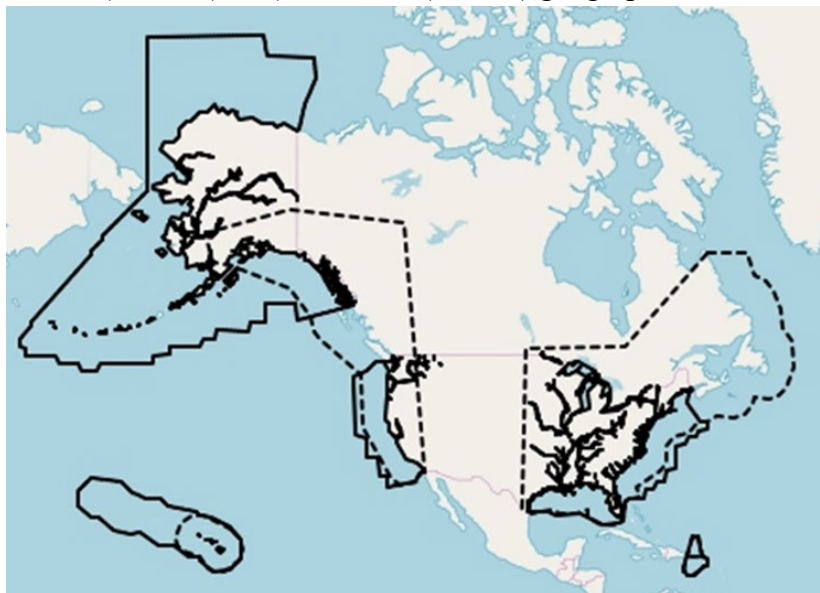
SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2280002101	Mobile Sources	Marine Vessels, Commercial	Diesel	C1C2 Port emissions: Main Engine
2280002102	Mobile Sources	Marine Vessels, Commercial	Diesel	C1C2 Port emissions: Auxiliary Engine
2280002201	Mobile Sources	Marine Vessels, Commercial	Diesel	C1C2 Underway emissions: Main Engine
2280002202	Mobile Sources	Marine Vessels, Commercial	Diesel	C1C2 Underway emissions: Auxiliary Engine

Category 1 and 2 CMV emissions were developed for 2019 using methods compatible with the 2020 NEI.⁴ The 2019 emissions were developed based signals from Automated Identification System (AIS) transmitters. AIS is a tracking system used by vessels to enhance navigation and avoid collision with other AIS transmitting vessels. The USEPA Office of Transportation and Air Quality received AIS data from the U.S. Coast Guard (USCG) to quantify all ship activity which occurred between January 1 and December 31, 2019. To ensure coverage for all of the areas needed by the NEI, the requested and provided AIS data extend beyond 200 nautical miles from the U.S. coast. The area covered by the NEI is shown in Figure 2-4 (a). This boundary is roughly equivalent to the border of the U.S Exclusive Economic Zone and the North American ECA, although some non-ECA activity are captured as well. Two types of AIS data were received: satellite (S-AIS) and terrestrial (T-AIS). The same request boxes were used for the 2019 modeling platform and for the 2020 NEI. The counts of data received for S-AIS and T-AIS for the 2020 NEI are shown in Figure 2-4 (b).

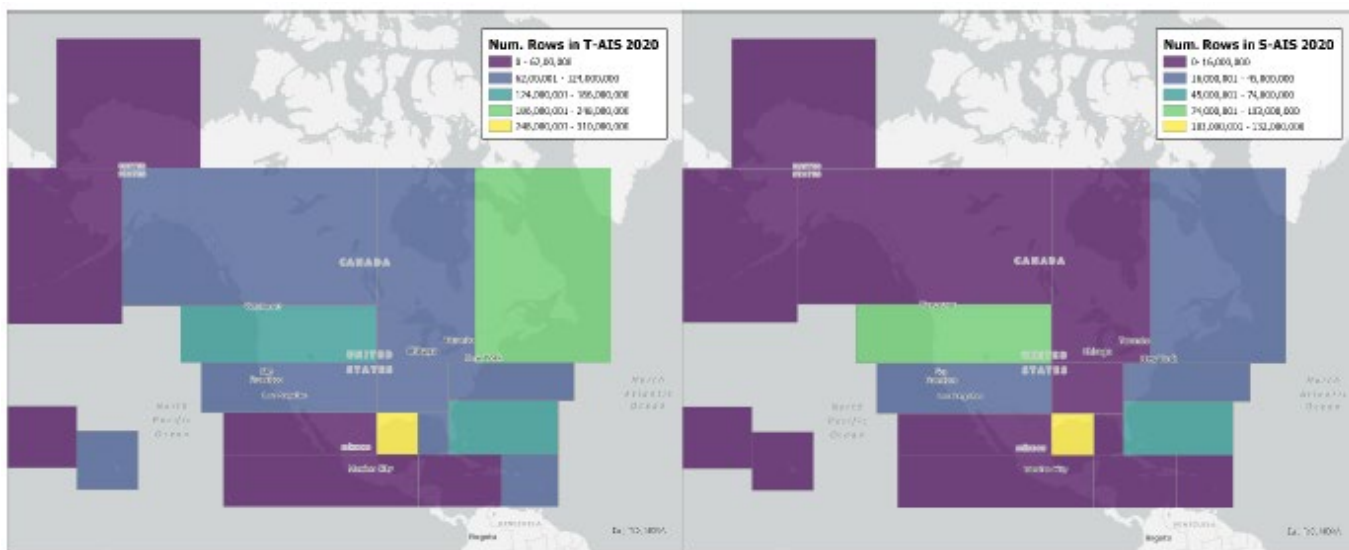
⁴ https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/nonpoint/CMV/.

Figure 2-4. NEI Commercial Marine Vessel Boundaries and Automatic Identification System Request Boxes for 2029

a) NEI (solid) and ECA (dashed) geographical extent



b) Areas of AIS request boxes and amount of data received



The AIS data were compiled into five-minute intervals by the USCG, providing a reasonably refined assessment of a vessel’s movement. For example, using a five-minute average, a vessel traveling at 25 knots would be captured every two nautical miles that the vessel travels. For slower moving vessels, the distance between transmissions would be less. The ability to track vessel movements through AIS data and link them to attribute data, has allowed for the development of an inventory of very accurate emission estimates. These AIS data were used to define the locations of individual vessel movements, estimate hours of operation, and quantify propulsion engine loads. The compiled AIS data also included the vessel’s International Marine Organization (IMO) number and Maritime Mobile Service Identifier

(MMSI); which allowed each vessel to be matched to their characteristics obtained from the Clarksons ship registry (Clarksons, 2021).

The engine bore and stroke data were used to calculate cylinder volume. Any vessel that had a calculated cylinder volume greater than 30 liters was incorporated into the USEPA’s new Category 3 Commercial Marine Vessel (C3CMV) model. The remaining records were assumed to represent Category 1 and 2 (C1C2) or non-ship activity. The C1C2 AIS data were quality assured including the removal of duplicate messages, signals from pleasure craft, and signals that were not from CMV vessels (e.g., buoys, helicopters, and vessels that are not self-propelled).

The emissions were calculated for each time interval between consecutive AIS messages for each vessel and allocated to the location of the message following to the interval. Emissions were calculated according to Equation 2-1.

$$Emissions_{interval} = Time (hr)_{interval} \times Power(kW) \times EF\left(\frac{g}{kWh}\right) \times LLAF \quad \text{Equation 2-1}$$

Power is calculated for the propulsive (main), auxiliary, and auxiliary boiler engines for each interval and emission factor (EF) reflects the assigned emission factors for each engine, as described below. LLAF represents the low load adjustment factor, a unitless factor which reflects increasing propulsive emissions during low load operations. Time indicates the activity duration time between consecutive intervals.

Next, vessels were identified in order determine their vessel type, and thus their vessel group, power rating, and engine tier information which are required for the emissions calculations. See the 2020 NEI documentation for more details on this process. Following the identification, 108 different vessel types were matched to the C1C2 vessels. Vessel attribute data was not available for all these vessel types, so the vessel types were aggregated into 13 different vessel groups for which surrogate data were available as shown in Table 2-15⁵. For the 2020 NEI, 11,302 vessels were directly identified by their ship and cargo number. The remaining group of miscellaneous ships represent 13 percent of the AIS vessels (excluding recreational vessels) for which a specific vessel type could not be assigned.

Table 2-15. Vessel groups in the cmv_c1c2 sector

Vessel Group	NEI Area Ship Count
Bulk Carrier	37
Commercial Fishing	1,147
Container Ship	7
Ferry Excursion	441
General Cargo	1,498
Government	1,338
Miscellaneous	1,475
Offshore support	1,149

⁵ The number of matched vessels shown here were computed for the 2020 NEI, but the numbers should be similar for the 2019 modeling platform.

Vessel Group	NEI Area Ship Count
Reefer	13
Ro Ro	26
Tanker	100
Tug	3,994
Work Boat	77
Total in Inventory:	11,302

As shown in Equation 2-1, power is an important component of the emissions computation. Vessel-specific installed propulsive power ratings and service speeds were pulled from Clarksons ship registry and adopted from the Global Fishing Watch (GFW) dataset when available. However, there is limited vessel specific attribute data for most of the C1C2 fleet. This necessitated the use of surrogate engine power and load factors, which were computed for each vessel group. In addition to the power required by propulsive engines, power needs for auxiliary engines were also computed for each vessel group. Emissions from main and auxiliary engines are inventoried with different SCCs as shown in Table 2-14.

The final components of the emissions computation equation are the emission factors and the low load adjustment factor. The emission factors used in this inventory take into consideration the EPA’s marine vessel fuel regulations as well as exhaust standards that are based on the year that the vessel was manufactured to determine the appropriate regulatory tier. Emission factors in g/kWhr by tier for NO_x, PM₁₀, PM_{2.5}, CO, CO₂, SO₂ and VOC were developed using Tables 3-7 through 3-10 in USEPA’s (2008) Regulatory Impact Analysis on engines less than 30 liters per cylinder. To compile these emissions factors, population-weighted average emission factors were calculated per tier based on C1C2 population distributions grouped by engine displacement. Boiler emission factors were obtained from an earlier Swedish Environmental Protection Agency study (Swedish EPA, 2004). If the year of manufacture was unknown then it was assumed that the vessel was Tier 0, such that actual emissions may be less than those estimated in this inventory. Without more specific data, the magnitude of this emissions difference cannot be estimated.

Propulsive emissions from low-load operations were adjusted to account for elevated emission rates associated with activities outside the engines’ optimal operating range. The emission factor adjustments were applied by load and pollutant, based on the data compiled for the Port Everglades 2015 Emission Inventory.⁶ Hazardous air pollutants and ammonia were added to the inventory according to multiplicative factors applied either to VOC or PM_{2.5}.

The stack parameters used for cmv_c1c2 are a stack height of 1 ft, stack diameter of 1 ft, stack temperature of 70°F, and a stack velocity of 0.1 ft/s. These parameters force emissions into layer 1.

⁶ USEPA. EPA and Port Everglades Partnership: Emission Inventories and Reduction Strategies. US Environmental Protection Agency, Office of Transportation and Air Quality, June 2018.
<https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UKV8.pdf>

For more information on the emission computations for 2019, see the supporting documentation for the 2020 NEI C1C2 CMV emissions. The cmv_c1c2 emissions were aggregated to total hourly values in each grid cell and run through SMOKE as point sources. SMOKE requires an annual inventory file to go along with the hourly data, so the annual inventory file was also generated for 2019.

2.4.2 Category 3 Commercial Marine Vessels (cmv_c3)

This sector contains large engine CMV emissions. Category 3 (C3) marine diesel engines are those at or above 30 liters per cylinder, typically these are the largest engines rated at 3,000 to 100,000 hp. C3 engines are typically used for propulsion on ocean-going vessels including container ships, oil tankers, bulk carriers, and cruise ships. Emissions control technologies for C3 CMV sources are limited due to the nature of the residual fuel used by these vessels.⁷ The cmv_c3 sector contains sources that traverse state and federal waters; along with sources in waters not covered by the NEI in surrounding areas of Canada, Mexico, and international waters. For more information on the 2019 CMV sources, see the supplemental documentation for the 2020 NEI CMV⁸.

The cmv_c3 sources that operate outside of state waters but within the federal Emissions Control Area (ECA) are encoded with a FIPS state code of 85, with the “county code” digits representing broad regions such as the Atlantic, Gulf of Mexico, and Pacific. The ECA areas include parts of the Gulf of Mexico, and parts of the Atlantic and Pacific coasts. CMV C3 sources around Puerto Rico, Hawaii and Alaska, which are outside the ECA areas, are included in the inventory but are in separate files from the emissions around the continental United States (CONUS). The cmv_c3 sources in the inventory are categorized as operating either in-port or underway and are encoded using the SCCs listed in Table 2-16. and distinguish between diesel and residual fuel, in port areas versus underway, and main and auxiliary engines.

⁷ <https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-marine-vessels>.

⁸ https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/nonpoint/CMV.

Table 2-16. SCCs for cmv_c3 sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2280002103	Mobile Sources	Marine Vessels, Commercial	Diesel	C3 Port emissions: Main Engine
2280002104	Mobile Sources	Marine Vessels, Commercial	Diesel	C3 Port emissions: Auxiliary Engine
2280002203	Mobile Sources	Marine Vessels, Commercial	Diesel	C3 Underway emissions: Main Engine
2280002204	Mobile Sources	Marine Vessels, Commercial	Diesel	C3 Underway emissions: Auxiliary Engine
2280003103	Mobile Sources	Marine Vessels, Commercial	Residual	C3 Port emissions: Main Engine
2280003104	Mobile Sources	Marine Vessels, Commercial	Residual	1 C3 Port emissions: Auxiliary Engine
2280003203	Mobile Sources	Marine Vessels, Commercial	Residual	C3 Underway emissions: Main Engine
2280003204	Mobile Sources	Marine Vessels, Commercial	Residual	C3 Underway emissions: Auxiliary Engine

Prior to creation of the 2019 CMV inventory, the EPA received Automated Identification System (AIS) data from United States Coast Guard (USCG) to quantify all ship activity which occurred between January 1 and December 31, 2019. The International Maritime Organization’s (IMO’s) International Convention for the Safety of Life at Sea (SOLAS) requires AIS to be fitted aboard all international voyaging ships with gross tonnage of 300 or more, and all passenger ships regardless of size.⁹ In addition, the USCG has mandated that all commercial marine vessels continuously transmit AIS signals while transiting U.S. navigable waters. As the vast majority of C3 vessels meet these requirements, any omitted from the inventory due to lack of AIS adoption are deemed to have a negligible impact on national C3 emissions estimates. The activity described by this inventory reflects ship operations within 200 nautical miles of the official U.S. baseline. This boundary is roughly equivalent to the border of the U.S Exclusive Economic Zone and the North American ECA, although some non-ECA activity is captured as well (Figure 2-4).

The 2019 CMV data were computed based on the AIS data from the USGS for the year of 2019. The AIS data were coupled with ship registry data that contained engine parameters, vessel power parameters, and other factors such as tonnage and year of manufacture which helped to separate the C3 vessels from the C1C2 vessels. Where specific ship parameters were not available, they were gap-filled. The types of vessels that remain in the C3 data set include bulk carrier, chemical tanker, liquified gas tanker, oil tanker, other tanker, container ship, cruise, ferry, general cargo, fishing, refrigerated vessel, roll-on/roll-off, tug, and yacht.

⁹ International Maritime Organization (IMO) Resolution MSC.99(73) adopted December 12th, 2000 and entered into force July 1st, 2002; as amended by SOLAS Resolution CONF.5/32 adopted December 13th, 2002.

Prior to use, the AIS data were reviewed - data deemed to be erroneous were removed, and data found to be at intervals greater than 5 minutes were interpolated to ensure that each ship had data every five minutes. The five-minute average data provide a reasonably refined assessment of a vessel's movement. For example, using a five-minute average, a vessel traveling at 25 knots would be captured every two nautical miles that the vessel travels. For slower moving vessels, the distance between transmissions would be less.

The emissions were calculated for each C3 vessel in the dataset for each 5-minute time range and allocated to the location of the message following to the interval. Emissions were calculated according to Equation 2-2.

$$Emissions_{interval} = Time (hr)_{interval} \times Power(kW) \times EF\left(\frac{g}{kWh}\right) \times LLAFF \quad \text{Equation 2-2}$$

Power is calculated for the propulsive (main), auxiliary, and auxiliary boiler engines for each interval and emission factor (EF) reflects the assigned emission factors for each engine, as described below. LLAFF represents the low load adjustment factor, a unitless factor which reflects increasing propulsive emissions during low load operations. Time indicates the activity duration time between consecutive intervals.

Emissions were computed according to a computed power need (kW) multiplied by the time (hr) and by an engine-specific emission factor (g/kWh) and finally by a low load adjustment factor that reflects increasing propulsive emissions during low load operations.

The resulting emissions were available at 5-minute intervals. Code was developed to aggregate these emissions to modeling grid cells and up to hourly levels so that the emissions data could be input to SMOKE for emissions modeling with SMOKE. Within SMOKE, the data were speciated into the pollutants needed by the air quality model,¹⁰ but since the data were already in the form of point sources at the center of each grid cell, and they were already hourly, no other processing was needed within SMOKE. SMOKE requires an annual inventory file to go along with the hourly data, so the annual files were also generated for 2019.

On January 1st, 2015, the ECA initiated a fuel sulfur standard which regulated large marine vessels to use fuel with 1,000 ppm sulfur or less. These standards are reflected in the cmv_c3 inventories.

Figure 2-4A set of standard stack parameters were assigned to each release point in the cmv_c3 inventory. The assigned stack height was 65.62 ft, the stack diameter was 2.625 ft, the stack temperature was 539.6 °F, and the velocity was 82.02 ft/s. Emissions were computed for each grid cell needed for modeling.

¹⁰ Ammonia (NH₃) was also added by SMOKE in the speciation step.

2.4.3 Railway Locomotives (rail)

The rail sector includes all locomotives in the NEI nonpoint data category including line haul locomotives on Class 1, 2, and 3 railroads along with emissions from commuter rail lines and Amtrak. The rail sector excludes railway maintenance locomotives and point source yard locomotives. Railway maintenance emissions are included in the nonroad sector. The point source yard locomotives are included in the ptnonipm sector. Typically in the NEI, yard locomotive emissions are split between the nonpoint and point categories, but for this study, all yard locomotive emissions are represented as point sources and included in the ptnonipm sector.

This study uses the 2017 rail inventory developed for the 2017 NEI by the Lake Michigan Air Directors Consortium (LADCO) and the State of Illinois with support from various other states. Class I railroad emissions are based on confidential link-level line-haul activity GIS data layer maintained by the Federal Railroad Administration (FRA). In addition, the Association of American Railroads (AAR) provided national emission tier fleet mix information. Class II and III railroad emissions are based on a comprehensive nationwide GIS database of locations where short line and regional railroads operate. Passenger rail (Amtrak) emissions follow a similar procedure as Class II and III, except using a database of Amtrak rail lines. Yard locomotive emissions are based on a combination of yard data provided by individual rail companies, and by using Google Earth and other tools to identify rail yard locations for rail companies which did not provide yard data. Information on specific yards were combined with fuel use data and emission factors to create an emissions inventory for rail yards. Pollutant-specific factors were applied on top of the activity-based changes for the Class I rail. The inventory SCCs are shown in Table 2-17. More detailed information on the development of the 2017 NEI rail inventory for this study is available in the 2017 NEI TSD and in the [Specification Sheet: Rail 2017 National Emissions Inventory](#) on the 2017 NEI supporting data FTP site. The 2017 NEI rail inventory was projected to 2019 using activity-based factors show in Table 2-18.

Table 2-17. SCCs for the Rail Sector

SCC	Sector	Description: Mobile Sources prefix for all
2285002006	Rail	Railroad Equipment; Diesel; Line Haul Locomotives: Class I Operations
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 (nonpoint)
28500201	Rail	Railroad Equipment; Diesel; Yard Locomotives (point)

Table 2-18. 2017-to-2019 projection factors for rail

Category	NO _x	PM	VOC	other pollutants
Class I	-8.65%	-5.33%	-17.05%	-1.18%
Class II/III and Yards	-1.18%	-1.18%	-1.18%	-1.18%
Passenger/Commuter	+3.83%	+3.83%	+3.83%	+3.83%

Class I Line-haul Methodology

In 2008, air quality planners in the eastern US formed the Eastern Technical Advisory Committee (ERTAC) for solving persistent emissions inventory issues. This work is the fourth inventory created by the ERTAC rail group. For the 2017 inventory, the Class I railroads granted ERTAC Rail permission to use the confidential link-level line-haul activity GIS data layer maintained by the Federal Railroad Administration (FRA) for 2016. In addition, the Association of American Railroads (AAR) provided national emission tier fleet mix information. This allowed ERTAC Rail to calculate weighted emission factors for each pollutant based on the percentage of the Class I line-haul locomotives in each USEPA Tier level category. These two datasets, along with 2017 Class I line-haul fuel use data reported to the Surface Transportation Board were used to create a link-level Class I emissions inventory, based on a methodology recommended by Sierra Research. Rail Fuel Consumption Index (RFCI) is a measure of fuel use per ton mile of freight. This link-level inventory is nationwide in extent, but it can be aggregated at either the state or county level.

Annual default emission factors for locomotives based on operating patterns (“duty cycles”) and the estimated nationwide fleet mixes for both switcher and line-haul locomotives are available. However, Tier level fleet mixes vary significantly between the Class I and Class II/III railroads. As can be seen in Figure 2-5 and Figure 2-6, Class I railroad activity is highly regionalized in nature and is subject to variations in terrain across the country which can have a significant impact on fuel efficiency and overall fuel consumption.

Figure 2-5. 2017 US Railroad Traffic Density in Millions of Gross Tons per Route Mile (MGT)

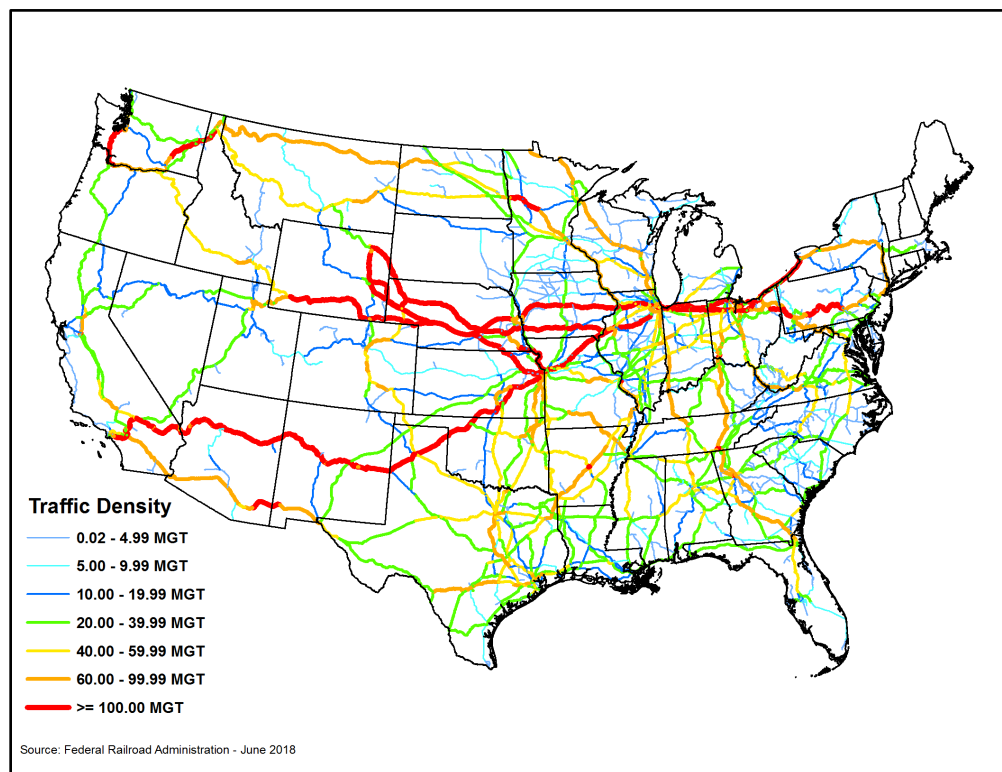
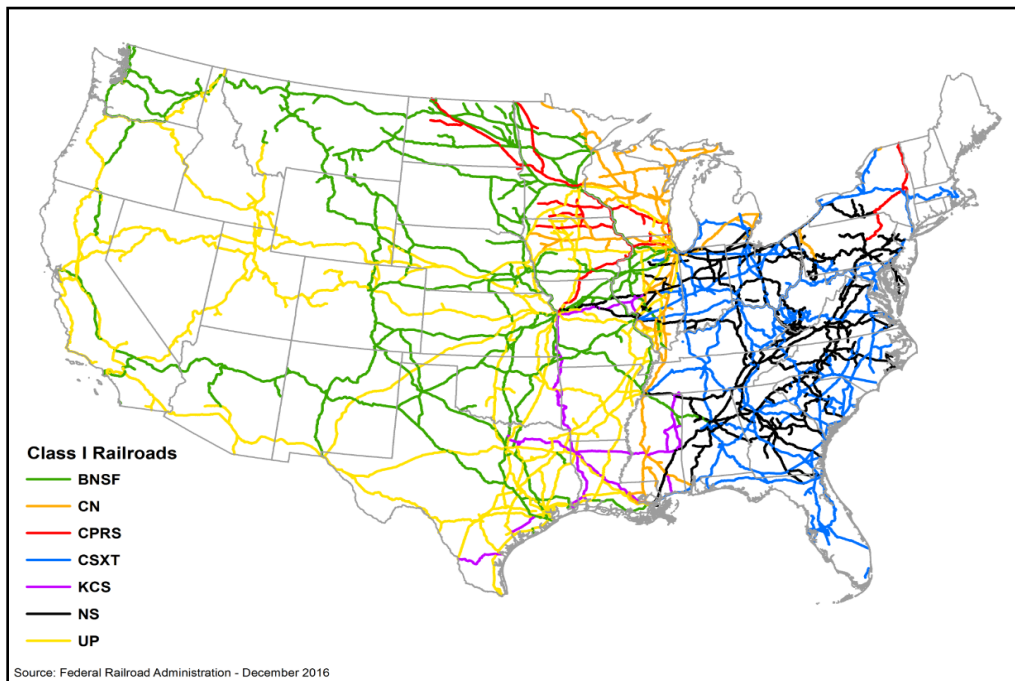


Figure 2-6. Class I Railroads in the United States

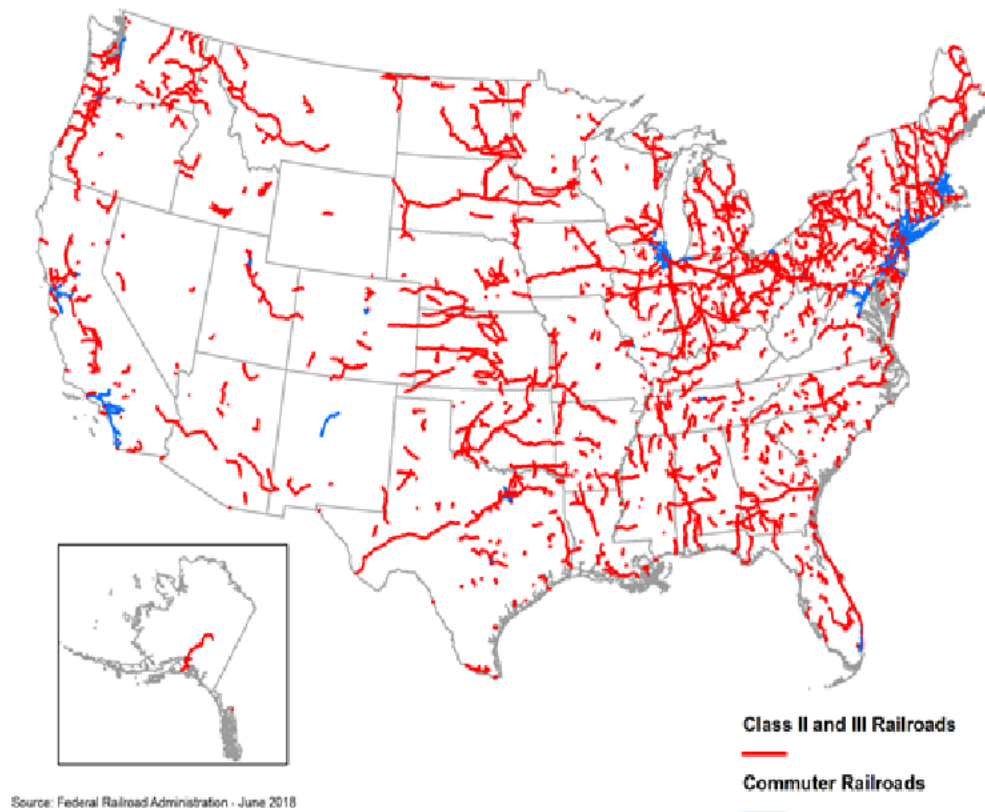


Class II and III Methodology

There are approximately 560 Class II and III Railroads operating in the United States, most of which are members of the American Short Line and Regional Railroad Association (ASLRRA). While there is a lot of information about individual Class II and III railroads available online, a significant amount of effort would be required to convert this data into a usable format for the creation of emission inventories. In addition, the Class II and III rail sector has been in a constant state of flux ever since the railroad industry was deregulated under the Staggers Act in 1980. Some states have conducted independent surveys of their Class II and III railroads and produced emission estimates, but no national level emissions inventory existed for this sector of the railroad industry prior to ERTAC Rail’s work for the 2008 NEI.

Class II and III railroad activities account for nearly 4 percent of the total locomotive fuel use in the combined ERTAC Rail emission inventories and for approximately 35 percent of the industry’s national freight rail track mileage. These railroads are widely dispersed across the country and often utilize older, higher emitting locomotives than their Class I counterparts. Class II and III railroads provide transportation services to a wide range of industries. Individual railroads in this sector range from small switching operations serving a single industrial plant to large regional railroads that operate hundreds of miles of track. Figure 2-7 shows the distribution of Class II and III railroads and commuter railroads across the country. This inventory will be useful for regional and local modeling, helps identify where Class II and III railroads may need to be better characterized, and provides a strong foundation for the future development of a more accurate nationwide short line and regional railroad emissions inventory. A picture of the locations of class II and III railroads is shown in Figure 2-7.

Figure 2-7. Class II and III Railroads in the United States⁵



Commuter Rail Methodology

Commuter rail emissions were calculated in the same way as the Class II and III railroads. The primary difference is that the fuel use estimates were based on data collected by the Federal Transit Administration (FTA) for the National Transit Database. For the 2017 NEI, 2016 fuel use was estimated for each of the commuter railroads by multiplying the fuel and lube cost total by 0.95, then dividing the result by Metra's average diesel fuel cost of \$1.93/gallon. These fuel use estimates were replaced with reported fuel use statistics for MARC (Maryland), MBTA (Massachusetts), Metra (Illinois), and NJT (New Jersey). The commuter railroads were separated from the Class II and III railroads so that the appropriate SCC codes could be entered into the emissions calculation sheet.

Intercity Passenger Methodology (Amtrak)

2016 and 2017 marked the first times that a nationwide intercity passenger rail emissions inventory was created for Amtrak. The calculation methodology mimics that used for the Class II and III and commuter railroads with a few modifications. Since link-level activity data for Amtrak was unavailable, the default assumption was made to evenly distribute Amtrak's 2016 reported fuel use across all of its diesel-powered route-miles shown in Figure 2-8. Participating states were instructed that they could alter the fuel use distribution within their jurisdictions by analyzing Amtrak's 2016 national timetable and calculating passenger train-miles for each affected route. Illinois and Connecticut chose to do this and were able to derive activity-based fuel use numbers for their states based on Amtrak's 2016 reported average fuel use of 2.2 gallons per passenger train-mile. In addition, Connecticut provided supplemental data for selected counties in Massachusetts, New Hampshire, and Vermont. Amtrak also submitted company-specific fleet mix information and company-specific weighted emission factors were derived. Amtrak's emission rates were 25% lower than the default Class II and III and commuter railroad emission rate.

Figure 2-8. Amtrak Routes with Diesel-powered Passenger Trains



Other Data Sources

The California Air Resources Board (CARB) provided rail inventories for inclusion in the 2017 NEI. CARB's rail inventories were used in California, in place of the national dataset described above. For rail yards, the national point source rail yard dataset was used to allocate CARB-submitted rail yard emissions to point sources where possible. That is, for each California county with at least one rail yard in the national dataset, the emissions in the national rail yard dataset were adjusted so that county total rail yard emissions matched the CARB dataset. In other words, county total rail yard emissions from CARB are

used, but the locations of rail yards are based on the national methodology. There are three counties with CARB-submitted rail yard emissions, but no rail yard locations in the national dataset; for those counties, the rail yard emissions were included in the rail sector using SCC 2285002010.

HAPs were not provided with the rail inventory but were augmented for the NEI. For VOC speciation, the EPA preferred augmenting the inventory with HAPs and using those HAPs for integration, rather than running the sector as a no-integrate sector.

2.4.4 Nonroad Mobile Equipment (nonroad)

The mobile nonroad equipment sector includes all mobile source emissions that do not operate on roads, excluding commercial marine vehicles, railways, and aircraft. Types of nonroad equipment include recreational vehicles, pleasure craft, and construction, agricultural, mining, and lawn and garden equipment. Nonroad equipment emissions were computed by running MOVES3 which incorporates the NONROAD model. MOVES3 incorporated updated nonroad engine population growth rates, nonroad Tier 4 engine emission rates, and sulfur levels of nonroad diesel fuels. MOVES provides a complete set of HAPs and incorporates updated nonroad emission factors for HAPs. MOVES3 was used for all states other than California, which uses their own model, and the Texas Commission on Environmental Quality (TCEQ), which provided their own emissions. California nonroad emissions were provided by the California Air Resources Board (CARB) for the 2017 NEI. The 2019 California nonroad emissions were interpolated from the 2017 NEI and a 2023 projection from the 2016v1 modeling platform, with HAP augmentation. For Texas, the EPA interpolated to 2019 between data provided for 2017 and 2020 and applied HAP augmentation.

MOVES creates a monthly emissions inventory for criteria air pollutants (CAPs) and a full set of HAPs, plus additional pollutants such as NONHAPTOG and ETHANOL, which are not part of the NEI but are used for speciation. MOVES provides estimates of NONHAPTOG along with the speciation profile code for the NONHAPTOG emission source. This was accomplished by using NHTOG##### as the pollutant code in the Flat File 2010 (FF10) inventory file that can be read into SMOKE, where ##### is a speciation profile code. For California and Texas, NHTOG#####-VOC and HAP-VOC ratios from MOVES-based emissions were applied to VOC emissions so that VOC emissions can be speciated consistently with other states.

MOVES also provides estimates of PM_{2.5} by speciation profile code for the PM_{2.5} emission source, using PM25_##### as the pollutant code in the FF10 inventory file, where ##### is a speciation profile code. To facilitate calculation of PMC within SMOKE, and to help create emissions summaries, an additional pollutant representing total PM_{2.5} called PM25TOTAL was added to the inventory. As with VOC, PM25_#####-PM25TOTAL ratios were calculated and applied to PM_{2.5} emissions in California and Texas so that PM_{2.5} emissions in California and Texas can be speciated consistently with other states.

MOVES3 outputs emissions data in county-specific databases, and a post-processing script converts the data into FF10 format. Additional post-processing steps were performed as follows:

- County-specific FF10s were combined into a single FF10 file.
- Emissions were aggregated from the more detailed SCCs modeled in MOVES to the SCCs modeled in SMOKE. A list of the aggregated SMOKE SCCs is in Appendix A of the 2016v1 platform nonroad specification sheet (NEIC, 2019).

- To reduce the size of the inventory, HAPs that are not needed for air quality modeling, such as dioxins and furans, were removed from the inventory.
- To reduce the size of the inventory further, all emissions for sources (identified by county/SCC) for which total CAP emissions are less than 1×10^{-10} were removed from the inventory. The MOVES model attributes a very tiny amount of emissions to sources that are actually zero, for example, snowmobile emissions in Florida. Removing these sources from the inventory reduces the total size of the inventory by about 7%.
- Gas and particulate components of HAPs that come out of MOVES separately, such as naphthalene, were combined.
- VOC was renamed VOC_INV so that SMOKE does not speciate both VOC and NONHAPTOG, which would result in a double count.
- PM25TOTAL, referenced above, was also created at this stage of the process.
- Emissions for airport ground support vehicles (SCCs ending in -8005), and oil field equipment (SCCs ending in -10010), were removed from the inventory at this stage, to prevent a double count with the airports and np_oilgas sectors, respectively.
- California emissions from MOVES were deleted and replaced with the CARB-supplied emissions.

National Updates: Agricultural and Construction Equipment Allocation

The methodology for developing Agricultural equipment allocation data for the 2016v1 platform was developed by the North Carolina Department of Environmental Quality (NCDEQ). The construction equipment allocation data used in MOVES for this platform

For the Construction sector, by default MOVES2014b used estimates of 2003 total dollar value of construction by county to allocate national Construction equipment populations to the state and local levels.¹¹ The 2016 National Emissions Inventory Collaborative (NEIC) Nonroad Work Group updated the surrogate data used to geographically allocate Construction equipment with a more recent data source thought to be more reflective of emissions-generating Construction equipment activity at the county level: acres disturbed by residential, non-residential, and road construction activity.

More information on the development of the updates to agricultural and construction equipment allocations is available in Section 2.4.4 of the Technical Support Document (TSD): Preparation of Emissions Inventories for the 2017 North American Emissions Modeling Platform (EPA, 2022a). Updated *nrsurrogate*, *nrstatesurrogate*, and *nrbaseyearequippopulation* tables, along with instructions for utilizing these tables in MOVES runs, are available for download from EPA's ftp site: <https://gaftp.epa.gov/air/emismod/2016/v1/reports/nonroad/>). Note that these are not included in MOVES3.

Emissions Inside California and Texas

¹¹ <https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1004LDX.pdf>.

California nonroad emissions were provided by CARB for 2017NEI, and for several years including 2016 and 2023 as part of the 2016 version 1 modeling platform. The 2017 and 2023 datasets provided by CARB were used to estimate California nonroad emissions for 2019. Specifically, county-level trends by pollutant were calculated for the six year period from 2017 to 2023, converted (interpolated) to a one year trend, and then applied to the 2017 emissions to estimate 2019. Trends based on county totals were used instead of more specific trends (e.g. by SCC) because of possible differences in SCC delineations between the different CARB datasets.

All California nonroad inventories are annual, with monthly temporalization applied in SMOKE. Emissions for oil field equipment (SCCs ending in -10010) were removed from the California inventory in order to prevent a double count with the `np_oilgas` sector. VOC and PM_{2.5} emissions were allocated to speciation profiles, and VOC HAPs were created, using MOVES data in California. For example, ratios of VOC (PM_{2.5}) by speciation profile to total VOC (PM_{2.5}), and ratios of VOC HAPs to total VOC, were calculated by county and SCC from the MOVES run in California, and then applied CARB-provided VOC (PM_{2.5}) in the inventory so that California nonroad emissions could be speciated consistently with the rest of the country.

Texas nonroad emissions were provided by TCEQ for years 2017 and 2020, and then interpolated to 2019 for each county, SCC, and pollutant. The Texas nonroad inventories are seasonal (summer, fall, winter, spring), split to monthly by dividing the seasonal total by three for each month. As in California, VOC and PM_{2.5} emissions were allocated to speciation profiles, and VOC HAPs were created, using MOVES data in Texas.

Nonroad Updates from State Comments

The 2016 Nonroad Collaborative workgroup received a small number of comments on the 2016beta inventory (EPA and NEIC, 2019), all of which were addressed and implemented in the 2017 NEI nonroad inventory and the 2019 inventory used for this study:

- **Georgia Department of Natural Resources:** utilize updated geographic allocation factors (*nrstatesurrogate* table) for the Commercial, Lawn & Garden (commercial, public, and residential), Logging, Manufacturing, Golf Carts, Recreational, Railroad Maintenance Equipment and A/C/Refrigeration sectors, using data from the U.S. Census Bureau and U.S. Forest Service.
- **Lake Michigan Air Directors Consortium (LADCO):** update seasonal allocation of agricultural equipment activity (*nrmonthallocation* table) for Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, Ohio, and Wisconsin.
- **Texas Commission on Environmental Quality:** replace MOVES nonroad emissions for Texas with emissions calculated with TCEQ's TexN2 model.
- **Alaska Department of Environmental Conservation:** remove emissions as calculated by MOVES for several equipment sector-county/census areas combinations in Alaska, due to an absence of nonroad activity (see Table 2-19).

Table 2-19. Alaska counties/census areas for which nonroad equipment sector-specific emissions were removed

Nonroad Equipment Sector	Counties/Census Areas (FIPS) for which equipment sector emissions are removed in 2016
Agricultural	Aleutians East (02013), Aleutians West (02016), Bethel Census Area (02050), Bristol Bay Borough (02060), Dillingham Census Area (02070), Haines Borough (02100), Hoonah-Angoon Census Area (02105), Ketchikan Gateway (02130), Kodiak Island Borough (02150), Lake and Peninsula (02164), Nome (02180), North Slope Borough (02185), Northwest Arctic (02188), Petersburg Borough (02195), Pr of Wales-Hyder Census Area (02198), Sitka Borough (02220), Skagway Borough (02230), Valdez-Cordova Census Area (02261), Wade Hampton Census Area (02270), Wrangell City + Borough (02275), Yakutat City + Borough (02282), Yukon-Koyukuk Census Area (02290)
Logging	Aleutians East (02013), Aleutians West (02016), Nome (02180), North Slope Borough (02185), Northwest Arctic (02188), Wade Hampton Census Area (02270)
Railway Maintenance	Aleutians East (02013), Aleutians West (02016), Bethel Census Area (02050), Bristol Bay Borough (02060), Dillingham Census Area (02070), Haines Borough (02100), Hoonah-Angoon Census Area (02105), Juneau City + Borough (02110), Ketchikan Gateway (02130), Kodiak Island Borough (02150), Lake and Peninsula (02164), Nome (02180), , North Slope Borough (02185), Northwest Arctic (02188), Petersburg Borough (02195), Pr of Wales-Hyder Census Area (02198), Sitka Borough (02220), Southeast Fairbanks (02240), Wade Hampton Census Area (02270), Wrangell City + Borough (02275), Yakutat City + Borough (02282), Yukon-Koyukuk Census Area (02290)

2.5 Fires (*ptfire-rx*, *ptfire-wild*, *ptagfire*)

Multiple types of fires are represented in the modeling platform. These include wild and prescribed fires that are grouped into the *ptfire-wild* and *ptfire-rx* sectors, respectively, and agricultural fires that comprise the *ptagfire* sector. All *ptfire* and *ptagfire* fires are in the United States. Fires outside of the United States are described in the *ptfire_othna* sector later in this document.

2.5.1 Wild and Prescribed Fires (*ptfire-rx*, *ptfire-wild*)

Wildfire and prescribed burning emissions are contained in the *ptfire-wild* and *ptfire-rx* sectors, respectively. The *ptfire* sector has emissions provided at geographic coordinates (point locations) and has daily emissions values. The *ptfire* sector excludes agricultural burning and other open burning sources that are included in the *ptagfire* 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.

The SCCs used for the *ptfire-rx* and *ptfire-wild* sources are shown in Table 2-20. The *ptfire-rx* and *ptfire-wild* inventories include separate SCCs for the flaming and smoldering combustion phases for wildfire

and prescribed burns. Note that prescribed grassland fires or Flint Hills, Kansas have their own SCC (2811021000) in the inventory. These wild grassland fires were assigned the standard wildfire SCCs shown in Table 2-20.

Table 2-20. SCCs included in the ptfire sector for the 2019 platform

SCC	Description
2810001001	Forest Wildfires; Smoldering; Residual smoldering only (includes grassland wildfires)
2810001002	Forest Wildfires; Flaming (includes grassland wildfires)
2811015001	Prescribed Forest Burning; Smoldering; Residual smoldering only
2811015002	Prescribed Forest Burning; Flaming
2811020002	Prescribed Rangeland Burning
2811021000	Prescribed Rangeland Burning - Tallgrass Prairie

Fire Information Data

Inputs to SMARTFIRE2 for 2019 include:

- The National Oceanic and Atmospheric Administration’s (NOAA’s) Hazard Mapping System (HMS) fire location information
- GeoMAC (Geospatial Multi-Agency Coordination), an online wildfire mapping application designed for fire managers to access maps of current fire locations and perimeters in the United States
- The Incident Status Summary, also known as the “ICS-209”, used for reporting specific information on fire incidents of significance
- Hazardous fuel treatment reduction polygons for prescribed burns from the Forest Service Activity Tracking System (FACTS)
- Fire activity on federal lands from the United States Fish and Wildlife Service (USFWS)
- Burn scar/fire activity shapefiles for wildfires and some prescribed burns from Monitoring trends in burn severity (MTBS) website (<https://www.mtbs.gov/direct-download>)
- Prescribed burn activity on federal lands from the Department of Interior (DOI)
- Prescribed burn activity from California Air Resources Board (CARB) specifically from their Prescribed Fire Incident Reporting System (PFIRS)
- Prescribed burn activity from Texas Parks and Wildlife Division (TPWD)
- Active fire perimeters from Bureau of Land Management (BLM)
- Wildfire and prescribed date, location, and locations from a few S/L/T activity submitters (includes Georgia, Florida and Kansas(Flint Hills only))

The Hazard Mapping System (HMS) was developed in 2001 by the National Oceanic and Atmospheric Administration’s (NOAA) National Environmental Satellite and Data Information Service (NESDIS) as a tool to identify fires over North America in an operational environment. The system utilizes geostationary and polar orbiting environmental satellites. Automated fire detection

algorithms are employed for each of the sensors. When possible, HMS data analysts apply quality control procedures for the automated fire detections by eliminating those that are deemed to be false and adding hotspots that the algorithms have not detected via a thorough examination of the satellite imagery.

The HMS product used for the 2019 inventory consisted of daily comma-delimited files containing fire detect information including latitude-longitude, satellite used, time detected, and other information. These detects were processed through Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2 (SMARTFIRE2) and BlueSky Pipeline. New size assumptions for HMS detects were used in SMARTFIRE2 for 2019 to accommodate new, higher resolution satellites that came online. A geospatial analysis of HMS detects that overlapped perimeter datasets in space and time was used by general land classification to calculate the acres per detect assumptions. GeoMAC (Geospatial Multi-Agency Coordination) is an online wildfire mapping application designed for fire managers to access maps of current U.S. fire locations and perimeters. The wildfire perimeter data is based upon input from incident intelligence sources from multiple agencies, GPS data, and infrared (IR) imagery from fixed wing and satellite platforms.

The Incident Status Summary, also known as the “ICS-209” is used for reporting specific information on significant fire incidents. The ICS-209 report is a critical interagency incident reporting tool giving daily ‘snapshots’ of the wildland fire management situation and individual incident information which include fire behavior, size, location, cost, and other information. Data from two tables in the ICS-209 database were merged and used for the 2016v1 ptfire inventory: the SIT209_HISTORY_INCIDENT_209_REPORTS table contained daily 209 data records for large fires, and the SIT209_HISTORY_INCIDENTS table contained summary data for additional smaller fires.

Monitoring Trends in Burn Severity (MTBS) is an interagency program whose goal is to consistently map the burn severity and extent of large fires across the U.S. from 1984 to present. The MTBS data includes all fires 1,000 acres or greater in the western United States and 500 acres or greater in the eastern United States. The extent of coverage includes the continental U.S., Alaska, Hawaii, and Puerto Rico. Fire occurrence and satellite data from various sources are compiled to create numerous MTBS fire products. The MTBS Burned Areas Boundaries Dataset shapefiles include year 2018 fires and that are classified as either wildfires, prescribed burns or unknown fire types. The unknown fire type shapes were omitted in the inventory development due to temporal and spatial problems found when trying to use these data.

The US Forest Service (USFS) compiles a variety of fire information every year. Year 2019 data from the USFS Natural Resource Manager (NRM) Forest Activity Tracking System (FACTS) were acquired and used for emissions inventory development. This database includes information about activities related to fire/fuels, silviculture, and invasive species. The FACTS database consists of shapefiles for prescribed burns that provide acres burned and start and ending time information.

The US Fish and Wildland Service (USFWS) also compiles wildfire and prescribed burn activity on their federal lands every year. Year 2019 data were acquired from USFWS through direct communication with USFWS staff and were used for 2019 platform development. The USFWS fire information provided fire type, acres burned, latitude-longitude, and start and ending times. The Department of Interior provided prescribed burn information for the other bureaus/departments in DOI (Bureau of Land Management, Bureau of Indian Affairs and National Parks System). Perimeter shapefiles of year 2019 active fires on Bureau of Land Management (BLM) land in the western US was also used to capture small, mid-size, and large fires.

The state-specific activity data acquired and used included data from California, Florida, Georgia, Kansas and Texas. Activity from Florida and Georgia contained wild and prescribed fires for the entire states.

Fire Emissions Estimation Methodology

The national and S/L/T data mentioned earlier were used to estimate daily wildfire and prescribed burn emissions from flaming combustion and smoldering combustion phases for the 2019 inventory. Flaming combustion is more complete combustion than smoldering and is more prevalent with fuels that have a high surface-to-volume ratio, a low bulk density, and low moisture content. Smoldering combustion occurs without a flame, is a less complete burn, and produces some pollutants, such as PM_{2.5}, VOCs, and CO, at higher rates than flaming combustion. Smoldering combustion is more prevalent with fuels that have low surface-to-volume ratios, high bulk density, and high moisture content. Models sometimes differentiate between smoldering emissions that are lofted with a smoke plume and those that remain near the ground (residual emissions), but for the purposes of the inventory the residual smoldering emissions were allocated to the smoldering SCCs listed in Table 2-20. The lofted smoldering emissions were assigned to the flaming emissions SCCs in Table 2-20.

Figure 2-9 is a schematic of the data processing stream for the inventory of wildfire and prescribed burn sources. The ptfire-rx and ptfire-wild inventory sources were estimated using Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2 (SMARTFIRE2) and Blue Sky Pipeline. SMARTFIRE2 is an algorithm and database system that operate within a geographic information system (GIS). SMARTFIRE2 combines multiple sources of fire information and reconciles them into a unified GIS database. It reconciles fire data from space-borne sensors and ground-based reports, thus drawing on the strengths of both data types while avoiding double-counting of fire events. At its core, SMARTFIRE2 is an association engine that links reports covering the same fire in any number of multiple databases. In this process, all input information is preserved, and no attempt is made to reconcile conflicting or potentially contradictory information (for example, the existence of a fire in one database but not another).

For the 2019 platform, the national and S/L/T fire information was input into SMARTFIRE2 and then merged and associated based on user-defined weights for each fire information dataset. The output from SMARTFIRE2 was daily acres burned by fire type, and latitude-longitude coordinates for each fire. The fire type assignments were made using the fire information datasets. If the only information for a fire was a satellite detect for fire activity, then the flow described in Figure 2-10 was used to make fire type assignment by state and by month.

Figure 2-9. Processing flow for fire emission estimates in the 2019 inventory

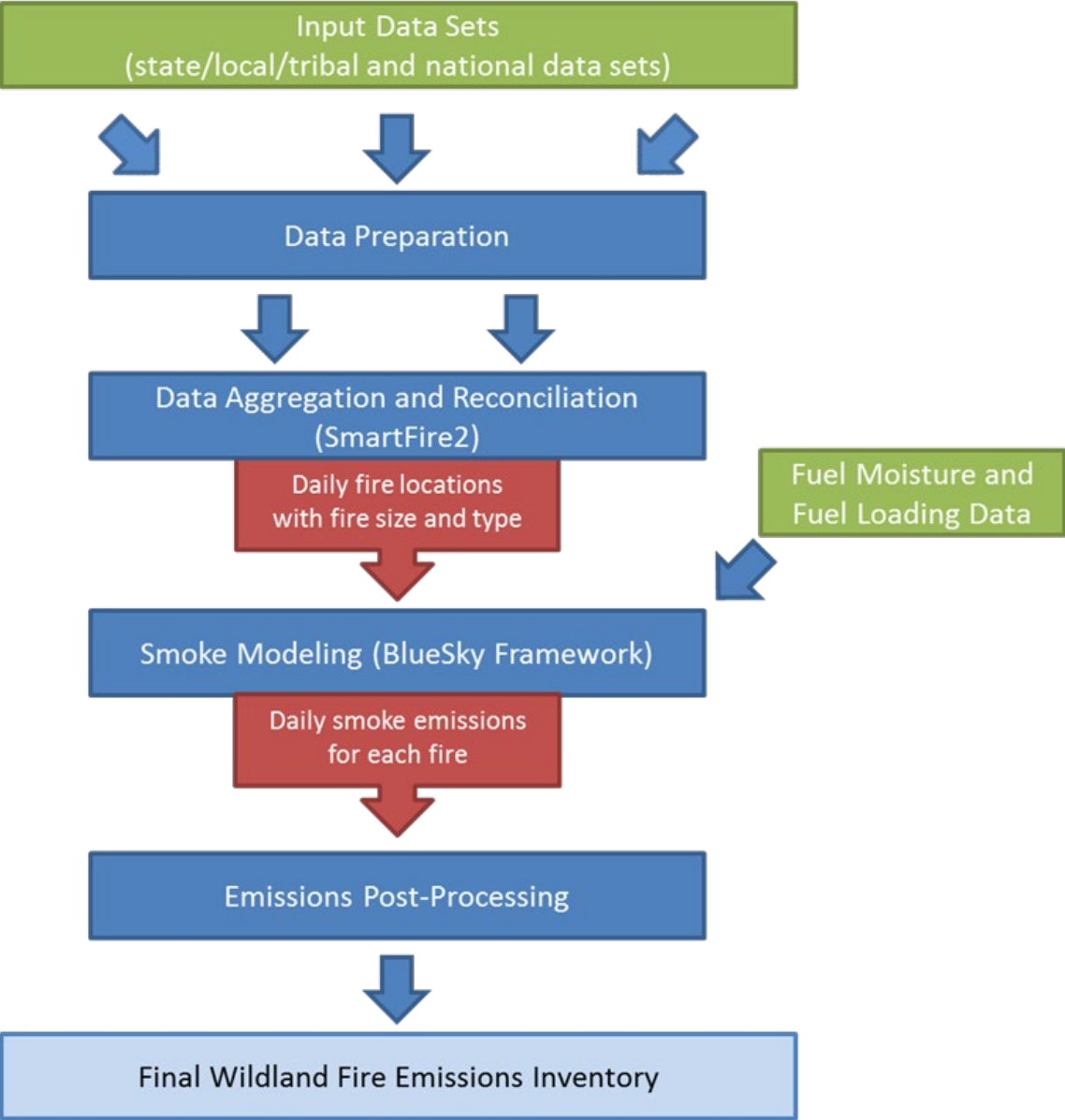
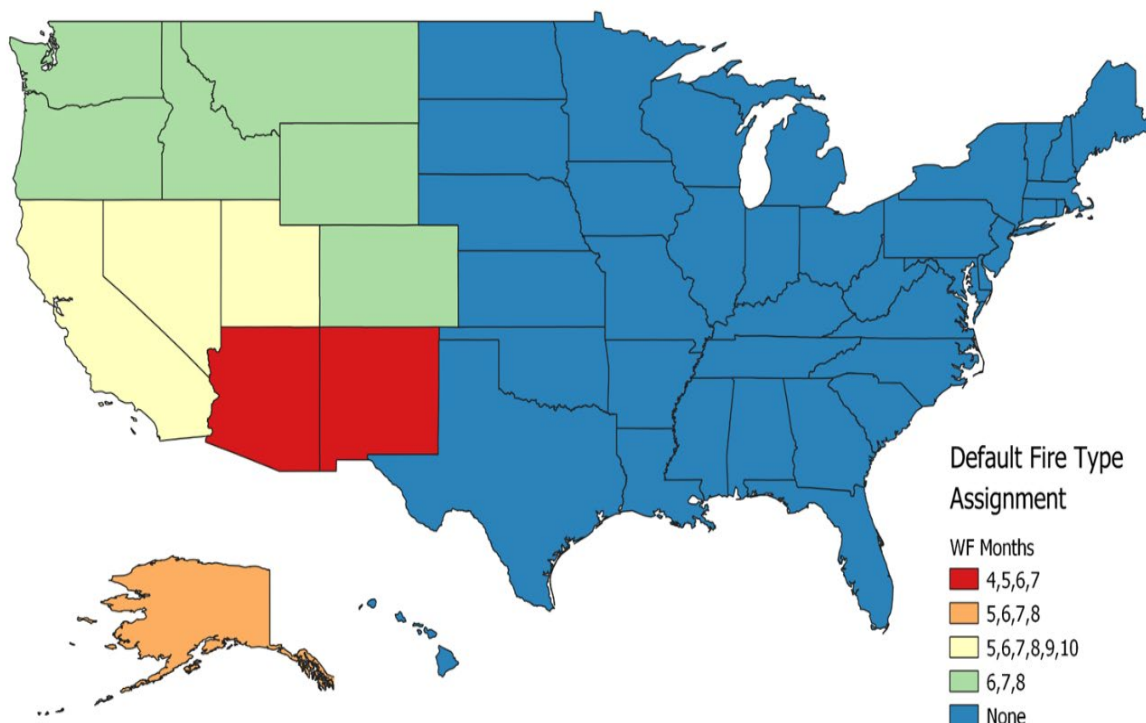
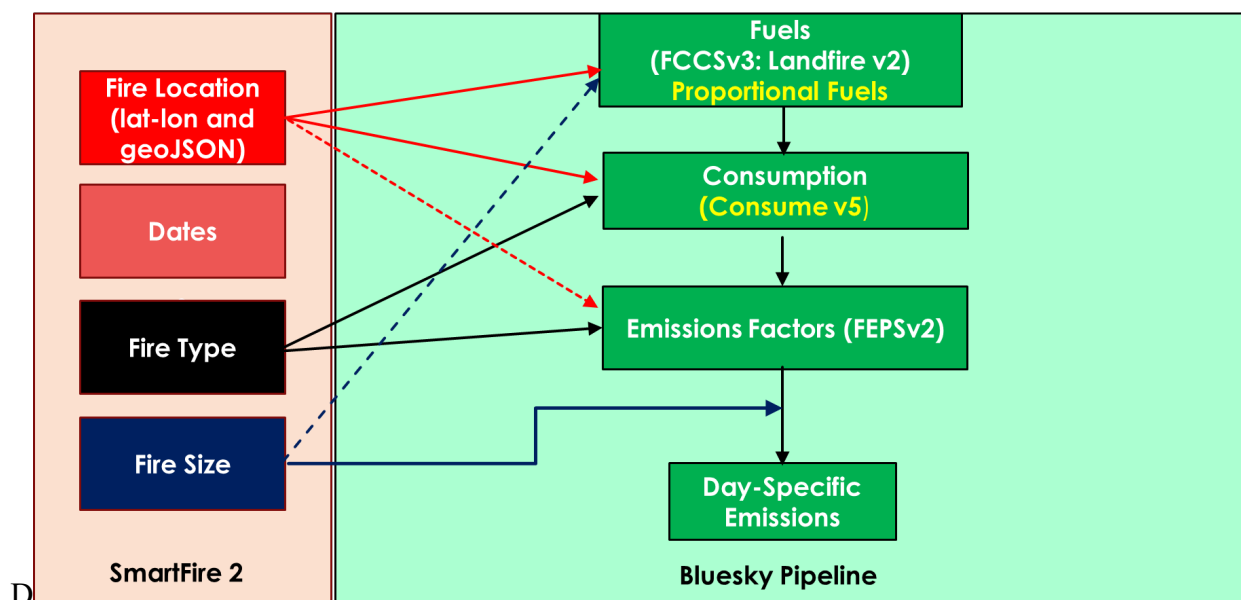


Figure 2-10. Default fire type assignment by state and month where data are only from satellites.



The second system used to estimate emissions is the BlueSky Modeling Pipeline. The framework supports the calculation of fuel loading and consumption, and emissions using various models depending on the available inputs as well as the desired results. The contiguous United States and Alaska, where Fuel Characteristic Classification System (FCCS) fuel loading data are available, were processed using the modeling chain described in Figure 2-1. The Fire Emissions Production Simulator (FEPS) in the BlueSky Pipeline generates all the CAP emission factors for wildland fires used in the 2019 study. HAP emission factors were obtained from Urbanski’s (2014) work and applied by region and by fire type.

Figure 2-11. Blue Sky Modeling Framework



The FCCSv3 cross-reference was implemented along with the LANDFIREv2 (at 200 meter resolution) to provide better fuel bed information for the BlueSky Pipeline (BSP). The LANDFIREv2 was aggregated from the native resolution and projection to 200 meter using a nearest-neighbor methodology. Aggregation and projection was required for the proper function on BSP.

The final products from this process are annual and daily FF10-formatted emissions inventories. These SMOKE-ready inventory files contain both CAPs and HAPs. The BAFM HAP emissions from the inventory were used directly in modeling and were not overwritten with VOC speciation profiles (i.e., an “integrate HAP” use case).

2.5.2 Point source Agriculture Fires (ptagfire)

In the NEI, agricultural fires are stored as county-annual emissions and are part of the nonpoint data category. For this study agricultural fires are modeled as day specific fires derived from satellite data for the year 2019 in a similar way to the emissions in ptfire. The state of Florida provided their own emissions (separate from the other states) for this study.

Daily year-specific agricultural burning emissions are derived from HMS fire activity data, which contains the date and location of remote-sensed anomalies. The activity is filtered using the 2019 USDA cropland data layer (CDL). Satellite fire detects over agricultural lands are assumed to be agricultural burns and assigned a crop type. Detects that are not over agricultural lands are output to a separate file for use in the ptfire sector. Each detect is assigned an average size of between 40 and 80 acres based on crop type. Grassland/pasture fires are in the ptfire sector for this modeling platform. Depending on their origin, grassland fires are in both ptfire-rx and ptfire-wild sectors because both fire types do involve grassy fuels.

The point source agricultural fire (ptagfire) inventory sector contains daily agricultural burning emissions. Daily fire activity was derived from the NOAA Hazard Mapping System (HMS) fire activity data. The agricultural fires sector includes SCCs starting with '28015'. 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. The SCCs for this sector listed are in Table 2-21.

Table 2-21. SCCs included in the ptagfire sector

SCC	Description
2801500000	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Unspecified crop type and Burn Method
2801500141	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Bean (red): Headfire Burning
2801500150	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Corn: Burning Techniques Not Important
2801500151	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Double Crop Winter Wheat and Corn
2801500152	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; DoubleCrop Corn and Soybeans
2801500160	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Cotton: Burning Techniques Not Important
2801500171	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Fallow
2801500220	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Rice: Burning Techniques Not Significant
2801500250	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Sugar Cane: Burning Techniques Not Significant
2801500262	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; Field Crop is Wheat: Backfire Burning
2801500263	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; DoubleCrop Winter Wheat and Cotton
2801500264	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; DoubleCrop Winter Wheat and Soybeans

Another feature of the ptagfire database is that the satellite detections for 2019 were filtered out to exclude areas covered by snow during the winter months. To do this, the daily snow cover fraction per grid cell was extracted from a 2019 meteorological Weather Research Forecast (WRF) model simulation. The locations of fire detections were then compared with this daily snow cover file. For any day in which a grid cell had snow cover, the fire detections in that grid cell on that day were excluded from the inventory. Due to the inconsistent reporting of fire detections from the Visible Infrared Imaging Radiometer Suite (VIIRS) platform, any fire detections in the HMS dataset that were flagged as VIIRS or Suomi National Polar-orbiting Partnership satellite were excluded. In addition, certain crop types (corn and soybeans) have been excluded from these specific midwestern states: Iowa, Kansas, Indiana, Illinois, Michigan, Missouri, Minnesota, Wisconsin, and Ohio. The reason for these crop types being excluded is because states have indicated that these crop types are not burned.

Heat flux for plume rise was calculated using the size and assumed fuel loading of each daily agricultural fire. This information is needed for a plume rise calculation within a chemical transport modeling system.

The daily agricultural and open burning emissions were converted from a tabular format into the SMOKE-ready daily point flat file format. The daily emissions were also aggregated into annual values by location and converted into the annual point flat file format.

For this modeling platform, a SMOKE update allows the use of HAP integration for speciation for PTDAY inventories. The 2019 agricultural fire inventories include emissions for HAPs, so HAP integration was used for this study.

2.6 Biogenic Sources (beis)

Biogenic emissions were computed based on the 19k version of the 2019 meteorology data used for the air quality modeling and were developed using the Biogenic Emission Inventory System version 3.7 (BEIS3.7) within CMAQ. The BEIS3.7 creates gridded, hourly, model-species emissions from vegetation and soils. It estimates CO, VOC (most notably isoprene, terpene, and sesquiterpene), and NO emissions for the contiguous U.S. and for portions of Mexico and Canada. In the BEIS 3.7 two-layer canopy model, the layer structure varies with light intensity and solar zenith angle (Pouliot and Bash, 2015). Both layers 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 3.7

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 surface
RN	nonconvective precipitation per met TSTEP
RSTOMI	inverse of bulk stomatal resistance
SLYTP	soil texture type by USDA category

Variable	Description
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

BEIS 3.7 was used in conjunction with Version 5 of the Biogenic Emissions Landuse Database (BELD5). The BELD5 is based on an updated version of the USDA-USFS Forest Inventory and Analysis (FIA) vegetation speciation-based data from 2001 to 2017 from the FIA version 8.0. Canopy coverage is based on the Global Moderate Resolution Imaging Spectroradiometer (MODIS) 20 category data with enhanced lakes and Fraction of Photosynthetically Active Radiation (FPAR) for vegetation coverage from National Center for Atmospheric Research (NCAR). 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 MODIS canopy coverage. For land areas outside the conterminous United States, 500 meter grid spacing land cover data from the Moderate Resolution Imaging Spectroradiometer (MODIS) is used. BELDv5 also incorporates the following datasets:

- Canadian BELD land use, updates to Version 4 of the Biogenic Emissions Landuse Database (BELD4) for Canada and Impacts on Biogenic VOC Emissions (https://www.epa.gov/sites/default/files/2019-08/documents/800am_zhang_2_0.pdf).
- 2017 30 meter USDA Cropland Data Layer (CDL) data (<http://www.nass.usda.gov/research/Cropland/Release/>).

Biogenic emissions computed with BEIS were used to review and prepare summaries, but were left out of the CMAQ-ready merged emissions in favor of inline biogenics produced during the CMAQ model run itself using the same algorithm described above but with finer time steps within the air quality model.

2.7 Sources Outside of the United States

The emissions from Canada and Mexico are included as part of the emissions modeling sectors: othpt, othar, othafdust, othptdust, onroad_can, and onroad_mex, canada_ag, and canada_og2D. The “oth” refers to the fact that these emissions are usually “other” than those in the U.S. state-county geographic FIPS, and the remaining characters provide the SMOKE source types: “pt” for point, “ar” for area and nonroad mobile, “afdust” for area fugitive dust (Canada only), and “ptdust” for point fugitive dust (Canada only). The onroad emissions for Canada and Mexico are in the onroad_can and onroad_mex sectors, respectively. Canadian agricultural and low-level (2-D) oil and gas emissions are split into separate sectors from other Canada point sources to reduce the size of the othpt sector.

Emissions in these sectors were taken from the EQUATES 2016 inventories. Environment and Climate Change Canada (ECCC) provided the following inventories for use in EQUATES 2016 and 2017 modeling, which are described in more detail below:

- Agricultural livestock and fertilizer, point source format (canada_ag sector)
- CMV were provided as area sources but converted to point (not currently used)

- Agricultural fugitive dust, point source format (othptdust sector)
- Other area source dust (othafdust sector)
- Onroad (onroad_can sector)
- Nonroad and rail (othar sector)
- Oil and gas surces (low-level in canada_og2D sector, elevated in othpt sector)
- Other area sources (othar sector)
- Airports (othpt sector)
- Other point sources (othpt sector)

Canadian CMV inventories that had been included in this sector in past modeling platforms are no longer needed in the cmv_c1c2 and cmv_c3 sectors.

Temporal profiles, and shapefiles for creating spatial surrogates, were provided by ECCC in a previous Canadian emissions dataset and were reused for this study. Other than the CB6 species of NBAFM present in the speciated point source data, there are no explicit HAP emissions in these Canadian inventories.

2.7.1 Point Sources in Canada and Mexico (othpt, canada_ag, canada_og2D)

Canadian point source inventories provided by ECCC for the EQUATES project for 2016 were used as-is for 2019. These inventories include emissions for airports and other point sources. The Canadian point source inventory is pre-speciated for the CB6 chemical mechanism. Point sources in Mexico were compiled based on inventories projected from the Inventario Nacional de Emisiones de Mexico, 2016 (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)). The point source emissions were converted to English units and into the FF10 format that could be read by SMOKE, missing stack parameters were gapped using SCC-based defaults, and latitude and longitude coordinates were verified and adjusted if they were not consistent with the reported municipality. Only CAPs are covered in the Mexico point source inventory. For this study, Mexico emissions were projected from 2016 to 2019 using projection factors derived from the Community Emissions Data System (CEDS). The CEDS dataset includes emissions totals for 2016 and 2019 for Mexico and other countries by emissions sector. For each CEDS sector and pollutant, a 2016-to-2019 projection factor was calculated based on the Mexico national total emissions from each year. Each SCC in the Mexico inventory was mapped to a CEDS sector so that the appropriate projection factor is applied.

Due to the large number of points in the Canada inventories, the agricultural sources were split into a separate sector called canada_ag so that the sources could be placed into layer 1 as plume rise calculations were not needed. Similarly, there were a very large number of Canadian oil and gas point sources, many of which would be appropriate modeled in layer 1. These sources were placed into the canada_og2D sector for layer 1 modeling. Reducing the size of the othpt sector sped up the air quality model run.

2.7.2 Fugitive Dust Sources in Canada (othafdust, othptdust)

Fugitive dust sources of particulate matter emissions excluding land tilling from agricultural activities, were provided by Environment and Climate Change Canada (ECCC) as part of their 2016 emission inventory. Different source categories were provided as gridded point sources and area (nonpoint) source inventories. Gridded point source emissions resulting from land tilling due to agricultural activities were provided as part of the ECCC 2016 emission inventory. The provided wind erosion emissions were removed. The othptdust emissions have a monthly resolution. A transport fraction adjustment that reduces dust emissions based on land cover types was applied to both point and nonpoint dust emissions, along

with a meteorology-based (precipitation and snow/ice cover) zero-out of emissions when the ground is snow covered or wet. The EQUATES 2016 inventory was used as-is with 2019 meteorology applied.

2.7.3 Nonpoint and Nonroad Sources in Canada and Mexico (othar)

ECCC provided year 2016 Canada province, and in some cases sub-province, resolution emissions from for nonpoint and nonroad sources (othar). The nonroad sources were monthly while the nonpoint and rail emissions were annual. The 2016 Canada nonroad emissions were projected to 2019 using US MOVES-based trends. For Mexico, year 2016 Mexico nonpoint and nonroad inventories at the municipio resolution provided by SEMARNAT were projected to 2019 using projection factors derived from the Community Emissions Data System (CEDS). More information on CEDS is provided in Section 2.7.1. All Mexico inventories were annual resolution.

2.7.4 Onroad Sources in Canada and Mexico (onroad_can, onroad_mex)

The onroad emissions for Canada and Mexico are in the onroad_can and onroad_mex sectors, respectively. Emissions for Canada come from the EQUATES 2016 (2016 was the latest year provided by Environment and Climate Change Canada (ECCC)) and were projected from 2016 to 2019 using US MOVES-based trends.

For Mexico onroad emissions, a version of the MOVES model for Mexico was run that provided the same VOC HAPs and speciated VOCs as for the U.S. MOVES model (ERG, 2016a). This includes NBAFM plus several other VOC HAPs such as toluene, xylene, ethylbenzene and others. Except for VOC HAPs that are part of the speciation, no other HAPs are included in the Mexico onroad inventory (such as particulate HAPs nor diesel particulate matter). Mexico onroad inventories were generated by MOVES for the years 2017 and 2020, and then interpolated to 2019 for this study.

2.7.5 Fires in Canada and Mexico (ptfire_othna)

Annual 2019 wildland fire emissions for Mexico, Canada, Central America, and Caribbean nations are included in the ptfire_othna sector. Canadian fires, along with fires in Mexico, Central America, and the Caribbean, were developed from Fire Inventory from NCAR (FINN) 2017 v1.5 daily fire emissions. For FINN fires, listed vegetation type codes of 1 and 9 are defined as agricultural burning, all other fire detections and assumed to be wildfires. All wildland fires that are not defined as agricultural are assumed to be wildfires rather than prescribed. FINN fire detects of less than 50 square meters (0.012 acres) are removed from the inventory. The locations of FINN fires are geocoded from latitude and longitude to FIPS code.

2.7.6 Ocean Chlorine, Ocean Sea Salt, and Volcanic Mercury

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 12 km resolution were available and were not modified other than the model-species name “CHLORINE” was changed to “CL2” to support CMAQ modeling.

For mercury, the volcanic mercury emissions that were used in the last several modeling platforms were not included in this study. The emissions were originally developed for a 2002 multipollutant modeling platform with coordination and data from Christian Seigneur and Jerry Lin for 2001 (Seigneur et. al, 2004 and Seigneur et. al, 2001).). The volcanic emissions from the most recent eruption were not included in the because they have diminished by the year 2019. Thus no volcanic emissions were included.

Because of mercury bidirectional flux within the latest version of CMAQ, no other natural mercury emissions are included in the emissions merge step.

3 Emissions Modeling

The CMAQ and CAMx air quality 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 and vertical resolution required by the air quality model. Emissions modeling includes temporal allocation, spatial allocation, and pollutant speciation. Emissions modeling sometimes includes the vertical allocation (i.e., plume rise) 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 vertical layers of the sources are not included.

As seen in Section 2, the temporal resolutions of the emissions inventories input to SMOKE vary across sectors and may be hourly, daily, monthly, or annual total emissions. The spatial resolution may be individual point sources; totals by county (U.S.), province (Canada), or municipio (Mexico); or gridded emissions. This section provides some basic information about the tools and data files used for emissions modeling as part of the modeling platform.

3.1 Emissions Modeling Overview

SMOKE version 4.8.1 was used to process the raw emissions inventories into emissions inputs for each modeling sector into a format compatible with CMAQ. SMOKE executables and source code are available from the Community Multiscale Analysis System (CMAS) Center at <http://www.cmascenter.org>. Additional information about SMOKE is available from <http://www.smoke-model.org>. For sectors that have plume rise, the in-line plume rise capability allows for the use of emissions files that are much smaller than full three-dimensional gridded emissions files. For quality assurance of the emissions modeling steps, emissions totals by specie for 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.

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 2-D gridded 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 with the columns as follows.

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 biogenics 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. In all of the “in-line” sectors, all sources are output by SMOKE into point source files which are subject to plume rise calculations in the air quality model. In other words, no emissions are output to layer 1 gridded emissions files from those sectors as has been done in past platforms. The air quality model computes the plume rise using stack parameters, the Briggs algorithm, and the hourly emissions in the SMOKE output files for each emissions sector. The height of the plume rise determines the model layers into which the emissions are placed. The plume top and bottom are computed, along with the plumes’ distributions into the vertical layers that the plumes intersect. The pressure difference across each layer divided by the pressure difference across the entire plume is used as a weighting factor to assign the emissions to layers. This approach gives plume fractions by layer and source. Day-specific point fire emissions are treated differently in CMAQ. After plume rise is applied, there are emissions in every layer from the ground up to the top of the plume.

Table 3-1. Key emissions modeling steps by sector.

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
afdust_adj	Surrogates	Yes	Annual	
airports	Point	Yes	Annual	None
beis	Pre-gridded land use	in BEIS3.7	computed hourly	
fertilizer	Surrogates	No	computed hourly	
livestock	Surrogates	Yes	Annual	
cmv_c1c2	Point	Yes	hourly	in-line
cmv_c3	Point	Yes	hourly	in-line
nonpt	Surrogates & area-to-point	Yes	Annual	
nonroad	Surrogates	Yes	monthly	
np_oilgas	Surrogates	Yes	Annual	
np_solvents	Surrogates	Yes	annual	
onroad	Surrogates	Yes	monthly activity, computed hourly	
onroad_ca_adj	Surrogates	Yes	monthly activity, computed hourly	
onroad_can	Surrogates	Yes	monthly	
onroad_mex	Surrogates	Yes	monthly	
othafdust_adj	Surrogates	Yes	annual	
othar	Surrogates	Yes	annual & monthly	
othpt	Point	Yes	annual & monthly	in-line
othptdust_adj	Point	Yes	monthly	None
ptagfire	Point	Yes	daily	in-line

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
pt oilgas	Point	Yes	annual	in-line
Ptegu	Point	Yes	daily & hourly	in-line
ptfire-rx	Point	Yes	daily	in-line
ptfire-wild	Point	Yes	daily	in-line
ptfire_othna	Point	Yes	daily	in-line
ptnonipm	Point	Yes	annual	in-line
rail	Surrogates	Yes	annual	
rwc	Surrogates	Yes	annual	

Note that SMOKE has the option of grouping sources so that they are treated as a single stack when computing plume rise. For the modeling cases discussed in this document, no grouping was performed because grouping combined with “in-line” processing will not give identical results as “offline” processing (i.e., when SMOKE creates 3-dimensional files). This occurs when stacks with different stack parameters or latitude and 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 stack grouping.

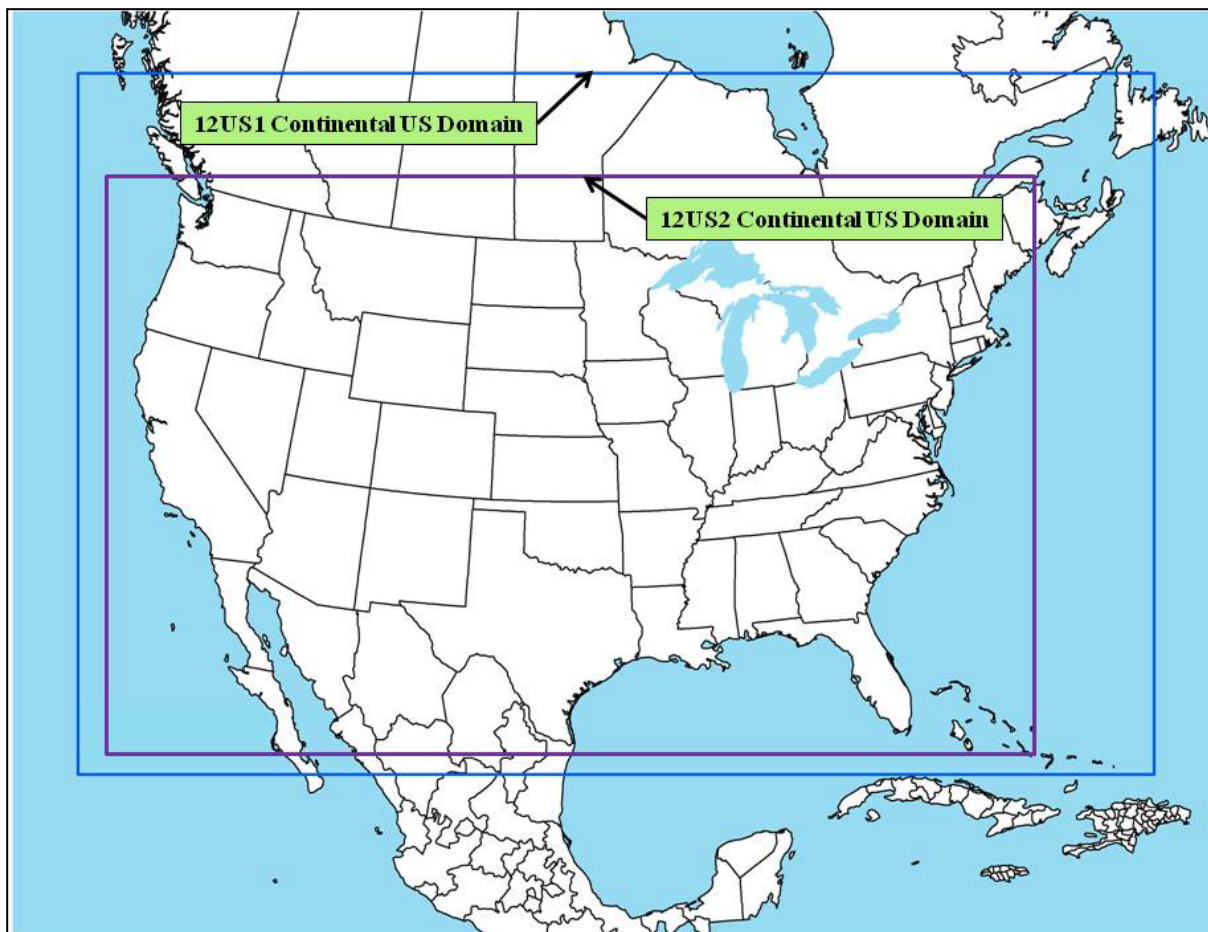
Biogenic emissions can be modeled two different ways in the CMAQ model. The BEIS model in SMOKE can produce gridded biogenic emissions that are then included in the gridded CMAQ-ready emissions inputs, or alternatively, CMAQ can be configured to create “in-line” biogenic emissions within CMAQ itself. For this study, the in-line biogenic emissions option was used, and so biogenic emissions from BEIS were not included in the gridded CMAQ-ready emissions.

For this study, SMOKE was run for the larger 12-km Continental United States “CONUS” modeling domain (12US1) shown in Figure 3-1, but the air quality model was run on the smaller 12-km domain (12US2). More specifically, SMOKE was run on the 12US1 domain and emissions were extracted from 12US1 data files to create 12US2 emissions. The grids used a Lambert-Conformal projection, with Alpha = 33, Beta = 45 and Gamma = -97, with a center of X = -97 and Y = 40. Later sections provide details on the spatial surrogates and area-to-point data used to accomplish spatial allocation with SMOKE. Table 3-2 describes the grids.

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

Figure 3-1. Emissions modeling domain (12US1) and air quality modeling domain (12US2)



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 this platform is the CB6R3AE7 mechanism (Yarwood, 2010, Luecken, 2019). We used an updated version of CB6 that we refer to as “CB6R3AE7” which includes four new species that were not in the previous version of CB6: AACD, FACD, APIN, and IVOC. This mapping uses a new systematic methodology for mapping low volatility compounds. Compounds with very low vapor pressure are mapped to model species NVOL and intermediate volatility compounds are mapped to a species called IVOC. In previous mappings, some of these low vapor pressure compounds were mapped to CB6 species. The mechanism and mapping are described in more detail in a [memorandum](#) describing the mechanism files supplied with the Speciation Tool, the software used to create the CB6 profiles used in SMOKE. It should be noted that the onroad mobile sector does not use this newer mapping because the speciation is done within MOVES and the mapping change was made after MOVES had been run.

This platform generates the PM_{2.5} model species associated with the CMAQ Aerosol Module version 7 (AE7) which has the same PM_{2.5} model species as version 6 (AE6). The AE7 mechanism is built on the

AE6 and identical in terms of model species and mechanism definition but requires that alpha-pinene (APIN) be separate from all other monoterpenes (TERP) and not included in TERP to avoid double counting.

Table 3-3 lists the model species produced by SMOKE in the CMAQ platform used for this study. Species assignments for CB05 and CB6 are described in Appendix A. Table 3-4 and Table 3-5 list additional CMAQ model species generated specifically for HAP toxics modeling. Pollutants groups exist for chromium VI (hexavalent), cresol cresylic acid (mixed isomers), cyanide compounds, glycol ethers, nickel compounds, PAHPOM, polychlorinated biphenyls (aroclors), and xylenes (mixed isomers). Table 3-6 lists a mapping of polycyclic aromatic hydrocarbons (PAHs) to the PAH groups used in CMAQ modeling.

Table 3-3. Emission model species produced for CB6R3AE7 for CMAQ

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
NO _x	NO2	Nitrogen dioxide
NO _x	HONO	Nitrous acid
SO ₂	SO2	Sulfur dioxide
SO ₂	SULF	Sulfuric acid vapor
NH ₃	NH3	Ammonia
NH ₃	NH3_FERT	Ammonia from fertilizer
VOC	AACD	Acetic acid
VOC	ACET	Acetone
VOC	ALD2	Acetaldehyde
VOC	ALDX	Propionaldehyde and higher aldehydes
VOC	APIN	Alpha pinene
VOC	BENZ	Benzene (not part of CB05)
VOC	CH4	Methane
VOC	ETH	Ethene
VOC	ETHA	Ethane
VOC	ETHY	Ethyne
VOC	ETOH	Ethanol
VOC	FACD	Formic acid
VOC	FORM	Formaldehyde
VOC	IOLE	Internal olefin carbon bond (R-C=C-R)
VOC	ISOP	Isoprene
VOC	IVOC	Intermediate volatility organic compounds
VOC	KET	Ketone Groups
VOC	MEOH	Methanol
VOC	NAPH	Naphthalene
VOC	NVOL	Non-volatile compounds
VOC	OLE	Terminal olefin carbon bond (R-C=C)
VOC	PAR	Paraffin carbon bond
VOC	PRPA	Propane

Inventory Pollutant	Model Species	Model species description
VOC	SESQ	Sesquiterpenes (from biogenics only)
VOC	SOAALK	Secondary Organic Aerosol (SOA) tracer
VOC	TERP	Terpenes (from biogenics only)
VOC	TOL	Toluene and other monoalkyl aromatics
VOC	UNR	Unreactive
VOC	XYLMN	Xylene and other polyalkyl aromatics, minus naphthalene
Naphthalene	NAPH	Naphthalene from inventory
Benzene	BENZ	Benzene from the inventory
Acetaldehyde	ALD2	Acetaldehyde from inventory
Formaldehyde	FORM	Formaldehyde from inventory
Methanol	MEOH	Methanol from inventory
PM ₁₀	PMC	Coarse PM > 2.5 microns and ≤ 10 microns
PM _{2.5}	PEC	Particulate elemental carbon ≤ 2.5 microns
PM _{2.5}	PNO3	Particulate nitrate ≤ 2.5 microns
PM _{2.5}	POC	Particulate organic carbon (carbon only) ≤ 2.5 microns
PM _{2.5}	PSO4	Particulate Sulfate ≤ 2.5 microns
PM _{2.5}	PAL	Aluminum
PM _{2.5}	PCA	Calcium
PM _{2.5}	PCL	Chloride
PM _{2.5}	PFE	Iron
PM _{2.5}	PK	Potassium
PM _{2.5}	PH2O	Water
PM _{2.5}	PMG	Magnesium
PM _{2.5}	PMN	Manganese
PM _{2.5}	PMOTHR	PM _{2.5} not in other AE6 species
PM _{2.5}	PNA	Sodium
PM _{2.5}	PNA	Sodium
PM _{2.5}	PNCOM	Non-carbon organic matter
PM _{2.5}	PNH4	Ammonium
PM _{2.5}	PSI	Silica
PM _{2.5}	PTI	Titanium

Table 3-4. Additional HAP Gaseous model species produced for CMAQ multipollutant specifically for toxics modeling (not used within CB6)

Inventory Pollutant	Model Species
Acetaldehyde	ALD2_PRIMARY
Formaldehyde	FORM_PRIMARY
Acetonitrile	ACETONITRILE
Acrolein	ACROLEIN
Acrylic acid	ACRYLICACID
Acrylonitrile	ACRYLONITRILE
Benzo[a]Pyrene	BENZOAPYRNE
1,3-Butadiene	BUTADIENE13
Carbon tetrachloride	CARBONTET
Carbonyl Sulfide	CARBSULFIDE
Chloroform	CHCL3
Chloroprene	CHLOROPRENE
1,4-Dichlorobenzene(p)	DICHLOROBENZENE
1,3-Dichloropropene	DICHLOROPROPENE
Ethylbenzene	ETHYLBENZ
Ethylene dibromide (Dibromoethane)	BR2_C2_12
Ethylene dichloride (1,2-Dichloroethane)	CL2_C2_12
Ethylene oxide	ETOX
Hexamethylene-1,6-diisocyanate	HEXAMETH_DIIS
Hexane	HEXANE
Hydrazine	HYDRAZINE
Maleic Anyhydride	MAL_ANYHYDRIDE
Methyl Chloride	METHCLORIDE
Methylene chloride (Dichloromethane)	CL2_ME
Specific PAHs assigned with URE =0	PAH_000E0
Specific PAHs assigned with URE =9.6E-06 (previously 1.76E-5)	PAH_176E5
Specific PAHs assigned with URE =4.8E-05 (previously 8.8E-5)	PAH_880E5
Specific PAHs assigned with URE =9.6E-05 (previously 1.76E-4)	PAH_176E4
Specific PAHs assigned with URE =9.6E-04 (previously 1.76E-3)	PAH_176E3
Specific PAHs assigned with URE =9.6E-03 (previously 1.76E-2)	PAH_176E2
Specific PAHs assigned with URE =0.01 (previously 1.01E-2)	PAH_101E2
Specific PAHs assigned with URE =1.14E-1	PAH_114E1
Specific PAHs assigned with URE =9.9E-04 (previously 1.92E-3)	PAH_192E3
Propylene dichloride (1,2-Dichloropropane)	PROPDICHLORIDE
Quinoline	QUINOLINE
Styrene	STYRENE
1,1,2,2-Tetrachloroethane	CL4_ETHANE1122
Tetrachloroethylene (Perchloroethylene)	CL4_ETHE
Toluene	TOLU
2,4-Toluene diisocyanate	TOL_DIIS
Trichloroethylene	CL3_ETHE
Triethylamine	TRIETHYLAMINE
m-xylene, o-xylene, p-xylene, xylenes (mixed isomers)	XYLENES
Vinyl chloride	CL_ETHE

Table 3-5. Additional HAP Particulate* model species produced for CMAQ multipollutant modeling

Inventory Pollutant	Model Species
Arsenic	ARSENIC_C, ARSENIC_F
Beryllium	BERYLLIUM_C, BERYLLIUM_F
Cadmium	CADMIUM_C, CADMIUM_F
Chromium VI, Chromic Acid (VI), Chromium Trioxide	CHROMHEX_C, CHROMHEX_F
Chromium III	CHROMTRI_C, CHROMTRI_F
Lead	LEAD_C, LEAD_F
Manganese	MANGANESE_C, MANGANESE_F
Mercury ¹	HGIIGAS, HGNRVA, PHGI
Nickel, Nickel Oxide, Nickel Refinery Dust	NICKEL_C, NICKEL_F
Diesel-PM10, Diesel-PM25	DIESEL_PMC , DIESEL_PMFINE, DIESEL_PMEC, DIESEL_PMOC, DIESEL_PMNO3, DIESEL_PMSO4

¹Mercury is multi-phase

Table 3-6. PAH/POM pollutant groups

PAH Group	NEI Pollutant Code	NEI Pollutant Description	URE 1/($\mu\text{g}/\text{m}^3$)
PAH 000E0	120127	Anthracene	0
PAH 000E0	129000	Pyrene	0
PAH 000E0	85018	Phenanthrene	0
PAH 101E2	56495	3-Methylcholanthrene	0.01
PAH 114E1	57976	7,12-Dimethylbenz[a]Anthracene	0.114
PAH 176E2	189559	Dibenzo[a,i]Pyrene	9.6E-03
PAH 176E2	189640	Dibenzo[a,h]Pyrene	9.6E-03
PAH 176E2	191300	Dibenzo[a,l]Pyrene	9.6E-03
PAH 176E3	192654	Dibenzo[a,e]Pyrene	9.6E-04
PAH 176E3	194592	7H-Dibenzo[c,g]carbazole	9.6E-04
PAH 176E3	3697243	5-Methylchrysene	9.6E-04
PAH 176E3	41637905	Methylchrysene	9.6E-04
PAH 176E3	53703	Dibenzo[a,h]Anthracene	9.6E-04
PAH 176E4	193395	Indeno[1,2,3-c,d]Pyrene	9.6E-05
PAH 176E4	205823	Benzo[j]Fluoranthene	9.6E-05
PAH 176E4	205992	Benzo[b]Fluoranthene	9.6E-05
PAH 176E4	224420	Dibenzo[a,j]Acridine	9.6E-05
PAH 176E4	226368	Dibenz[a,h]acridine	9.6E-05
PAH 176E4	5522430	1-Nitropyrene	9.6E-05
PAH 176E4	56553	Benz[a]Anthracene	9.6E-05
PAH 176E5	207089	Benzo[k]Fluoranthene	9.6E-06
PAH 176E5	218019	Chrysene	9.6E-06
PAH 176E5	86748	Carbazole	9.6E-06
PAH 192E3	8007452	Coal Tar	9.9E-04
PAH 880E5	130498292	PAH, total	4.8E-05

PAH Group	NEI Pollutant Code	NEI Pollutant Description	URE 1/($\mu\text{g}/\text{m}^3$)
PAH 880E5	191242	Benzo[g,h,i]Perylene	4.8E-05
PAH 880E5	192972	Benzo[e]Pyrene	4.8E-05
PAH 880E5	195197	Benzo(c)phenanthrene	4.8E-05
PAH 880E5	198550	Perylene	4.8E-05
PAH 880E5	203123	Benzo(g,h,i)Fluoranthene	4.8E-05
PAH 880E5	203338	Benzo(a)fluoranthene	4.8E-05
PAH 880E5	206440	Fluoranthene	4.8E-05
PAH 880E5	208968	Acenaphthylene	4.8E-05
PAH 880E5	2381217	1-Methylpyrene	4.8E-05
PAH 880E5	2422799	12-Methylbenz(a)Anthracene	4.8E-05
PAH 880E5	250	PAH/POM - Unspecified	4.8E-05
PAH 880E5	2531842	2-Methylphenanthrene	4.8E-05
PAH 880E5	26914181	Methylanthracene	4.8E-05
PAH 880E5	284	Extractable Organic Matter (EOM)	4.8E-05
PAH 880E5	56832736	Benzofluoranthenes	4.8E-05
PAH 880E5	65357699	Methylbenzopyrene	4.8E-05
PAH 880E5	779022	9-Methyl Anthracene	4.8E-05
PAH 880E5	832699	1-Methylphenanthrene	4.8E-05
PAH 880E5	83329	Acenaphthene	4.8E-05
PAH 880E5	86737	Fluorene	4.8E-05
PAH 880E5	90120	1-Methylnaphthalene	4.8E-05
PAH 880E5	91576	2-Methylnaphthalene	4.8E-05
PAH 880E5	91587	2-Chloronaphthalene	4.8E-05
PAH 880E5	N590	Polycyclic aromatic compounds (includes PAH/POM)	4.8E-05

The TOG and PM_{2.5} speciation factors that are the basis of the chemical speciation approach were developed from a draft version of the SPECIATE 5.2 database (<https://www.epa.gov/air-emissions-modeling/speciate>), the EPA's repository of TOG and PM speciation profiles of air pollution sources. 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, 2022). 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}.

As with previous platforms, some Canadian point source inventories are provided from Environment Canada as pre-speciated emissions; although not all CB6 species are provided, the inventories were not supplemented with missing species due to the minimal impact of supplementation.

Some key features and updates to speciation from previous platforms include the following (the subsections below contain more details on the specific changes):

- Use of the CBR3AE7 mechanism, as described earlier

- Non-methane organic gases (NMOG), which are total organic gases with methane subtracted from it, is included as a pollutant in the emissions output files to assist with the use of these data with future versions of the CMAQ model.
- Several new VOC and PM_{2.5} profiles slated for the final version of SPECIATE 5.2 were used.
- PM_{2.5} speciation process for nonroad mobile use profiles assigned within MOVES3 (which outputs the emissions with those assignments).
- As with previous platforms, some Canadian point source inventories are provided from Environment Canada as pre-speciated emissions, and not all CB6 species were provided; missing species were supplemented by speciating total VOC.

Speciation profiles and cross-references for this study platform are available in the SMOKE input files for the platform. Emissions of VOC and PM_{2.5} emissions by county, sector, and profile for all sectors other than onroad mobile can be found in the sector summaries for the case. Totals of each model species by state and sector can be found in the state-sector totals workbook for this case.

For onroad mobile sources, speciation is done in MOVES, to allow for profiles that vary by model year, which is not part of the SCC code, to be used. Therefore, cross-references or emissions summaries by profile for onroad mobile sources are not provided. These profiles are documented in a [MOVES technical report on speciation](#) (EPA, 2020).

Updates to speciation profiles for VOC and PM_{2.5} that had been added in SPECIATE 5.1 and 5.2 were used. In addition, we changed profile assignments to incorporate data provided by states or correct errors in previous assignments.

For PM_{2.5} the following profile updates were made for the 2017 platform:

- Corrected the wildfire and prescribed fire profile due to error in compositing (the previous profile included creosote in the average)
- Updated the profile for aircraft
- Corrected several profile assignments for the petroleum industry

For PM_{2.5} the following profile and cross-reference updates were made for the 2018 platform:

- Corrected the speciation profile assignment for several SCCs which should have been mapped to the Heat Treating speciation profile for PM_{2.5} according to comments in the cross-reference file.
- Updated the profile for sugar cane burning in the ptagfire sector.
- Updated the wildfire and prescribed fire profiles.
- Updated SCC 30400740 to use the Natural Gas combustion profile (95475).

For PM_{2.5}, the following speciation profile and cross-reference updates were made for the 2019 platform:

- Updated the speciation profile assignments for two pulp and paper SCCs, changing from the overall default profile to the wood products drying profile (91128).
- Changed SCC 31000208 from the surface coating profile (91129) to the petroleum industry average profile (91145).
- Assignments for new PM_{2.5} SCCs in the 2019 point inventory were included.

For VOC the following profile updates were made for the 2017 platform:

- Volatile consumer products - recent methods to estimate emissions of Volatile Organic Compounds (VOC) and associated Hazardous Air Pollutants (HAPs) from Volatile Chemical Products (VCPs) aka solvents were used in this modeling platform. These methods result in improved emissions estimates for the nonpoint (county-wide) solvent emissions. This emissions method results in improved VOC and HAP estimates for nonpoint categories of coatings, pesticides, adhesives and sealants, oil & gas exploration solvent use, dry cleaning, printing inks, cleaning products, personal care products, and other miscellaneous solvent uses. See section 3.2.1 for more details.
- Oil and Gas – used additional region-specific profiles or updated assignments
 - Used county-specific profiles gas for several Wyoming counties developed from data provided by the Wyoming DEQ
 - Used Willison Basin gas composition data, separate profiles for the Montana and North Dakota portions of the basin, based on data developed by the Western Regional Air Partnership WRAP
 - Used Central Montana Uplift area gas composition data, based on data developed by the WRAP
 - Updated Uinta basin profile assignments (based on data provided by Utah)
 - Used Utah and Wyoming oil and gas produced water pond profiles
 - Updated profile assignments (by county and SCC) for nonpoint oil and gas sources that account for the portion of VOC estimated to come from flares. These were updated using results from the Oil and Gas estimation tool run that was used for the 2017 NEI
 - Updated profile assignment for miscellaneous engines to use internal combustion engine natural gas profile
- Commercial Marine vessel – changed profile assignment to an existing Pre-Tier 1 nonroad diesel profile because the previous profile was missing key species (aldehydes)
- Livestock – updated profile assignments
- Agricultural burning – updated profiles for rice straw and wheat straw burning, and used new sugar cane burning profile

For VOC the following cross reference updates were made for the 2018 platform:

- Changed all 8746 to G8746 (Profile name: Rice Straw and Wheat Straw Burning Composite of G4420 and G4421)
- Changed 2104008230/330 from 1084 to 4642 to match all other RWC SCCs
- For solvents, updated all speciation profiles for SCCs in the VCPy inventory
- Changed 2680001000 from 0000 to G95241TOG
- Uinta Basin oil/gas profiles:
 - Replaced profile 95417 with either UTUBOGC (2310010300, 2310011500, 2310111401, 2310010700, 2310010400, 31000107) or UTUBOGD (other SCCs)
 - Replaced profile 95418 with UTUBOGF
 - Replaced profile 95419 with UTUBOGE
- PA gas profiles: Replaced all 8949 with PAGAS01 (FIPS 42059 only), PAGAS02 (FIPS 42019 only), PAGAS03 (FIPS 42125 only). To do this, we first replaced existing county-specific 8949 profiles with the new PAGAS profiles for these three counties in the ERG COMBO GSREF. This covered 5 SCCs. For all SCCs other than those 5 SCCs, where the national profile assignment is 8949. New county-specific profile assignments were made to the appropriate PAGAS profile for each of the three counties, added to the Ramboll basin specific GSREF (since that GSREF is also county-specific and not combo).
- Colorado 2310030300: Set Archuleta/La Plata to SUIROGWT (counties are in Southern Ute reservation), rest of Colorado to DJTFLR95
- Colorado 2310030220: Set to DJTFLR95 (formerly FLR99)
- Colorado 2310021010: Set Archuleta/La Plata to SUIROGCT (counties are in Southern Ute reservation), rest of Colorado to 95398
- Changed 2310000551 (CBM produced water) to a new profile, CBMPWWY. Speciation Tool inputs for this profile tool run by GDIT. Documentation: Profiles are means from WY tests in SPECIATE, newly composited. Reference: <https://doi.org/10.1016/j.scitotenv.2017.11.161>
Reference: Lyman, Seth N.; Mansfield, Marc L.; Tran, Huy N. Q.; Evans, Jordan D.; Jones, Colleen; O'Neil, Trevor; Bowers, Ric; Smith, Ann; and Keslar, Cara, "Emissions of organic compounds from produced water ponds I: Characteristics and speciation" (2018). Chemistry and Biochemistry Faculty Presentations. Paper 154. Contact: Art Diem and Jeff Vukovich of the EPA's Office of Air Quality Planning and Standards (OAQPS)
- Assignments for new VOC SCCs in the 2018 point inventory were included along with changes to VOC profiles for 16 point SCCs.

For VOC, the following speciation profile and cross-reference updates were made for the 2019 platform:

- Speciation profiles were regenerated using version 5.2 of the SPECIATE database, and with the latest version of the Speciation Tool which includes greater number precision. SPECIATE 5.2 includes several new speciation profiles for solvents, and the cross-reference was updated to use those profiles.
- The definition of the model species SOAALK was changed and is now consistent with the definition from the original SOAALK publication (Pye and Pouliot, 2012). Now, SOAALK is defined as linear and branched alkanes with more than 8 carbons and cyclic alkanes with more than 6 carbons. Compared to the 2017 and 2018 platforms, the SOAALK emissions are now generally lower.
- Updated the speciation profile assignments for pulp and paper. Two pulp and paper SCCs were updated from the overall default profile to the pulp and paper industry composite profile (95326), and four other SCCs were updated from profile 95326 to the pulp and paper plywood veneer dryer profile (1189).
- For oil and gas, the portion of emissions for SCC 2310010200 which was speciated using profile 2487 was changed to profile 95247.
- All emissions which were previously speciated with profile 1011 were changed to profile 95404. This affects SCCs associated with oil production fugitive leaks and venting.
- All emissions which were previously speciated with profile 1207 were changed to profile 95782. This affects produced water from oil and gas production.
- Assignments for new VOC SCCs in the 2019 point inventory were included.

3.2.1 VOC speciation

The speciation of VOC includes HAP emissions from the emission inventories in the speciation process. Instead of speciating VOC to generate all of the species listed in Table 3-3, emissions of five specific HAPs: naphthalene, benzene, acetaldehyde, formaldehyde and methanol (collectively known as “NBAFM”) 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 NBAFM HAPs were chosen for integration because they are the only explicit VOC HAPs in CMAQ version 5.2. 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.”

The integration of HAP VOC with VOC is a feature available in SMOKE for all inventory formats, including PTDAY (the format used for the ptfire and ptgfire sectors). The ability to use integration with the PTDAY format is used for the ptfire sector in the 2017 platform, but not for the ptgfire sector which does not include HAPs. SMOKE allows the user to specify the particular HAPs to integrate via the INVTABLE. This is done by setting the “VOC or TOG component” field to “V” for all HAP pollutants chosen for integration. SMOKE allows the user to also choose the specific sources to integrate via the NHAPEXCLUDE file (which actually provides the sources to be *excluded* from integration¹²). 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.¹³ 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 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 in determining whether sectors would have full, no or partial integration (see Figure 3-2). For sectors with partial integration, all sources are integrated other than those that have either the sum of NBAFM > VOC or the sum of NBAFM = 0.

For an air toxics platform such as this, the “no-integrate” sources are treated differently from a criteria pollutant-focused (CAP) platform. For this case, the “no-integrate” approach removes the specified HAPs from the profile and still use the emissions of these HAPs from the NEI. It is very similar to the “integrate” case except that it does not renormalize the revised profile. In a CAP platform case, no-integrate means that no inventory HAPs are used. The explicit HAP model species are instead created by speciating the “no-integrate” source VOC emissions. In general, HAPs that are explicit in the chemical mechanism can be generated from either speciation or the inventory. We chose to use the HAPs in the inventory for this study since these are the data that are used to represent HAP emissions in the U.S. Also, HAP emissions in the NEI may be developed using more site-specific data (e.g., source testing, material balance) that would not be reflected by applying a speciation profile to VOC emissions. In addition, we have applied numerous HAP augmentation measures in the NEI. Since Canada and Mexico inventories do not contain HAPs, we use the approach of generating the HAPs via speciation, except for Mexico onroad mobile sources where emissions for integrate HAPs were available.

It should be noted that even though NBAFM were removed from the SPECIATE profiles used to create the GSPRO for both the NONHAPTOG and no-integrate TOG profiles, there still may be small fractions for “BENZ”, “FORM”, “ALD2”, and “MEOH” present. This is because these model species may have come from species in SPECIATE that are mixtures. The quantity of these model species is expected to be very small compared to the BAFM in the NEI. There are no NONHAPTOG profiles that produce “NAPH.”

In SMOKE, the INVTABLE allows the user to specify the specific HAPs to integrate. To support use of NBAFM emissions from the inventory for all sectors, regardless of integration status, all sectors used an

¹² Since 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 NBAFM or VOC, SMOKE will now raise an error.

¹³ 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 NBAFM.

INVTABLE in which the inventory NBAFM pollutants are kept and processed through SMOKE. NBAFM pollutants are labeled as integrate pollutants using the “VOC or TOG component” field, set to “V” for all five HAP pollutants. For the onroad and nonroad sectors, additional HAPs are labeled as integrate pollutants, in addition to NBAFM: 1,3 butadiene, acrolein, ethyl benzene, 2,2,4-Trimethylpentane, hexane, propionaldehyde, styrene, toluene, xylene, and methyl tert-butyl ether (MTBE). The integrated pollutants for this platform are shown in Table 3-7.

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

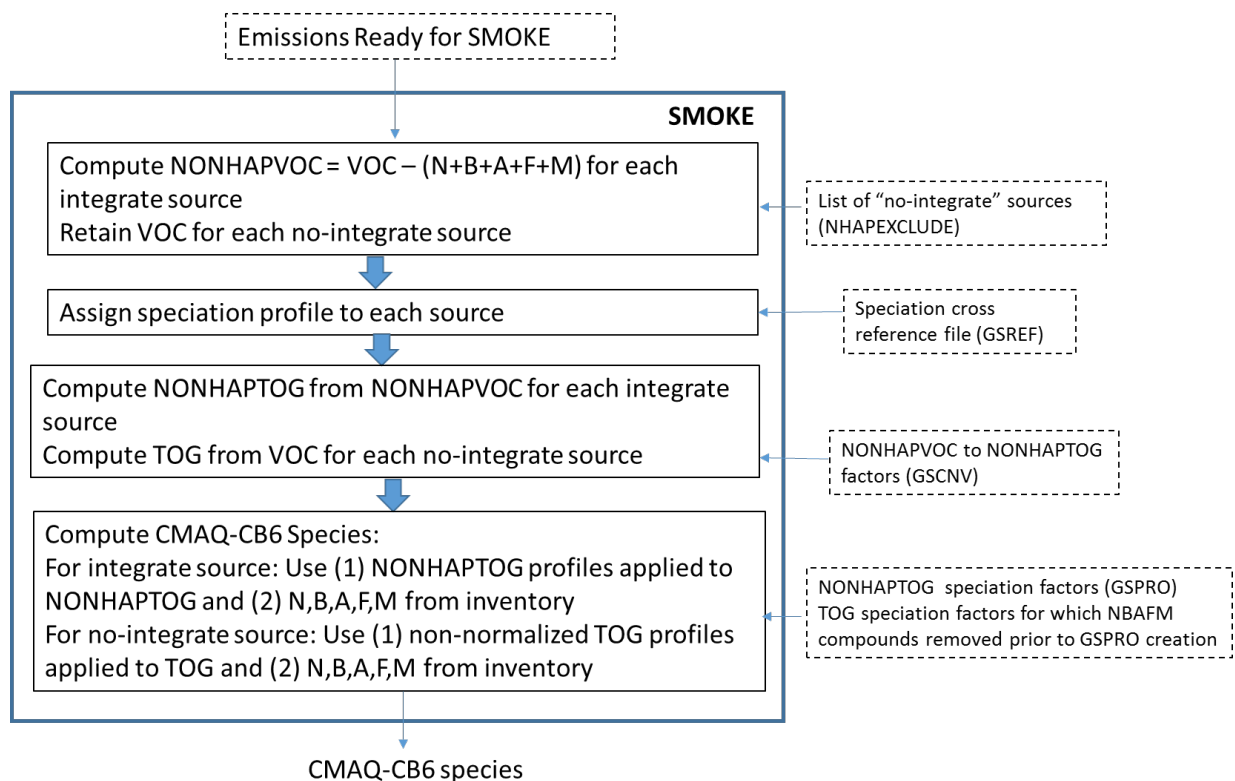


Table 3-7. Integration status of naphthalene, benzene, acetaldehyde, formaldehyde and methanol (NBAFM) for each platform sector

Platform Sector	Approach for Integrating NEI emissions of Naphthalene (N), Benzene (B), Acetaldehyde (A), Formaldehyde (F) and Methanol (M)
afdust	N/A – sector contains no VOC
airports	No integration, use NBAFM in inventory
beis	N/A – sector contains no inventory pollutant “VOC”; but rather specific VOC species
cmv c1c2	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
cmv c3	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
fertilizer	N/A – sector contains no VOC
livestock	Partial integration (NBAFM)
nonpt	Partial integration (NBAFM)
nonroad	Full integration (internal to MOVES)

Platform Sector	Approach for Integrating NEI emissions of Naphthalene (N), Benzene (B), Acetaldehyde (A), Formaldehyde (F) and Methanol (M)
np_oilgas	Partial integration (NBAFM)
np_solvents	Partial integration (NBAFM)
onroad	Full integration (internal to MOVES)
onroad_can	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
onroad_mex	Full integration (internal to MOVES-Mexico); however, MOVES-MEXICO speciation was older CB6, so post-SMOKE emissions were converted to CB6R3AE6
othafdust	N/A – sector contains no VOC
othar	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
othpt	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
othptdust	N/A – sector contains no VOC
pt_oilgas	No integration, use NBAFM in inventory
ptagfire	Full integration (NBAFM)
ptegu	No integration, use NBAFM in inventory
ptfire-rx	Partial integration (NBAFM)
ptfire-wild	Partial integration (NBAFM)
ptfire_othna	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
ptnonipm	No integration, use NBAFM in inventory
rail	Full integration (NBAFM)
rwc	Full integration (NBAFM)

Integration for the mobile sources estimated from MOVES (onroad and nonroad sectors) is done differently. Briefly there are three major differences: 1) for these sources integration is done using more than just NBAFM, 2) all sources from the MOVES model are integrated, and 3) integration is done fully or partially within MOVES. For onroad mobile, speciation is done fully within MOVES3 such that the MOVES model outputs emission factors for individual VOC model species along with the HAPs. This requires MOVES to be run for a specific chemical mechanism. For this platform MOVES was run for the CB6R3AE7 mechanism.

For nonroad mobile, speciation is partially done within MOVES such that it does not need to be run for a specific chemical mechanism. For nonroad, MOVES outputs emissions of HAPs and NONHAPTOG are split by speciation profile. Taking into account that integrated species were subtracted out by MOVES already, the appropriate speciation profiles are then applied in SMOKE to get the VOC model species. HAP integration for nonroad uses the same additional HAPs and ethanol as for onroad.

3.2.1.1 County specific profile combinations

In previous platforms, the GSPRO_COMBO 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. For this platform, GSPRO_COMBO is still used for certain gasoline-related stationary sources nationwide. GSPRO_COMBO is no longer needed for nonroad sources because nonroad emissions within MOVES have the speciation profiles built into the results, so there is no need to assign them via the GSREF or GSPRO_COMBO feature.

In Canada, ECCC provided estimates of ethanol mixes by Canadian province. These estimates were used to develop a GSPRO_COMBO for Canadian gasoline onroad emissions. For example, a province where the average ethanol mix is 6% would have 60% E10 speciation and 40% E0 speciation. A 10% ethanol mix would imply 100% E10 speciation. In Mexico, only E0 speciation profiles are used, but the GSPRO_COMBO feature is still used in Mexico for inventories where VOC emissions are not explicitly defined by mode (e.g., exhaust versus evaporative). Here, the GSPRO_COMBO specifies a mix of exhaust and evaporative speciation profiles. Using the GSPRO_COMBO to split total VOC into exhaust and evaporative components is no longer necessary for Canadian mobile sources, whose inventories include the mode in the pollutant, or for Mexico onroad sources, where VOC speciation is calculated by the MOVES model. The GSPRO_COMBO is still used for Mexican nonroad sources which do not have modes in the inventory.

3.2.1.2 Additional sector specific considerations for integrating HAP emissions from inventories into speciation

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 NBAFM or, in the case of MOVES (onroad, nonroad, and MOVES-Mexico), a larger set of HAPs plus ethanol are integrated. Table 3-7 above summarizes the integration method for each platform sector.

Speciation for the onroad sector is unique. First, SMOKE-MOVES 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 emission factor tables that include inventory pollutants (e.g., TOG) and model-ready species (e.g., PAR, OLE, etc).¹⁴ SMOKE essentially calculates the model-ready species by using the appropriate emission factor without further speciation.¹⁵ Third, MOVES' internal speciation uses full integration of an extended list of HAPs beyond NBAFM (called "M-profiles"). The M-profiles integration is very similar to NBAFM integration explained above except that the integration calculation (see Figure 3-2) is performed on emissions factors instead of on emissions, and a much larger set of pollutants are integrated besides NBAFM. The list of integrated pollutants is described in Table 3-8. 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, the EPA applied adjustment factors to SMOKE-MOVES to produce California adjusted model-ready files. By applying the ratios through SMOKE-MOVES, the CARB inventories are essentially speciated to match EPA estimated speciation. This resulted in changes to the VOC HAPs from what CARB submitted to the EPA.

¹⁴ 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.

¹⁵ 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 3-8. MOVES integrated species in M-profiles

MOVES ID	Pollutant Name
5	Methane (CH ₄)
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, all sources are integrated using the same list of integrated pollutants as shown in Table 3-8. The integration calculations are performed within MOVES. For California and Texas, all VOC HAPs were recalculated using MOVES HAP/VOC ratios based on the MOVES run so that VOC speciation methodology would be consistent across the country. NONHAPTOG emissions by speciation profile were also calculated based on MOVES data in California in Texas.

For nonroad emissions in California and Texas where the state provided emissions, MOVES-style speciation has been implemented, with NONHAPTOG and PM_{2.5} pre-split by profiles and with all the HAPs needed for VOC speciation augmented based on MOVES data in California. This means that the nonroad emissions in California and Texas are speciated consistently with the rest of the country.

MOVES-MEXICO for onroad used the same speciation approach as for the U.S. in that the larger list of species shown in Table 3-8 was used. However, MOVES-MEXICO used an older version of the CB6 mechanism sometimes referred to as “CB6-CAMx”. That mechanism is missing the XYLMN and SOAALK species in particular, so post-SMOKE we converted the emissions to CB6-CMAQ as follows:

- $XYLMN = XYL[1] - 0.966 * NAPHTHALENE[1]$
- $PAR = PAR[1] - 0.00001 * NAPHTHALENE[1]$
- $SOAALK = 0.108 * PAR[1]$

The CB6R3AE7 mechanism includes other new species which are not part of CB6-CAMx, such as IVOC. CB6R3AE7-specific species were not added to the MOVES-MEXICO emissions because those extra species would be expected to have only a minor impact.

For the beis sector, the speciation profiles used by BEIS are not included in SPECIATE. BEIS3.7 includes the species (SESQ) that is mapped to the BEIS model species SESQT (Sesquiterpenes). The profile code associated with BEIS3.7 for use with CB6R3AE7 is “BC6E7”. The difference in the biogenic profile compared to the previous version of CB6, based on profile code “B10C6”, is the explicit treatment of acetic acid, formic acid, and alpha-pinene emissions in BC6E7. The biogenic speciation files are managed in the CMAQ Github repository.²¹

3.2.1.3 Oil and gas-related speciation profiles

Several oil and gas profiles were developed or assigned to sources in np_oilgas and pt_oilgas to better reflect region-specific differences in VOC composition and whether the process SCC would include controlled emissions, considering the controls are not part of the SCC. The basin / region-specific profiles for oil and gas are shown in Table 3-9.

In addition to region-specific assignments, multiple profiles were assigned to particular county/SCC combinations using the SMOKE feature discussed in 3.2.1.1 that allows multiple profiles to be combined within the chemical speciation cross reference file (GSREF) by pollutant, state/county, and SCC. Oil and gas SCCs for associated gas, condensate tanks, crude oil tanks, dehydrators, liquids unloading and well completions represent the total VOC from the process, including the portions of process that may be flared or directed to a reboiler. For example, SCC 2310021400 (gas well dehydrators) consists of process, reboiler, and/or flaring emissions. There are not separate SCCs for the flared portion of the process or the reboiler. However, the VOC associated with these three portions can have very different speciation profiles. Therefore, it is necessary to have an estimate of the amount of VOC from each of the portions (process, flare, reboiler) so that the appropriate speciation profiles can be applied to each portion. The Nonpoint Oil and Gas Emission Estimation Tool generates an intermediate file which provides flare, non-flare (process), and reboiler (for dehydrators) emissions for six source categories that have flare emissions: by county FIPS and SCC code for the U.S. From these emissions the fraction of the emissions to assign to each profile was computed and incorporated into this platform. These fractions can vary by county FIPS, because they depend on the level of controls, which is an input to the Speciation Tool.

Table 3-9. Basin/Region-specific profiles for oil and gas

Profile Code	Description	Region (if not in profile name)
DJVNT_R	Denver-Julesburg Basin Produced Gas Composition from Non-CBM Gas Wells	
PNC01_R	Piceance Basin Produced Gas Composition from Non-CBM Gas Wells	
PNC02_R	Piceance Basin Produced Gas Composition from Oil Wells	
PRBCB_R	Powder River Basin Produced Gas Composition from CBM Wells	
PRBCO_R	Powder River Basin Produced Gas Composition from Non-CBM Wells	
PRM01_R	Permian Basin Produced Gas Composition for Non-CBM Wells	
SSJCB_R	South San Juan Basin Produced Gas Composition from CBM Wells	
SSJCO_R	South San Juan Basin Produced Gas Composition from Non-CBM Gas Wells	
SWFLA_R	SW Wyoming Basin Flash Gas Composition for Condensate Tanks	
SWVNT_R	SW Wyoming Basin Produced Gas Composition from Non-CBM Wells	
UNT01_R	Uinta Basin Produced Gas Composition from CBM Wells	
WRBCO_R	Wind River Basin Produced Gages Composition from Non-CBM Gas Wells	

Profile Code	Description	Region (if not in profile name)
95087a	Oil and Gas - Composite - Oil Field - Oil Tank Battery Vent Gas	East Texas
95109a	Oil and Gas - Composite - Oil Field - Condensate Tank Battery Vent Gas	East Texas
95417	Uinta Basin, Untreated Natural Gas	
95418	Uinta Basin, Condensate Tank Natural Gas	
95419	Uinta Basin, Oil Tank Natural Gas	
95420	Uinta Basin, Glycol Dehydrator	
95398	Composite Profile - Oil and Natural Gas Production - Condensate Tanks	Denver- Julesburg
95399	Composite Profile - Oil Field – Wells	California
95400	Composite Profile - Oil Field – Tanks	California
95403	Composite Profile - Gas Wells	San Joaquin
CMU01	Oil and Gas - Produced Gas Composition from Gas Wells - Central Montana Uplift – Montana	
PAGAS01	Oil and Gas-Produced Gas Composition from Gas Wells-Greene Co, PA	
PAGAS02	Oil and Gas-Produced Gas Composition from Gas Wells-Butler Co, PA	
PAGAS03	Oil and Gas-Produced Gas Composition from Gas Wells-Washington Co, PA	
SUIROGCT	Flash Gas from Condensate Tanks - Composite Southern Ute Indian Reservation	
SUIROGWT	Flash Gas from Produced Water Tanks - Composite Southern Ute Indian Reservation	
UTUBOGC	Raw Gas from Oil Wells - Composite Uinta basin	
UTUBOGD	Raw Gas from Gas Wells - Composite Uinta basin	
UTUBOGE	Flash Gas from Oil Tanks - including Carbonyls - Composite Uinta basin	
UTUBOGF	Flash Gas from Condensate Tanks - including Carbonyls - Composite Uinta basin	
WIL01	Oil and Gas - Flash Gas Composition from Tanks at Oil Wells - Williston Basin North Dakota	
WIL02	Oil and Gas - Flash Gas Composition from Tanks at Oil Wells - Williston Basin Montana	
WIL03	Oil and Gas - Produced Gas Composition from Oil Wells - Williston Basin North Dakota	
WIL04	Oil and Gas - Produced Gas Composition from Oil Wells - Williston Basin Montana	

3.2.1.4 Mobile source related VOC speciation profiles

The VOC speciation approach for mobile source and mobile source-related source categories is customized to account for the impact of fuels and engine type and technologies. The impact of fuels also affects the parts of the nonpt and ptnonipm sectors that are related to mobile sources such as portable fuel containers and gasoline distribution.

The VOC speciation profiles for the nonroad sector are listed in Table 3-10. They include new profiles (i.e., those that begin with “953”) for 2-stroke and 4-stroke gasoline engines running on E0 and E10 and

compression ignition engines with different technologies developed from recent EPA test programs, which also supported the updated toxics emission factor in MOVES2014a (Reichle, 2015 and EPA, 2015b).

Table 3-10. TOG MOVES-SMOKE Speciation for nonroad emissions

Profile	Profile Description	Engine Type	Engine Technology	Engine Size	Horse-power category	Fuel	Fuel Sub-type	Emission Process
95328	SI 2-stroke E10	SI 2-stroke	All	All	All	Gasoline	E10	exhaust
95330	SI 4-stroke E10	SI 4-stroke	All	All	All	Gasoline	E10	exhaust
95331	CI Pre-Tier 1	CI	Pre-Tier 1	All	All	Diesel	All	exhaust
95332	CI Tier 1	CI	Tier 1	All	All	Diesel	All	exhaust
95333	CI Tier 2	CI	Tier 2 and 3	all	All	Diesel	All	exhaust
95335a ¹⁶	CI Tier 2	CI	Tier 4	<56 kW (75 hp)	S	Diesel	All	exhaust
8775	ACES Phase 1 Diesel Onroad	CI Tier 4	Tier 4	>=56 kW (75 hp)	L	Diesel	All	exhaust
8754	E10 Evap	SI	All	all	All	Gasoline	E10	evaporative
8769	E10 evap permeation	SI	All	all	All	Gasoline	E10	permeation
8870	E10 Headspace	SI	All	all	All	Gasoline	E10	headspace
1001	CNG Exhaust	All	all	all	All	CNG	All	exhaust
8860	LPG exhaust	All	all	all	All	LPG	All	exhaust

Speciation profiles for VOC in the nonroad sector account for the ethanol content of fuels across years. A description of the actual fuel formulations can be found in NEITSD. For previous platforms, the EPA used “COMBO” profiles to model combinations of profiles for E0 and E10 fuel use, but beginning with 2014v7.0 platform, the appropriate allocation of E0 and E10 fuels is done by MOVES.

Combination profiles reflecting a combination of E10 and E0 fuel use ideally would be used for sources upstream of mobile sources such as portable fuel containers (PFCs) and other fuel distribution operations associated with the transfer of fuel from bulk terminals to pumps (BTP), which are in the nonpt sector. 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. Refinery-to-bulk terminal (RBT) fuel distribution and bulk plant storage (BPS) speciation does not change across the modeling cases because this is considered upstream from the introduction of ethanol into the fuel. The mapping of fuel distribution SCCs to PFC, BTP, BPS, and RBT emissions categories can be found in Appendix C. In this platform, all of these sources get E10 speciation.

Table 3-11 summarizes the different profiles utilized for the fuel-related sources in each of the sectors. The term “COMBO” indicates that a combination of the profiles listed was used to speciate that subcategory using the GSPRO_COMBO file.

¹⁶ 95335a replaced 95335. This correction was made to remove alcohols due to suspected contamination. Additional information is available in SPECIATE.

Table 3-11. Select mobile-related VOC profiles

Sector	Sub-category	Profile	
nonpt/ ptnonipm	PFC and BTP	8870	E10 Headspace
nonpt/ ptnonipm	Bulk plant storage (BPS) and refine-to-bulk terminal (RBT) sources	8870	E10 Headspace

The speciation of onroad VOC occurs completely within MOVES. MOVES accounts for fuel type and properties, emission standards as they affect different vehicle types and model years, and specific emission processes. Table 3-12 describes the M-profiles available to MOVES depending on the model year range, MOVES process (processID), fuel sub-type (fuelSubTypeID), and regulatory class (regClassID). While MOVES maps the liquid diesel profile to several processes, MOVES only estimates emissions from refueling spillage loss (processID 19). The other evaporative and refueling processes from diesel vehicles have zero emissions.

Table 3-13 through Table 3-15 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. More detailed information on how MOVES speciates VOC and the profiles used is provided in the technical document, “Speciation of Total Organic Gas and Particulate Matter Emissions from On-road Vehicles in MOVES2014” (EPA, 2015c).

Table 3-12. 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
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

Profile	Profile Description	Model Years	ProcessID	FuelSubTypeID	RegClassID
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 ¹⁷	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 ¹⁸	10,40,41,42,46,47,48
95120 ^m	Liquid Diesel	19602060	11	20,21,22	0
95120 ^m	Liquid Diesel	19602060	12,13,18,19	20,21,22	10,20,30,40,41,42,46,47,48
95335a	2010+ MY HDD exhaust	20102060	1,2,15,16,17,90	20,21,22	40,41,42,46,47,48

^m While MOVES maps the liquid diesel profile to several processes, MOVES only estimates emissions from refueling spillage loss (processID 19). The other evaporative and refueling processes from diesel vehicles have zero emissions.

Table 3-13. MOVES process IDs

Process ID	Process Name
1	Running Exhaust*
2	Start Exhaust
9	Brakewear
10	Tirewear
11	Evap Permeation

¹⁷ 91 is the processed for APUs which are diesel engines not covered by the 2007 Heavy-Duty Rule, so the older technology applies to all years.

¹⁸ The profile assignments 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.

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
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

** Off-network idling is a process in MOVES3 that is part of processes 1 and 15 but assigned to road type 1 (off-network) instead of types 2-5*

Table 3-14. 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 3-15. 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)

For portable fuel containers (PFCs) and fuel distribution operations associated with the bulk-plant-to-pump (BTP) distribution, a 10% ethanol mix (E10) was assumed for speciation purposes. 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.

3.2.2 PM speciation

In addition to VOC profiles, the SPECIATE database also contains profiles for speciating PM_{2.5}. PM_{2.5} was speciated into the AE6 species associated with CMAQ 5.0.1 and later versions. Most of the PM profiles come from the 911XX series (Reff et. al, 2009), which include updated AE6 speciation.¹⁹ Starting with the 2014v7.1 platform, profile 91112 (Natural Gas Combustion – Composite) was replaced with 95475 (Composite -Refinery Fuel Gas and Natural Gas Combustion). This updated profile is an AE6-ready profile based on the median of 3 SPECIATE4.5 profiles from which AE6 versions were made (to be added to SPECIATE5.0): boilers (95125a), process heaters (95126a) and internal combustion combined cycle/cogen plant exhaust (95127a). As with profile 91112, these profiles are based on tests using natural gas and refinery fuel gas (England et al., 2007). Profile 91112 which is also based on refinery gas and natural gas is thought to overestimate EC.

Profile 95475 (Composite -Refinery Fuel Gas and Natural Gas Combustion) is shown along with the underlying profiles composited in Figure 3-3. Figure 3-4 shows a comparison of the new profile as of the 2014v7.1 platform with the one that we had been using in the 2014v7.0 and earlier platforms.

¹⁹ The exceptions are 5675AE6 (Marine Vessel – Marine Engine – Heavy Fuel Oil) used for cmv_c3 and 92018 (Draft Cigarette Smoke – Simplified) used in nonpt. 5675AE6 is an update of profile 5675 to support AE6 PM speciation.

Figure 3-3. Profiles composited for PM gas combustion related sources

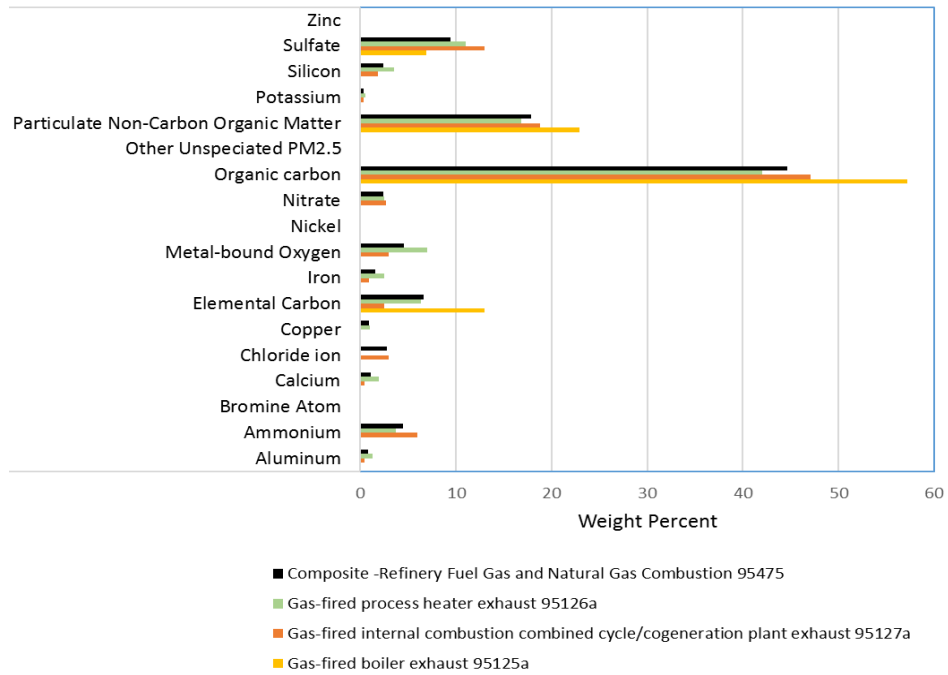
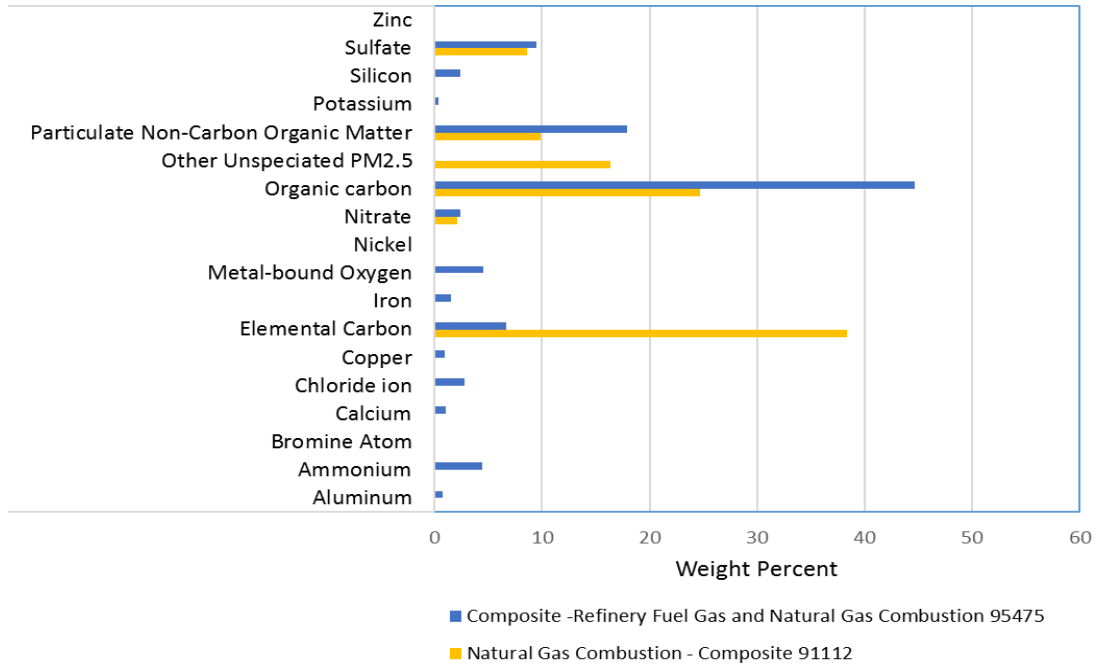


Figure 3-4. Comparison of PM profiles used for Natural gas combustion related sources



3.2.2.1 Mobile source related PM2.5 speciation profiles

For all processes except brake and tire wear in the onroad sector, 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 (e.g., PM₁₀ and PM_{2.5}) and speciated PM (e.g., PEC, PFE). SMOKE essentially calculates the PM components by using the appropriate EF without further speciation.²⁰ The specific profiles used within MOVES include two CNG profiles, 45219 and 45220, which were added to SPECIATE4.5. A list of profiles is provided in the technical document, “Speciation of Total Organic Gas and Particulate Matter Emissions from On-road Vehicles in MOVES2014” (EPA, 2015c).

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 from brake and tire wear profiles, which were updated from the v6.3 platform based on data from a Health Effects Institute report (Schauer, 2006). Table 3-16 shows the differences in the v7.1 (alpha) and 2011v6.3 profiles.

Table 3-16. Brake and tire PM2.5 profiles from Schauer (2006)

Inventory Pollutant	Model Species	SPECIATE4.5 brakewear profile: 95462	SPECIATE4.5 tirewear profile: 95460
PM2_5	PAL	0.000793208	3.32401E-05
PM2_5	PCA	0.001692177	
PM2_5	PCL		
PM2_5	PEC	0.012797085	0.003585907
PM2_5	PFE	0.213901692	0.00024779
PM2_5	PH2O		
PM2_5	PK	0.000687447	4.33129E-05
PM2_5	PMG	0.002961309	0.000018131
PM2_5	PMN	0.001373836	1.41E-06
PM2_5	PMOTHR	0.691704999	0.100663209
PM2_5	PNA	0.002749787	7.35312E-05
PM2_5	PNCOM	0.020115749	0.255808124
PM2_5	PNH4		
PM2_5	PNO3		
PM2_5	POC	0.050289372	0.639520309
PM2_5	PSI		
PM2_5	PSO4		
PM2_5	PTI	0.000933341	5.04E-06

For California onroad emissions, adjustment factors were applied to SMOKE-MOVES to produce California adjusted model-ready files. California did not supply speciated PM, therefore, the adjustment

²⁰ 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/>.

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.

For nonroad PM2.5, speciation is partially done within MOVES such that it does not need to be run for a specific chemical mechanism. For nonroad, MOVES outputs emissions of PM2.5 split by speciation profile. Similar to how VOC and NONHAPTOG are speciated, PM2.5 is now also speciated this way starting with MOVES2014b. For California, PM2.5 emissions split by speciation profile are estimated from total PM2.5 based on MOVES data in California, so that PM is speciated consistently across the country. The PM2.5 profiles assigned to nonroad sources are listed in Table 3-17.

Table 3-17. Nonroad PM2.5 profiles

SPECIATE4.5 Profile Code	SPECIATE4.5 Profile Name	Assigned to Nonroad sources based on Fuel Type
8996	Diesel Exhaust - Heavy-heavy duty truck - 2007 model year with NCOM	Diesel
91106	HDDV Exhaust – Composite	Diesel
91113	Nonroad Gasoline Exhaust – Composite	Gasoline
95219	CNG Transit Bus Exhaust	CNG and LPG

3.2.2.2 Diesel PM

Diesel particulate matter is neither a CAP nor HAP as defined by Section 112 of the CAA, however it was identified as a mobile source air toxic in EPA’s 2007 rule, “Control of Hazardous Air Pollutants From Mobile Sources final rule” (EPA 2007a). Starting with the 2014 NEI, diesel PM emissions are explicitly included in the NEI using pollutant names DIESEL-PM10 and DIESEL-PM25, respectively. Diesel PM emissions are tracked for mobile-source, engine-exhaust PM₁₀ and PM_{2.5} emissions from engines burning diesel or residual-oil fuels. These sources include on-road, nonroad, point-airport-ground support equipment, point-locomotives, nonpoint locomotives, and all PM from diesel or residual-oil-fueled nonpoint CMVs. For these sources, DIESEL-PM10 and DIESEL-PM25 are equal to primary PM10-PRI and PM25-PRI in the NEI. Although stationary engines also can burn diesel fuel, only mobile-related diesel engine SCCs have diesel PM emissions modeled.

Diesel PM is speciated in SMOKE using the same speciation profiles as primary PM, except that diesel PM is mapped to the following model species: DIESEL_PMC (PMC), DIESEL_PMEC (PEC), DIESEL_PMOC (POC), DIESEL_PMNO3 (PNO3), DIESEL_PMSO4 (PSO4), and DIESEL_PMFINE (all other PM_{2.5} species).

3.2.3 NO_x speciation

NO_x emission factors and therefore NO_x inventories are developed on a NO₂ weight basis. For air quality modeling, NO_x is speciated into NO, NO₂, and/or HONO. For the non-mobile sources, the EPA used a single profile “NHONO” to split NO_x into NO and NO₂.

The importance of HONO chemistry, identification of its presence in ambient air and the measurements of HONO from mobile sources have prompted the inclusion of HONO in NO_x speciation for mobile sources. Based on tunnel studies, a HONO to NO_x ratio of 0.008 was chosen (Sarwar, 2008). For the

mobile sources, except for onroad (including nonroad, cmv, rail, othon sectors), and for specific SCCs in othar and ptnonipm, the profile “HONO” is used. Table 3-18 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, NO₂, 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 NO₂ fraction is calculated as the remainder (i.e., NO₂ 1 – NO – HONO). For more details on the NO_x fractions within MOVES, see EPA report “Use of data from ‘Development of Emission Rates for the MOVES Model,’ Sierra Research, March 3, 2010” available at <https://nepis.epa.gov/Exec/ZipPDF.cgi?Dockey=P100F1A5.pdf>, [Exhaust Emission Rates for Heavy-Duty Onroad Vehicles in MOVES3](#) and [Exhaust Emission Rates for Light-Duty Onroad Vehicles in MOVES3](#).

Table 3-18. NO_x speciation profiles

Profile	Pollutant	species	Molar 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

3.2.4 Creation of Sulfuric Acid Vapor (SULF)

Since at least the 2002 Platform, sulfuric acid vapor (SULF) has been estimated through the SMOKE speciation process for coal combustion and residual and distillate oil fuel combustion sources. Profiles that compute SULF from SO₂ are assigned to coal and oil combustion SCCs in the GSREF ancillary file. The profiles were derived from information from AP-42 (EPA, 1998), which identifies the fractions of sulfur emitted as sulfate and SO₂ and relates the sulfate as a function of SO₂.

Sulfate is computed from SO₂ emissions assuming that gaseous sulfate, which is comprised of many components, is primarily H₂SO₄. The equation for calculating H₂SO₄ is given below.

$$\begin{aligned}
 & \text{Emissions of SULF (as H}_2\text{SO}_4\text{)} \\
 & = \text{SO}_2 \text{ emissions} \times \frac{\text{fraction of S emitted as sulfate}}{\text{fraction of S emitted as SO}_2} \times \frac{\text{MW H}_2\text{SO}_4}{\text{MW SO}_2}
 \end{aligned}
 \tag{Equation 3-1}$$

In the above, *MW* is the molecular weight of the compound. The molecular weights of H₂SO₄ and SO₂ are 98 g/mol and 64 g/mol, respectively.

This method does not reduce SO₂ emissions; it solely adds gaseous sulfate emissions as a function of SO₂ emissions. The derivation of the profiles is provided in Table 3-19; a summary of the profiles is provided in Table 3-20.

Table 3-19. Sulfate split factor computation

fuel	SCCs	Profile Code	Fraction as SO ₂	Fraction as Sulfate	Split factor (mass fraction)
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Bituminous	1-0X-002-YY, where X is 1, 2 or 3 and YY is 01 thru 19 and 21-ZZ-002-000 where ZZ is 02,03 or 04	95014	0.95	0.014	$.014/.95 * 98/64 = 0.0226$
Subbituminous	1-0X-002-YY, where X is 1, 2 or 3 and YY is 21 thru 38	87514	.875	0.014	$.014/.875 * 98/64 = 0.0245$
Lignite	1-0X-003-YY, where X is 1, 2 or 3 and YY is 01 thru 18 and 21-ZZ-002-000 where ZZ is 02,03 or 04	75014	0.75	0.014	$.014/.75 * 98/64 = 0.0286$
Residual oil	1-0X-004-YY, where X is 1, 2 or 3 and YY is 01 thru 06 and 21-ZZ-005-000 where ZZ is 02,03 or 04	99010	0.99	0.01	$.01/.99 * 98/64 = 0.0155$
Distillate oil	1-0X-005-YY, where X is 1, 2 or 3 and YY is 01 thru 06 and 21-ZZ-004-000 where ZZ is 02,03 or 04	99010	0.99	0.01	Same as residual oil

Table 3-20. SO₂ speciation profiles

Profile	pollutant	species	split factor
95014	SO ₂	SULF	0.0226
95014	SO ₂	SO ₂	1
87514	SO ₂	SULF	0.0245
87514	SO ₂	SO ₂	1
75014	SO ₂	SULF	0.0286
75014	SO ₂	SO ₂	1
99010	SO ₂	SULF	0.0155
99010	SO ₂	SO ₂	1

3.2.5 Speciation of Metals and Mercury

Mercury and other metals from the inventory were speciated for use in modeling. Other than the facility specific data for one facility provided by Minnesota, the profiles are the same as were used in previous modeling platforms and are documented in Appendix D of the Technical Support Document for the 2011 National-scale Air Toxics Assessment (<https://www.epa.gov/sites/production/files/2015-12/documents/2011-nata-tsd.pdf>). Mercury in the inventory was reported as pollutant code 7439976 and needs to be speciated into the three forms of mercury used by CMAQ: elemental, divalent gaseous, and divalent particulate. Metals (other than mercury) were speciated into coarse and fine particulate, which are needed by CMAQ. Table 3-21 contains summaries of the particle size profiles. Most were applied across an entire sector or multiple sectors (i.e., the nonroad profiles were applied to the nonroad-related sector and the stationary profile was applied to the stationary-related sectors). A Minnesota facility and process-specific profile were added based on data provided by the state during the 2014v1 emissions review.

Table 3-21. Particle size speciation of Metals

Source Type	Profile	pollutant	Fine	coarse
Onroad	OARS	Arsenic	.95	.05

Source Type	Profile	pollutant	Fine	coarse
Onroad	ONMN	Manganese	.4375	.5625
Onroad	ONNI	Nickel	.83	.17
Onroad	CRON	Chromhex	.86	.14
Nonroad	NOARS	Arsenic	.83	.17
Nonroad	NONMN	Manganese	.67	.33
Nonroad	NONNI	Nickel	.49	.51
Nonroad	CRNR	Chromhex	.8	.2
Stationary	STANI	Nickel	.59	.41
Stationary	STACD	Cadmium	.76	.24
Stationary	STAMN	Manganese	.67	.33
Stationary	STAPB	Lead	.74	.26
Stationary	STABE	Beryllium	.68	.32
Stationary	CRSTA	Chromhex	.71	.29
Stationary	STARS	Arsenic	.59	.41
Stationary ¹	MNBE	Beryllium	.15	.85
Stationary ¹	MNCD	Cadmium	.15	.85
Stationary ¹	MNMN	Manganese	.15	.85
Stationary ¹	MNNI	Nickel	.15	.85
Stationary ¹	MNRS	Arsenic	.15	.85
Stationary ¹	CRMN	Chromhex	.15	.85

¹Facility specific metal splits at United Taconite LLC - Thunderbird Mine facility in Minnesota as reported by Minnesota

Table 3-22 provides the mercury profiles used for sources using SCC-based speciation factors for electric generating units (i.e., the ptegu sector) and other sources (EPA, 2020).

Table 3-22. Speciation of Mercury

Profile Code	Description	Elemental	Divalent Gas	Particulate
HGCEM	Cement kiln exhaust	0.66	0.34	0
HGCLI	Cement clinker cooler	0	0	1
HBCMB	Fuel combustion	0.5	0.4	0.1
HGCRE	Human cremation	0.8	0.15	0.05
HGELE	Elemental only (used?)	1	0	0
HGGEO	Geothermal power plants	0.87	0.13	0
HGGLD	Gold mining	0.8	0.15	0.05
HGHCL	Chlor-Alkali plants	0.972	0.028	0
HGINC	Waste incineration	0.2	0.6	0.2
HGIND	Industrial average	0.73	0.22	0.05
HGMD	Mobile diesel	0.56	0.29	0.15
HGMG	Mobile gas	0.915	0.082	0.003
HGMET	Metal production	0.8	0.15	0.005

HGMWI	Medical waste incineration	0.2	0.6	0.2
HGPETCOKE	Petroleum coke	0.6	0.3	0.1

3.3 Temporal Allocation

Temporal allocation is the process of distributing aggregated emissions to a finer temporal resolution, thereby converting annual emissions to hourly emissions as is required by CMAQ. 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. Temporal allocation takes these aggregated emissions and distributes the 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, with monthly and day-of-week profiles applied only if the inventory is not already at that level of detail.

The temporal factors applied to the inventory are selected using some combination of country, state, county, SCC, and pollutant. Table 3-23 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 3-23. Temporal settings used for the platform sectors in SMOKE

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
Airports	Annual	Yes	week	week	Yes
Beis	Hourly		n/a	all	No
cmv_c1c2	Annual & hourly		All	all	No
cmv_c3	Annual & hourly		All	all	No
Fertilizer	Monthly		met-based	All	Yes
livestock	Annual	Yes	met-based	All	Yes
nonpt	Annual	Yes	week	week	Yes
nonroad	Monthly		mwdss	mwdss	Yes
np_oilgas	Annual	Yes	aveday	aveday	No
onroad	Annual & monthly ¹		all	all	Yes
onroad_ca_adj	Annual & monthly ¹		all	all	Yes
othafdust_adj	Annual	Yes	week	all	No
othar	Annual & monthly	Yes	week	week	No
onroad_can	Monthly		week	week	No

Platform sector short name	Inventory resolutions	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process holidays as separate days
onroad mex	Monthly		week	week	No
othpt	Annual & monthly	Yes	mwdss	mwdss	No
othptdust adj	Monthly		week	all	No
pt oilgas	Annual	Yes	mwdss	mwdss	Yes
ptegu	Annual & hourly	Yes ²	all	All	No
ptnonipm	Annual	Yes	mwdss	mwdss	Yes
ptagfire	Daily		all	all	No
ptfire-rx	Daily		all	all	No
ptfire-wild	Daily		all	all	No
ptfire_othna	Daily		all	all	No
rail	Annual	Yes	aveday	aveday	No
rwc	Annual	No ³	met-based ³	all	No ³
np solvents	annual	Yes	aveday	aveday	No

¹Note the annual and monthly “inventory” actually refers to the activity data (VMT, hoteling, and VPOP) for onroad. VMT and hoteling is monthly and VPOP is annual. The actual emissions are computed on an hourly basis.

²Only units that do not have matching hourly CEMS data use monthly temporal profiles.

³Except for 2 SCCs that do not use met-based speciation

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 temporal allocation 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, 2019, which is intended to mitigate the effects of initial condition concentrations. The ramp-up period was 10 days (December 22-31, 2018). For anthropogenic sectors, emissions from December 2019 were used to fill in surrogate emissions for the end of December 2018. For biogenic emissions, December 2018 emissions were computed using year 2018 meteorology.

3.3.1 Use of FF10 format for finer than annual emissions

The FF10 inventory format for SMOKE provides a consolidated format for monthly, daily, and hourly emissions inventories. 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 temporal allocation applied to it; rather, it should only have month-to-day and diurnal temporal allocation. This becomes particularly important when specific sectors have a mix of annual, monthly, daily, and/or hourly inventories. The flags that control temporal allocation 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 nonroad, onroad (for activity data), onroad_can, onroad_mex, othar, othpt, and othptdust. Commercial marine vessels in cmv_c3 and cmv_c1c2 use hourly data in the FF10 files.

3.3.2 Temporal allocation for non-EGU sources (ptnonipm)

Some sectors use straightforward temporal profiles not based on meteorology or other factors. For the ptfire, ptagfire, and ptfire_othna sectors, the inventories are in the daily point fire format, so temporal profiles are only used to go from day-specific to hourly emissions. For all agricultural burning, the diurnal temporal profile used reflected the fact that burning occurs during the daylight. This puts most of the emissions during the workday and suppresses the emissions during the middle of the night. This diurnal profile was used for each day of the week for all agricultural burning emissions in all states.

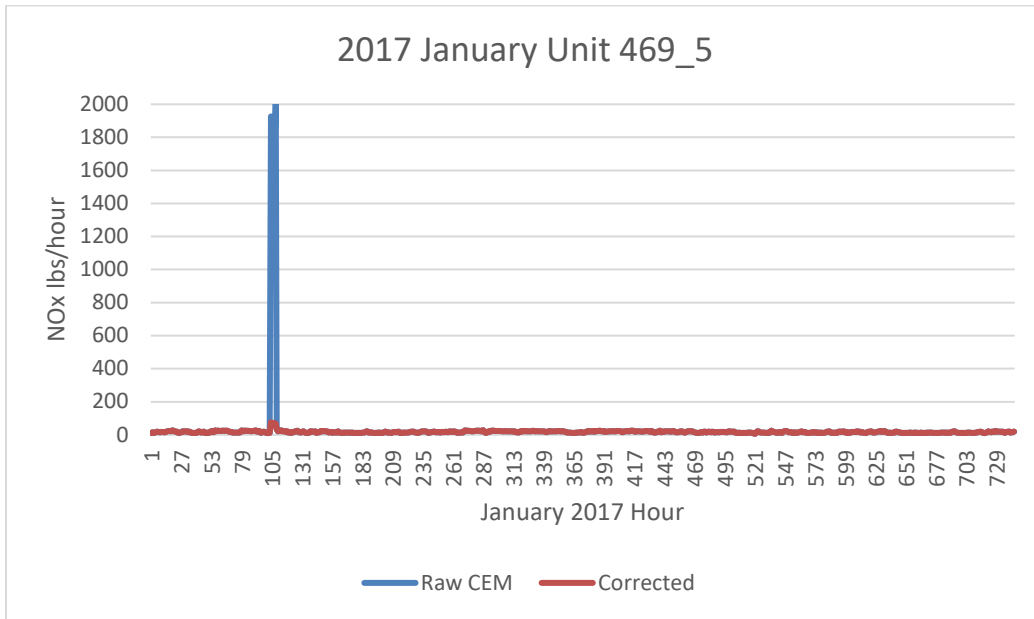
An update in the 2018 platform carried into this platform was an analysis of monthly temporal profiles for non-EGU point sources in the ptnonipm sector. A number of profiles were found to be not quite flat over the months but were so close to flat that the difference was not meaningful. These profiles were replaced in the cross reference to point instead to the flat monthly profile. The codes for the profiles that were replaced were: 202, 214, 220, 221, 222, 223, 227, 257, 263, 264, 265, 266, 267, 269, 271, 272, 279, 280, 295, 302, 303, 304, 305, 306, 309, 310, 327, 329, 332, and 333.

3.3.3 Electric Generating Utility temporal allocation (ptegu)

Electric generating unit (EGU) sources matched to ORIS units were temporally allocated to hourly emissions needed for modeling using the hourly CEMS data for units that could be matched to the CEMS emissions. Those hourly data were processed through v2.1 of the CEMCorrect tool to mitigate the impact of unmeasured values in the data. An example of before and after the application of the tool is shown in Figure 3-5.

The temporal allocation procedure for EGUs in the base year is differentiated by whether or not the unit could be directly matched to a unit with CEMS data via its ORIS facility code and boiler ID. Note that for units matched to CEMS data, annual totals of their emissions input to CMAQ may be different than the values in the annual inventory because the CEMS data replaces the NO_x and SO₂ annual 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. Prior to use of the CEMS data in SMOKE it is processed through the CEMCorrect tool. The CEMCorrect tool identifies hours for which the data were not measured as indicated by the data quality flags in the CEMS data files. Unmeasured data can be filled in with maximum values and thereby cause erroneously high values in the CEMS data. When data were flagged as unmeasured and the values were found to be more than three times the annual mean for that unit, the data for those hours are replaced with annual mean values (Adelman et al., 2012). These adjusted CEMS data were then used for the remainder of the temporal allocation process described below (see Figure 3-5 for an example).

Figure 3-5. Eliminating unmeasured spikes in CEMS data



The region, fuel, and type (peaking or non-peaking) must be identified for each input EGU with CEMS data that are used for generating profiles. The identification of peaking units was done using hourly heat input data from the 2019 base year and the two previous years (2017 and 2018). The heat input was summed for each year. Equation 1 shows how the annual heat input value is converted from heat units (BTU/year) to power units (MW) using the NEEDS v6 derived unit-level heat rate (BTU/kWh). In equation 2 a capacity factor is calculated by dividing the annual unit MW value by the NEEDS v6 unit capacity value (MW) multiplied by the hours in the year. A peaking unit was defined as any unit that had a maximum capacity factor of less than 0.2 for every year (2017, 2018, and 2019) and a 3-year average capacity factor of less than 0.1.

Equation 1. Annual unit power output

$$Annual\ Unit\ Output\ (MW) = \frac{\sum_{i=0}^{8760} \frac{Hourly\ HI\ (BTU)}{NEEDS\ Heat\ Rate\ (\frac{BTU}{kWh})} * 1000\ (\frac{MW}{kW})}{NEEDS\ Heat\ Rate\ (\frac{BTU}{kWh})}$$

Equation 2. Unit capacity factor

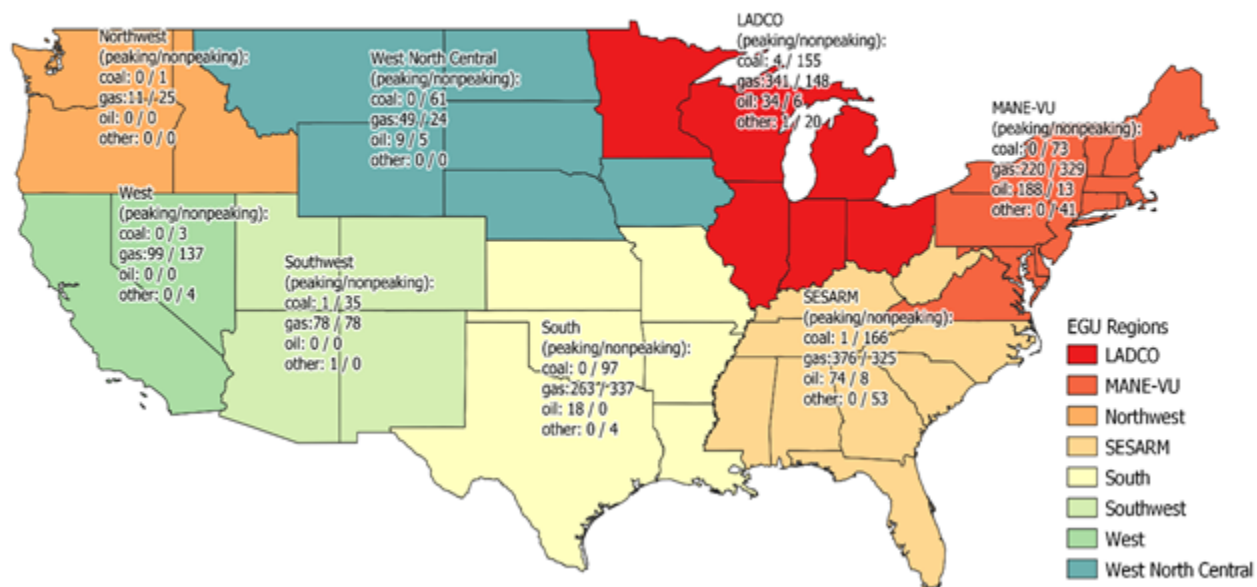
$$Capacity\ Factor = \frac{Annual\ Unit\ Output\ (MW)}{NEEDS\ Unit\ Capacity\ (\frac{MW}{h}) * 8760\ (h)}$$

Input regions were determined from one of the eight EGU modeling regions based on MJO and climate regions. Regions were used to group units with similar climate-based load demands. Region assignment is made on a state level, where all units within a state were assigned to the appropriate region. Unit fuel assignments were made using the primary NEEDS v6 fuel. Units fueled by bituminous, subbituminous, or lignite are assigned to the coal fuel type. Natural gas units were assigned to the gas fuel type. Distillate and residual fuel oil were assigned to the oil fuel type. Units with any other primary fuel were assigned

the “other” fuel type. The number of units used to calculate the daily and diurnal EGU temporal profiles are shown in Figure 3-6 by region, fuel, and for peaking/non-peaking. Currently there are 64 unique profiles available based on 8 regions, 4 fuels, and 2 for peaking unit status (peaking and non-peaking).

Figure 3-6. Temporal Profile Input Unit Counts by Fuel and Peaking Unit Classification

Small EGU 2016 Temporal Profile Input Unit Counts



The daily and diurnal profiles were calculated for each region, fuel, and peaking type group from the year 2019 CEMS heat input values. The heat input values were summed for each input group to the annual level at each level of temporal resolution: monthly, month-of-day, and diurnal. The sum by temporal resolution value was then divided by the sum of annual heat input in that group to get a set of temporalization factors. Diurnal factors were created for both the summer and winter seasons to account for the variation in hourly load demands between the seasons. For example, the sum of all hour 1 heat input values in the group was divided by the sum of all heat inputs over all hours to get the hour 1 factor. Each grouping contained 12 monthly factors, up to 31 daily factors per month, and two sets of 24 hourly factors. The profiles were weighted by unit size where the units with more heat input have a greater influence on the shape of the profile. Composite profiles were created for each region and type across all fuels as a way to provide profiles for a fuel type that does not have hourly CEMS data in that region. Figure 3-7 shows peaking and non-peaking daily temporal profiles for the gas fuel type in the LADCO region. Figure 3-8 shows the diurnal profiles for the coal fuel type in the Mid-Atlantic Northeast Visibility Union (MANE-VU) region.

Figure 3-7. Example Daily Temporal Profiles for the LADCO Region and the Gas Fuel Type

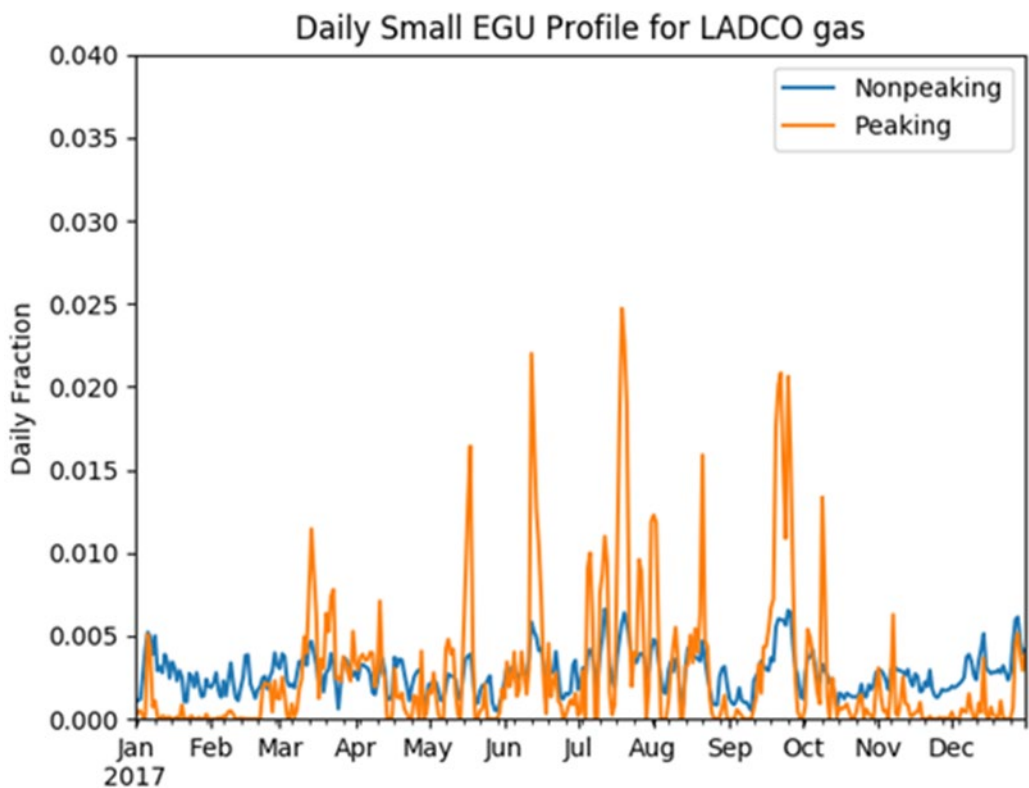
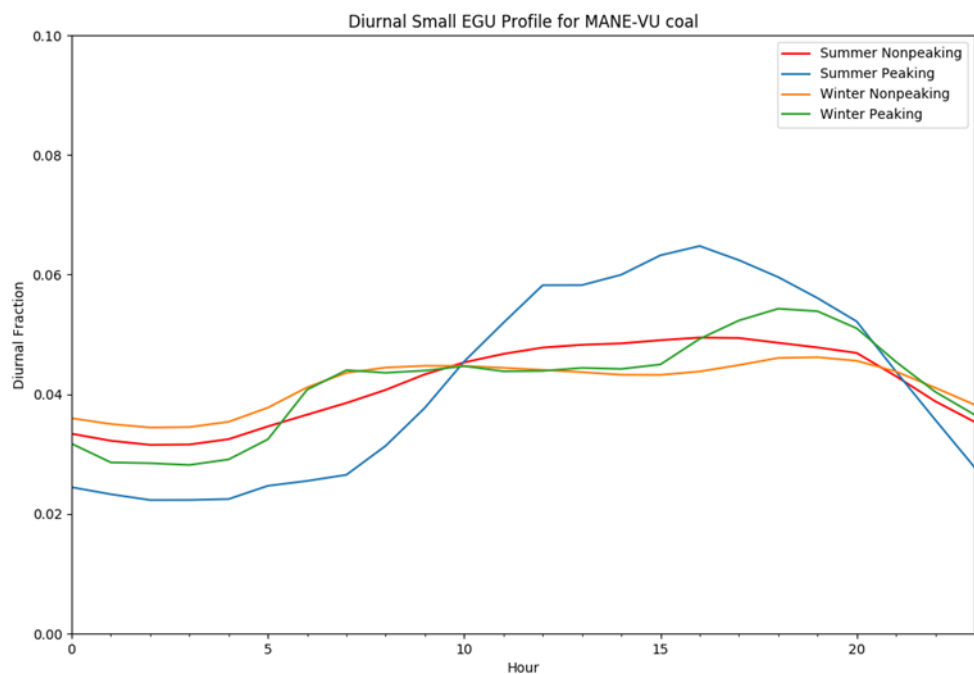
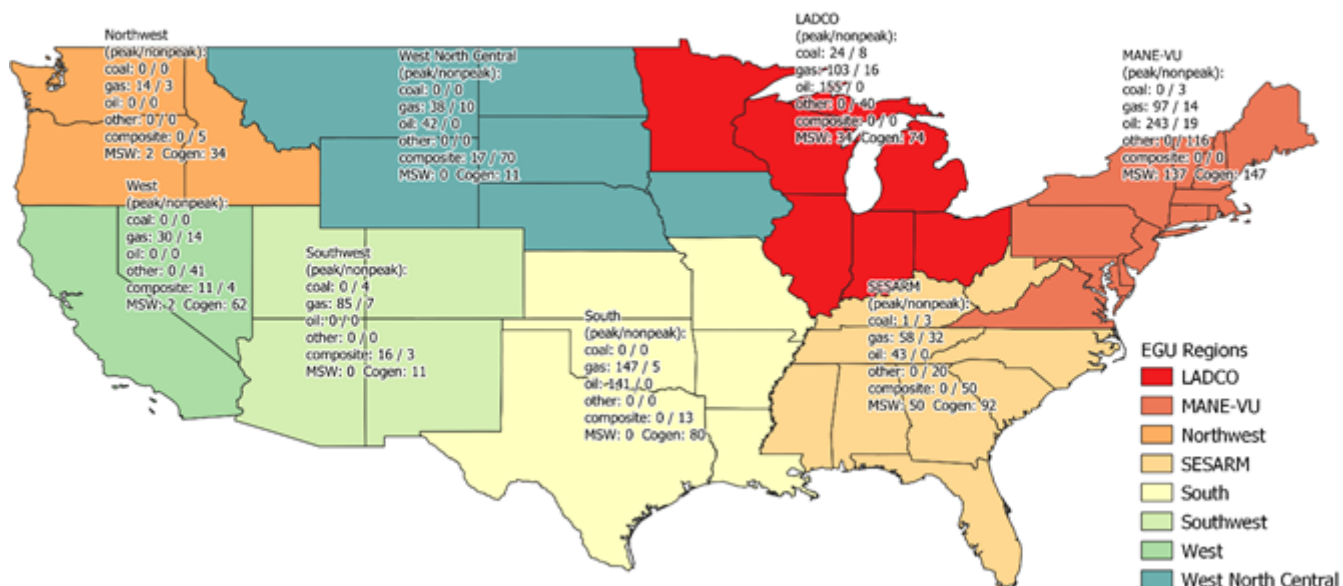


Figure 3-8. Example Diurnal Temporal Profiles for the MANE-VU Region and the Coal Fuel Type



SMOKE uses a cross-reference file to select a monthly, daily, and diurnal profile for each source. For this platform, the temporal profiles were assigned in the cross-reference at the unit level to EGU sources without hourly CEMS data. An inventory of all EGU sources without CEMS data was used to identify the region, fuel type, and type (peaking/non-peaking) of each source. As with the input unit the regions are assigned using the state from the unit FIPS. The fuel was assigned by SCC to one of the four fuel types: coal, gas, oil, and other. A fuel type unit assignment is made by summing the VOC, NOX, PM2.5, and SO2 for all SCCs in the unit. The SCC that contributed the highest total emissions to the unit for selected pollutants was used to assign the unit fuel type. Peaking units were identified as any unit with an oil, gas, or oil fuel type with a NAICS of 22111 or 22112. Some units may be assigned to a fuel type within a region that does not have an available input unit with a matching fuel type in that region. These units without an available profile for their group were assigned to use the regional composite profile. MWC and cogen units were identified using the NEEDS primary fuel type and cogeneration flag, respectively, from the NEEDS v6 database. The number of EGU units assigned each profile group are shown by region in Figure 3-9. In this plot, the unit counts are from 2016, but the 2019 unit counts should be similar.

Figure 3-9. Non-CEMS EGU Temporal Profile Application Counts
Small EGU 2016 Temporal Profile Application Counts



3.3.4 Airport Temporal allocation (airports)

Airport temporal profiles were updated in 2014v7.0 and were kept the same for this platform. All airport SCCs (i.e., 2275*, 2265008005, 2267008005, 2268008005 and 2270008005) were given the same hourly, weekly and monthly profile for all airports other than Alaska seaplanes (which are not in the CMAQ modeling domain). Hourly airport operations data were obtained from the Aviation System Performance Metrics (ASPM) Airport Analysis website (<https://aspm.faa.gov/apm/sys/AnalysisAP.asp>). A report of

2014 hourly Departures and Arrivals for Metric Computation was generated. An overview of the ASPM metrics is at http://aspmhelp.faa.gov/index.php/Aviation_Performance_Metrics_%28APM%29. Figure 3-10 shows the diurnal airport profile.

Weekly and monthly temporal profiles are based on 2014 data from the FAA Operations Network Air Traffic Activity System (<http://aspm.faa.gov/opsnet/sys/Terminal.asp>). A report of all airport operations (takeoffs and landings) by day for 2014 was generated. These data were then summed to month and day-of-week to derive the monthly and weekly temporal profiles shown in Figure 3-10, Figure 3-11, and Figure 3-12. An overview of the Operations Network data system is at http://aspmhelp.faa.gov/index.php/Operations_Network_%28OPSNET%29. The weekly and monthly profiles from 2014 are still used in this platform.

Alaska seaplanes, which are outside the CONUS domain use the monthly profile in Figure 3-13. These were assigned based on the facility ID.

Figure 3-10. Diurnal Profile for all Airport SCCs

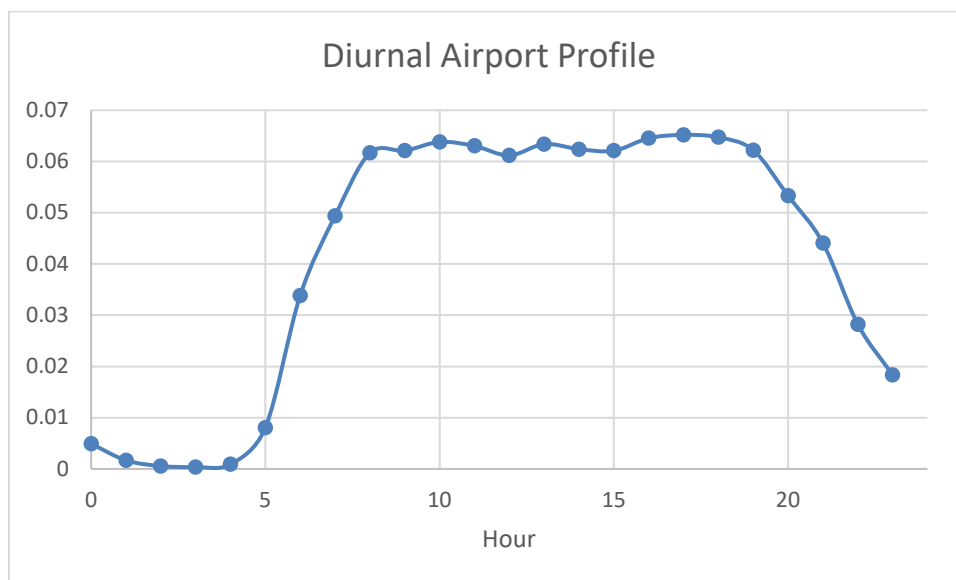


Figure 3-11. Weekly profile for all Airport SCCs

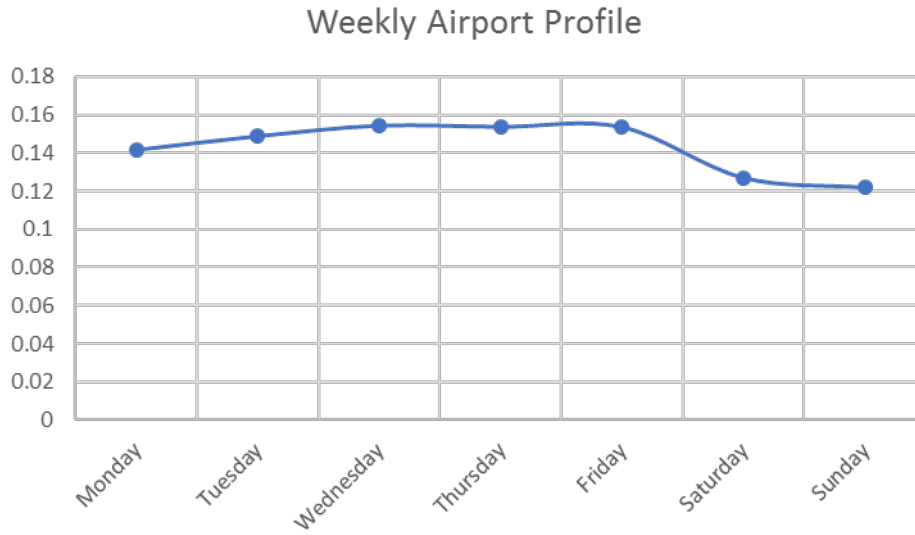


Figure 3-12. Monthly Profile for all Airport SCCs

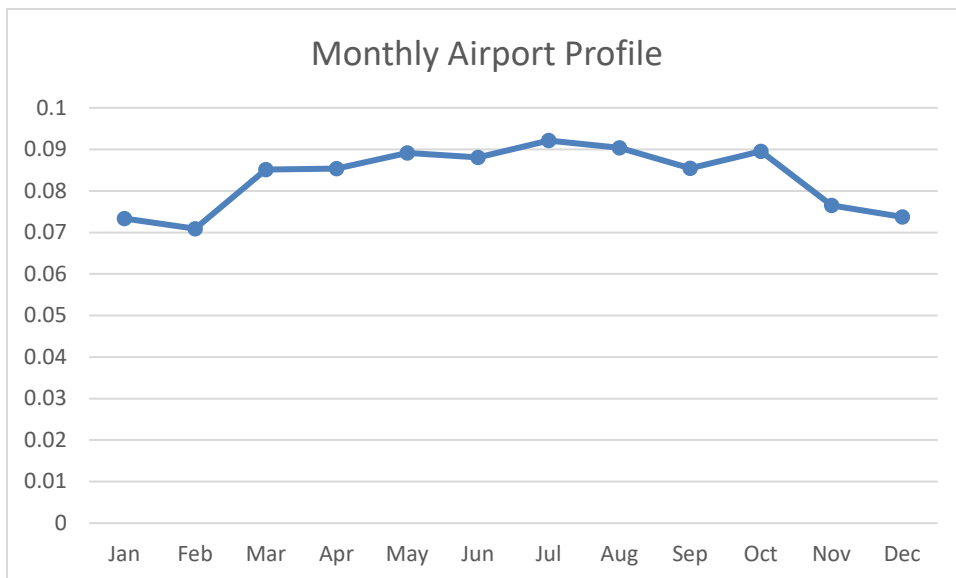
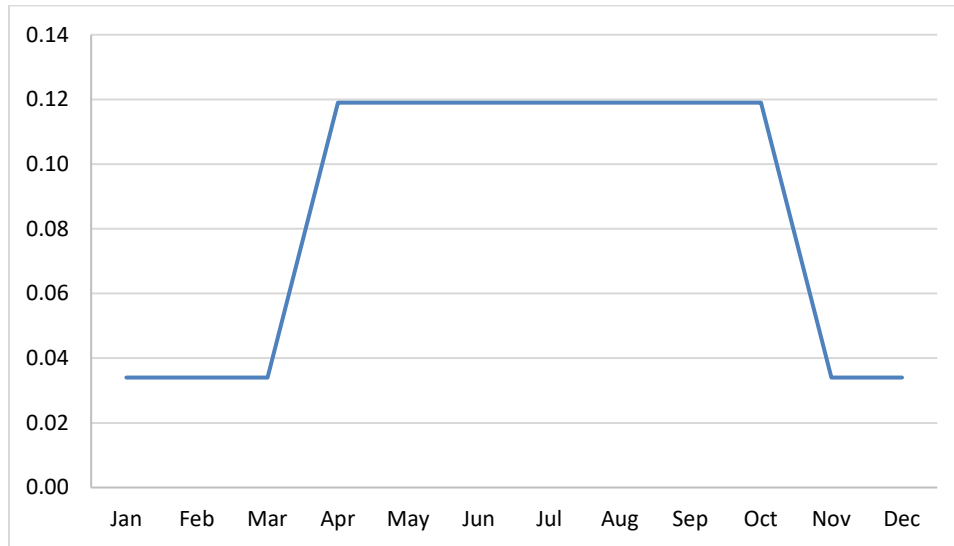


Figure 3-13. Alaska Seaplane Profile



3.3.5 Residential Wood Combustion Temporal allocation (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 a method for temporal allocation 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 temporal allocation.

The SMOKE program Gentpro provides a method for developing meteorology-based temporal allocation. Currently, the program can utilize three types of temporal algorithms: annual-to-day temporal allocation for residential wood combustion (RWC); month-to-hour temporal allocation for agricultural livestock NH₃; and a generic meteorology-based algorithm for other situations. Meteorological-based temporal allocation was used for portions of the rwc sector and for the entire 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/4.5/html/ch05s03s05.html>, respectively.

For the RWC algorithm, Gentpro uses the daily minimum temperature to determine the temporal allocation of emissions to days of the year. 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. The algorithm is as follows:

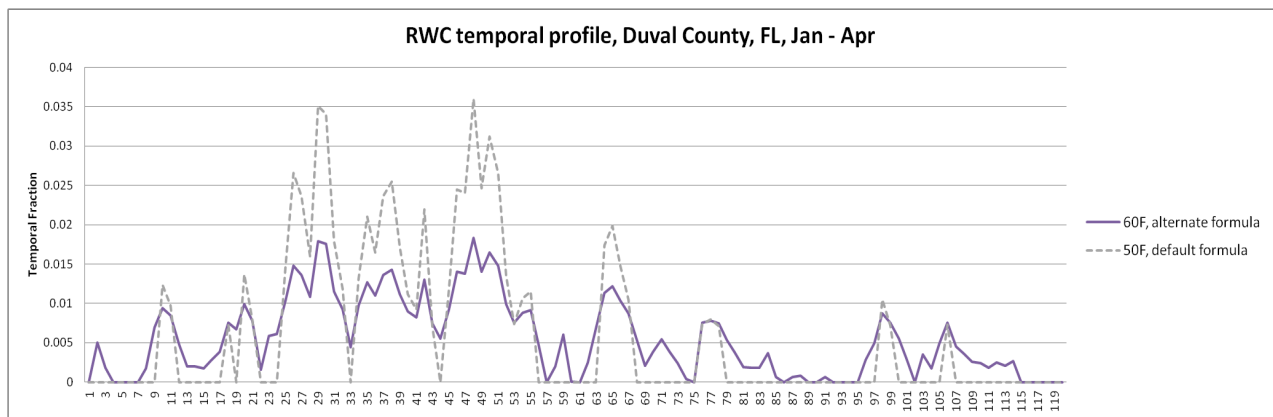
If $T_d \geq T_t$: no emissions that day
 If $T_d < T_t$: daily factor = $0.79 \cdot (T_t - T_d)$

where (T_d = minimum daily temperature; T_t = threshold temperature, which is 60 degrees F in southern states and 50 degrees F elsewhere).

Once computed, the factors are normalized to sum to 1 to ensure that the total annual emissions are unchanged (or minimally changed) during the temporal allocation process.

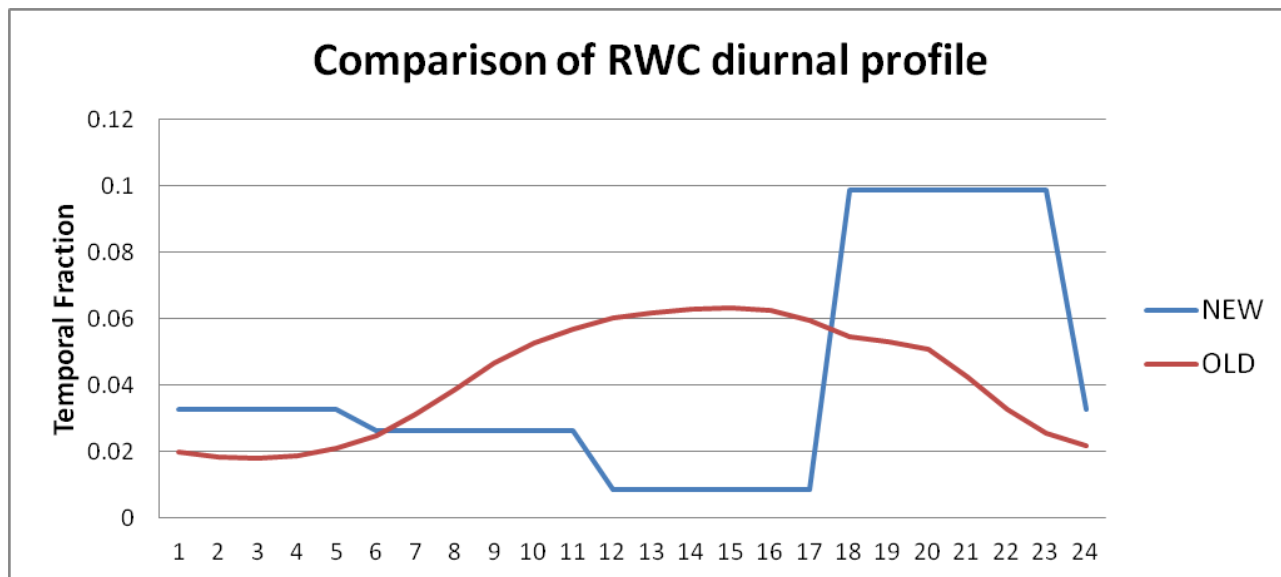
Figure 3-14 illustrates the impact of changing the temperature threshold for a warm climate county. The plot shows the temporal fraction by day for Duval County, Florida, for the first four months of 2007. The default 50 °F threshold creates large spikes on a few days, while the 60 °F threshold dampens these spikes and distributes a small amount of emissions to the days that have a minimum temperature between 50 and 60 °F.

Figure 3-14. Example of RWC temporal allocation in 2007 using a 50 versus 60 °F threshold



The diurnal profile used for most RWC sources (see Figure 3-15) 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 (https://s3.amazonaws.com/marama.org/wp-content/uploads/2019/11/04184303/Open_Burning_Residential_Areas_Emissions_Report-2004.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 days of the week and was found that the new RWC profile generally tracked the concentration based temporal patterns.

Figure 3-15. RWC diurnal temporal profile



The temporal profiles for hydronic heaters” (i.e., SCCs=2104008610 [outdoor], 2104008620 [indoor], and 2104008620 [pellet-fired]) and “Outdoor wood burning device, NEC (fire-pits, chimeneas, etc.)” (i.e., “recreational RWC,” SCC=2104008700) are not based on temperature data, because the meteorologically based temporal allocation used for the rest of the rwc sector did not agree with observations for how these appliances are used.

For hydronic heaters, 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.

Data used to create the diurnal profile for hydronic heaters, shown in Figure 3-16, are based on a conventional single-stage heat load unit burning red oak in Syracuse, New York. As shown in Figure 3-17, 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 temporal allocation for OHH as well as recreational RWC were computed from the MDNR 2008 survey and are illustrated in Figure 3-18. The hydronic heater 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 3-16. Data used to produce a diurnal profile for hydronic heaters

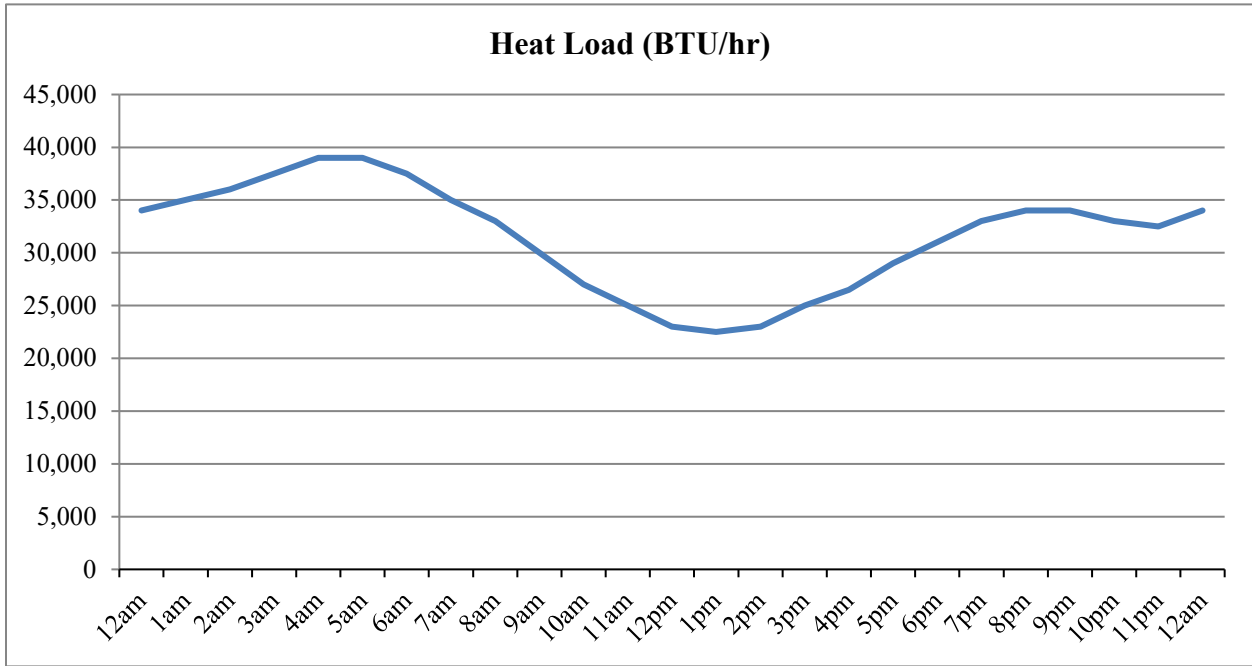


Figure 3-17. Day-of-week temporal profiles for hydronic heaters and recreational RWC

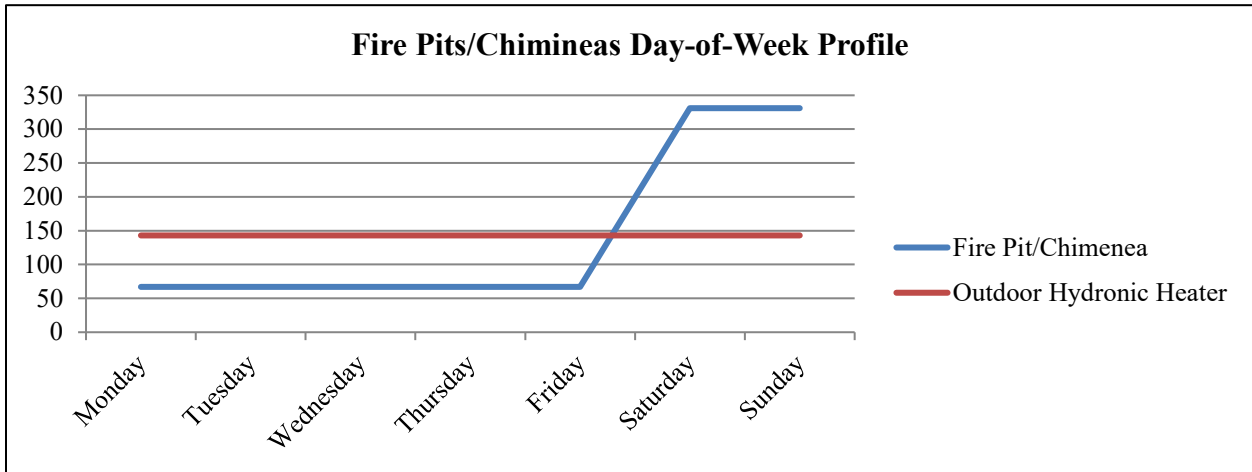
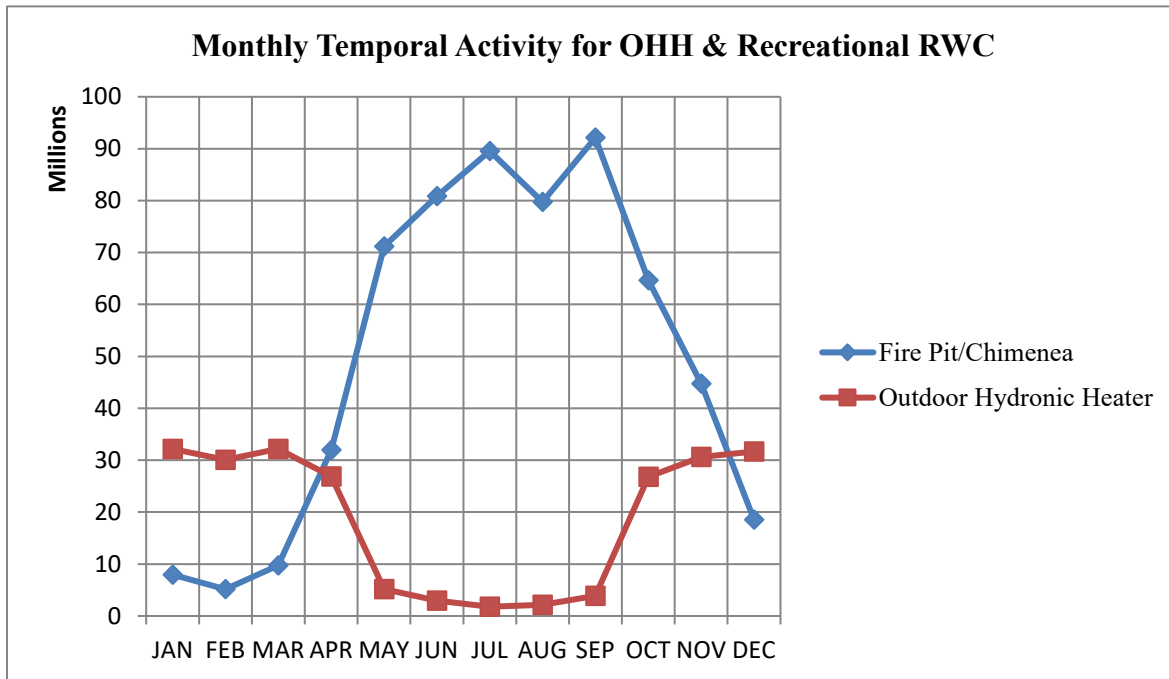


Figure 3-18. Annual-to-month temporal profiles for hydronic heaters and recreational RWC



3.3.6 Agricultural Ammonia Temporal Profiles (livestock)

For the ag sector, agricultural GenTPRO temporalization was applied to livestock emissions and to all pollutants within the sector, not just NH₃. The GenTPRO algorithm is based on an equation derived by Jesse Bash of EPA ORD based on the Zhu, Henze, et al. (2014) 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:

$$E_{i,h} = [161500/T_{i,h} \times e^{(-1380/T_{i,h})}] \times AR_{i,h} \quad \text{Equation 3-2}$$

$$PE_{i,h} = E_{i,h} / \text{Sum}(E_{i,h}) \quad \text{Equation 3-3}$$

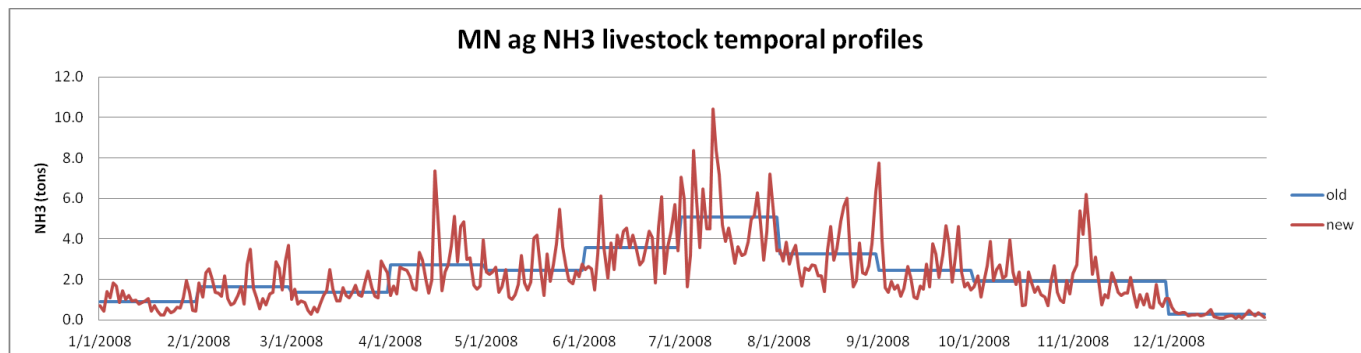
where

- 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*
- 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 3-19 compares the daily emissions for Minnesota from the “old” approach (uniform monthly profile) with the “new” approach (GenTPRO generated month-to-hour profiles) for 2014.

Although the GenTPRO profiles show daily (and hourly variability), the monthly total emissions are the same between the two approaches.

Figure 3-19. Example of animal NH₃ emissions temporal allocation approach (daily total emissions)



3.3.7 Oil and gas temporal allocation (np_oilgas)

Monthly temporalization of np_oilgas emissions is based primarily on monthly factors from the Oil and Gas Tool (OGT). Factors were specific to each county and SCC. For use in SMOKE, each unique set of factors was assigned a label (OG19_0001 through OG19_6617), and then a SMOKE-formatted ATPRO_MONTHLY and an ATREF were developed. This dataset of monthly temporal factors included profiles for all counties and SCCs in the Oil and Gas Tool inventory. Because we are using non-tool datasets in some states, this monthly temporalization dataset did not cover all counties and SCCs in the entire inventory used for this study. To fill in the gaps in those states, state average monthly profiles for oil, natural gas, and combination sources were calculated from Energy Information Administration (EIA) data and assigned to each county/SCC combination not already covered by the OGT monthly temporal profile dataset. Coal bed methane (CBM) and natural gas liquid sources in those states were assigned flat monthly profiles where there was not already a profile assignment in the ERG dataset.

3.3.8 Onroad mobile temporal allocation (onroad)

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

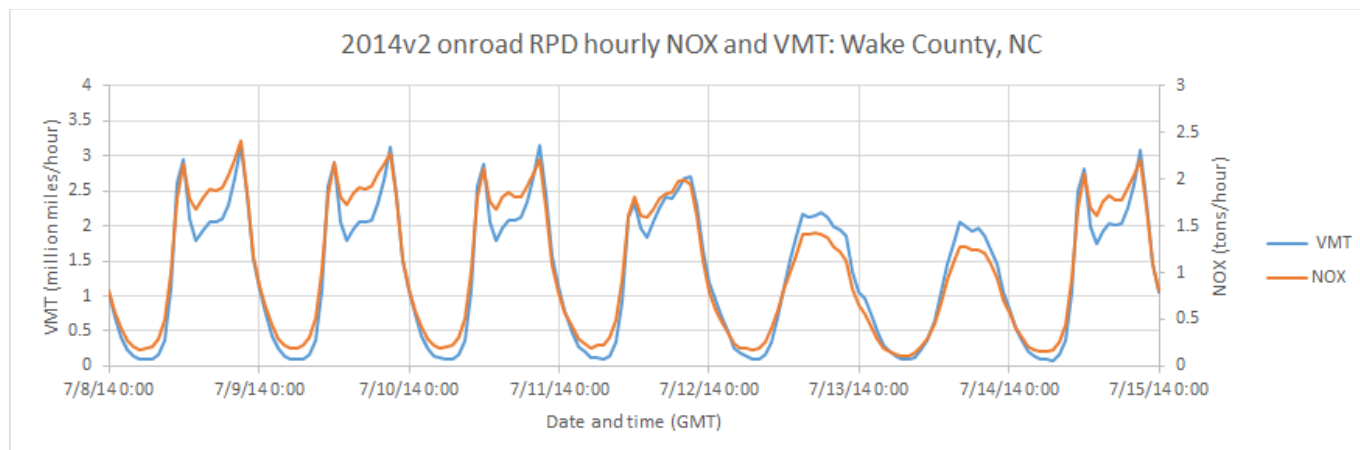
The “inventories” referred to in Table 3-23 consist of activity data for the onroad sector, not emissions. For the off-network emissions from the rate-per-profile (RPP) and rate-per-vehicle (RPV) processes, the VPOP activity data is annual and does not need temporal allocation. For rate-per-hour (RPH) processes that result from hoteling of combination trucks, the HOTELING inventory is annual and was temporalized to month, day of the week, and hour of the day through temporal profiles. Day-of-week and hour-of-day temporal profiles are also used to temporalize the starts activity used for rate-per-start (RPS) processes, and the off-network idling (ONI) hours activity used for rate-per-hour-ONI (RPHO) processes. The inventories for starts and ONI activity contain monthly activity so that monthly temporal profiles are not needed.

For on-roadway rate-per-distance (RPD) processes, the VMT activity data is annual for some sources and monthly for other sources, depending on the source of the data. Sources without monthly VMT were temporalized from annual to month through temporal profiles. VMT was also temporalized from month

to day of the week, and then to hourly through temporal profiles. The RPD processes also use hourly speed distributions (SPDIST) as discussed in Section 2.3.2. For onroad, the temporal profiles and SPDIST will impact not only the distribution of emissions through time but also the total emissions. Because SMOKE-MOVES (for RPD) calculates emissions based on the 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 temporal allocation of VMT changes. Figure 3-20 illustrates the temporal allocation of the onroad activity data (i.e., VMT) and the pattern of the emissions that result after running SMOKE-MOVES. In this figure, it can be seen that the meteorologically varying emission factors add variation on top of the temporal allocation of the activity data.

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 and stationary vehicle (RPV, RPH, RPHO, RPS, and RPP) processes use the gridded meteorology (MCIP) either directly or indirectly. For RPD, RPV, RPH, RPHO, and RPS, 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. For RPP, instead of reading gridded hourly meteorology, Movesmrg reads gridded daily minimum and maximum temperatures. The total of the emissions from the combination of these six processes (RPD, RPV, RPH, RPHO, RPS, and RPP) comprise the onroad sector emissions. The temporal patterns of emissions in the onroad sector are influenced by meteorology.

Figure 3-20. Example of temporal variability of NO_x emissions



New VMT day-of-week and hour-of-day temporal profiles were developed for use in the 2014NEIv2 and later platforms as part of the effort to update the inputs to MOVES and SMOKE-MOVES under CRC A-100 (Coordinating Research Council, 2017). CRC A-100 data includes profiles by region or county, road type, and broad vehicle category. There are three vehicle categories: passenger vehicles (11/21/31), commercial trucks (32/52), and combination trucks (53/61/62). CRC A-100 does not cover buses, refuse trucks, or motor homes, so those vehicle types were mapped to other vehicle types for which CRC A-100 did provide profiles as follows: 1) Intercity/transit buses were mapped to commercial trucks; 2) Motor homes were mapped to passenger vehicles for day-of-week and commercial trucks for hour-of-day; 3) School buses and refuse trucks were mapped to commercial trucks for hour-of-day and use a new custom

day-of-week profile called LOWSATSUN that has a very low weekend allocation, since school buses and refuse trucks operate primarily on business days. In addition to temporal profiles, CRC A-100 data were also used to develop the average hourly speed data (SPDPRO) used by SMOKE-MOVES. In areas where CRC A-100 data does not exist, hourly speed data is based on MOVES county databases.

The CRC A-100 dataset includes temporal profiles for individual counties, Metropolitan Statistical Areas (MSAs), and entire regions (e.g., West, South). For counties without county or MSA temporal profiles specific to itself, regional temporal profiles are used. Temporal profiles also vary by each of the MOVES road types, and there are distinct hour-of-day profiles for each day of the week. Plots of hour-of-day profiles for passenger vehicles in Fulton County, GA, are shown in Figure 3-21. Separate plots are shown for Monday, Friday, Saturday, and Sunday, and each line corresponds to a particular MOVES road type (i.e., road type 2 = rural restricted, 3 = rural unrestricted, 4 = urban restricted, and 5 = urban unrestricted). Figure 3-22 shows which counties have temporal profiles specific to that county, and which counties use regional average profiles in the CRC A-100 data.

Figure 3-21. Sample onroad diurnal profiles for Fulton County, GA

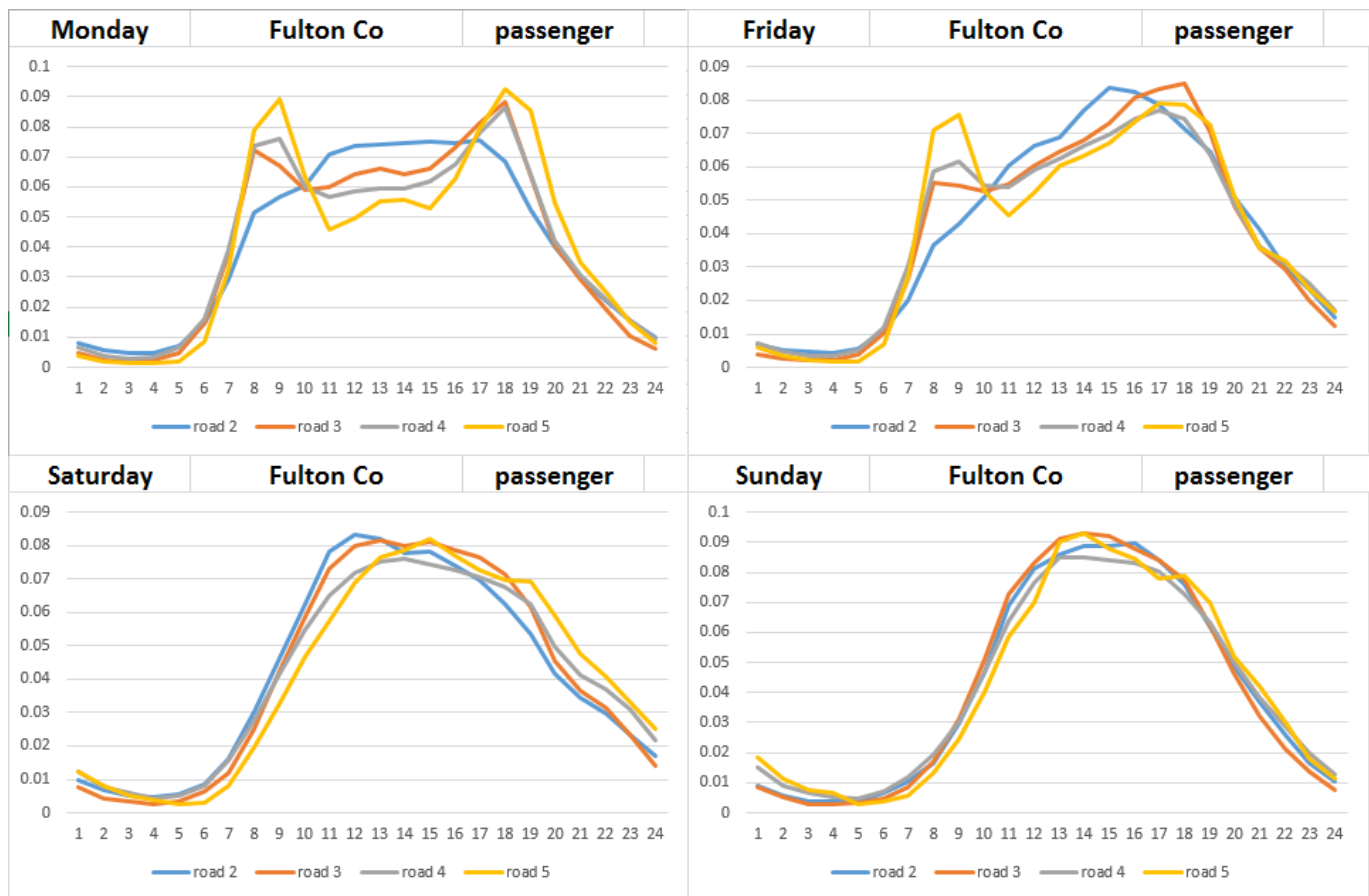
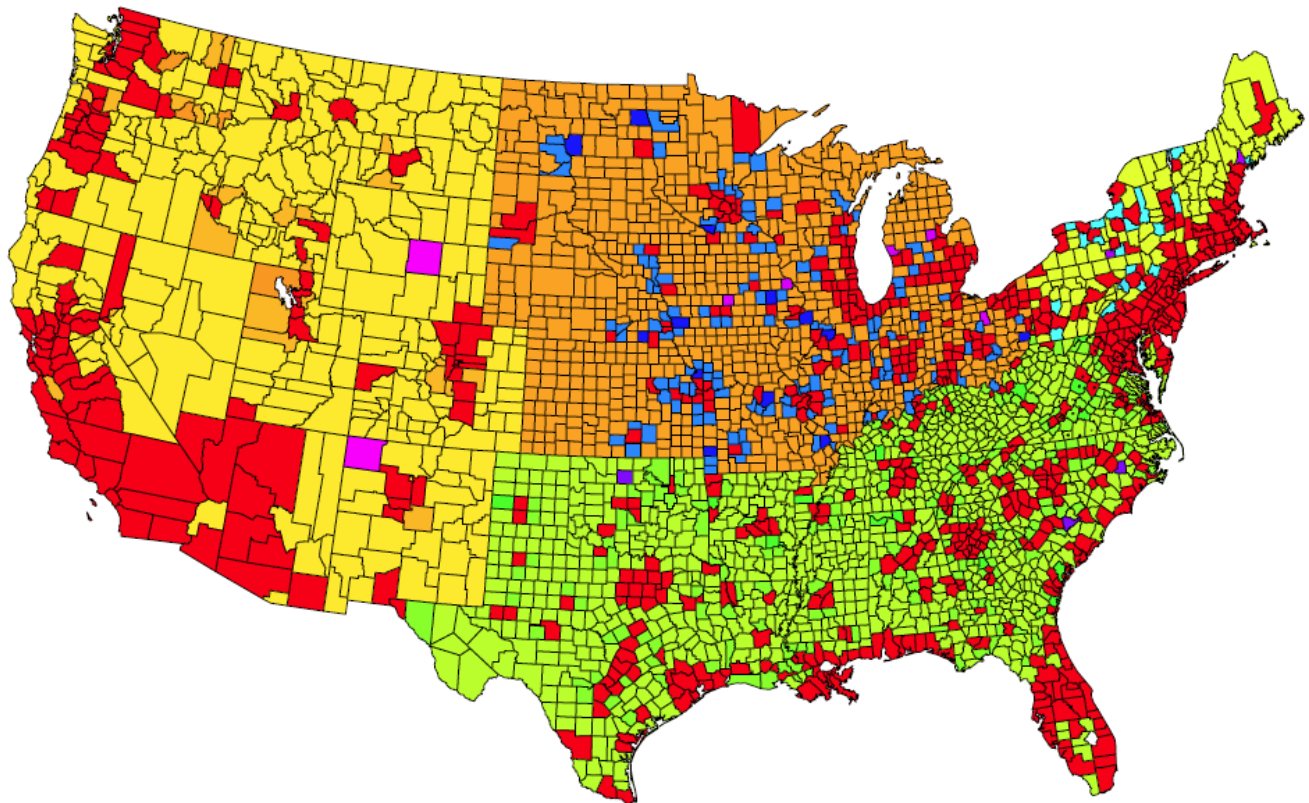
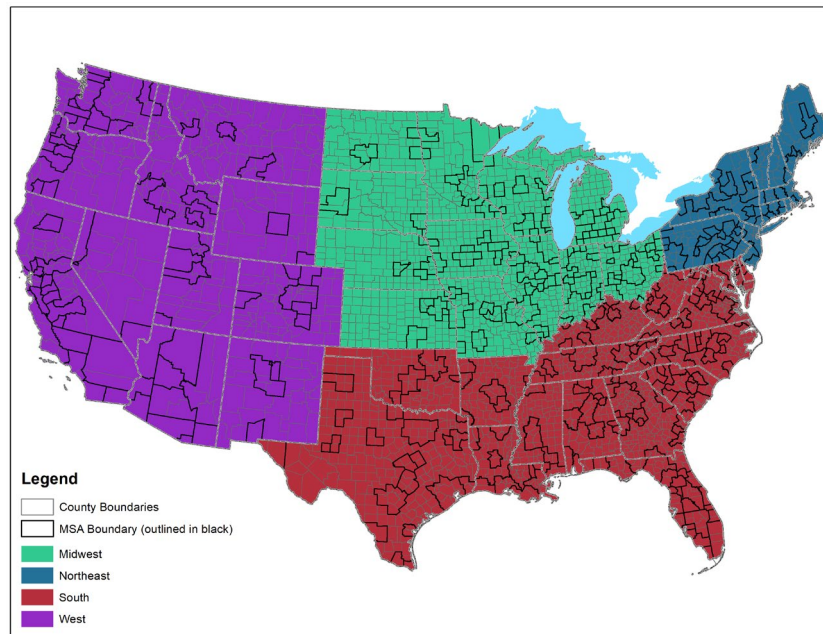


Figure 3-22. Methods to Populate Onroad Speeds and Temporal Profiles by Road Type



- | | |
|---|---|
| <p>Group</p> <ul style="list-style-type: none"> ■ Individual ■ Midwest Region Average of Single County MSA Counties ■ Midwest Region non-MSA Average ■ Northeast Region Average of Single County MSA Counties ■ Northeast Region non-MSA Average ■ South Region Average of Single County MSA Counties ■ South Region non-MSA Average ■ West Region Average of Single County MSA Counties ■ West Region non-MSA Average | <ul style="list-style-type: none"> ■ Midwest Region Average of Core Counties inside MSAs ■ Midwest Region Average of non-Core Counties inside MSAs ■ Northeast Region Average of Core Counties inside MSAs ■ Northeast Region Average of non-Core Counties inside MSAs ■ South Region Average of Core Counties inside MSAs ■ South Region Average of non-Core Counties inside MSAs ■ West Region Average of Core Counties inside MSAs ■ West Region Average of non-Core Counties inside MSAs |
|---|---|

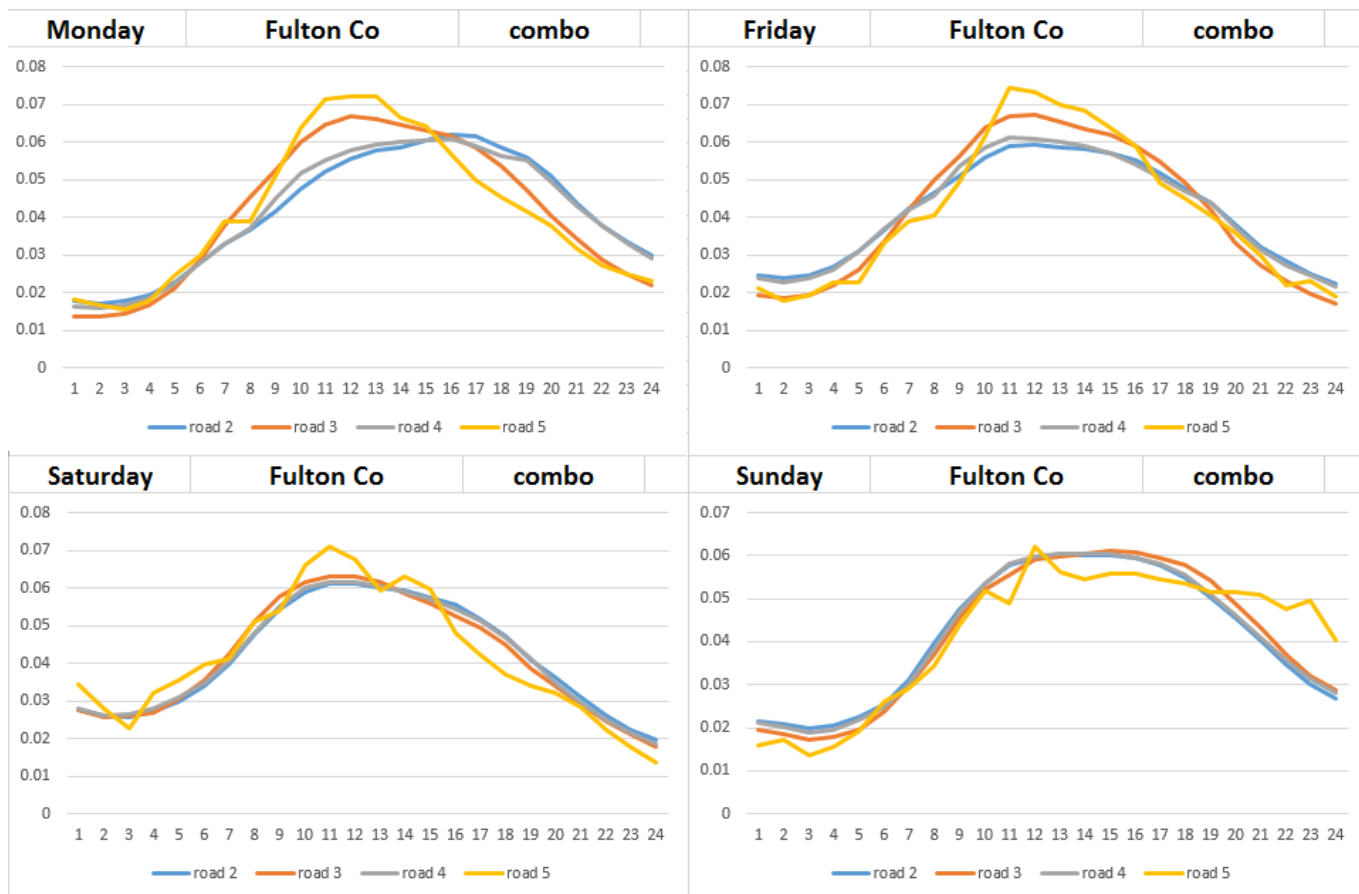
Figure 3-23. Regions for computing Region Average Speeds and Temporal Profiles



State/local-provided data for the 2017 NEI were accepted for use in the 2017 NEI if they were deemed to be at least as credible as the CRC A-100 data. The 2017 NEI TSD includes more details on which data were used for which counties. In areas of the contiguous United States where state/local-provided data were not provided or deemed unacceptable, the CRC A-100 temporal profiles were used, including in California. The CRC A-100 temporal profiles were used in areas of the contiguous United States that did not submit temporal profiles of sufficient detail for the 2017 NEI. For this platform, CRC A-100 profiles are used in most of the country, but day-of-week and hour-of-day profiles based on MOVES CDB submissions for the 2017NEI are used in Maricopa and Pima counties in Arizona, Delaware, Washington DC, Florida, some of Georgia, Idaho, Massachusetts, Maryland, Missouri, Clark County Nevada, New Jersey, New York, Ohio, Pennsylvania, Davidson and Knox counties in Tennessee, Texas, and Virginia.

For hoteling, day-of-week profiles are the same as non-hoteling for combination trucks, while hour-of-day non-hoteling profiles for combination trucks were inverted to create new hoteling profiles that peak overnight instead of during the day. The combination truck profiles for Fulton County are shown in Figure 3-24.

Figure 3-24. Example of Temporal Profiles for Combination Trucks



Temporal profiles for RPHO are based on the same temporal profiles as the on-network processes in RPD, but since the on-network profiles are road-type-specific and ONI is not road-type-specific, the RPHO profiles were assigned to use rural unrestricted profiles for counties considered "rural" and urban unrestricted profiles for counties considered "urban". RPS uses a separate set of temporal profiles specifically for starts activity. For starts, there is one day-of-week temporal profile for each source type (e.g. motorcycles, passenger cars, combination long haul trucks), and two hour-of-day temporal profiles for each source type, one for weekdays and one for weekends. The starts temporal profiles are applied nationally and are based on the default starts-per-day-per-vehicle and starts-hour-fraction tables from MOVES.

3.3.9 Nonroad mobile temporal allocation (nonroad)

For nonroad mobile sources, temporal allocation is performed differently for different SCCs. Beginning with the final 2011 platform and continuing in the 2016 platform, improvements to temporal allocation of nonroad mobile sources were made to make the temporal profiles more realistically reflect real-world practices. Some specific updates were made for agricultural sources (e.g., tractors), construction, and commercial residential lawn and garden sources.

Figure 3-25 shows two previously existing temporal profiles (9 and 18) and a newer temporal profile (19) which has lower emissions on weekends. In this platform, construction and commercial lawn and garden sources use the new profile 19 which has lower emissions on weekends. Residential lawn and garden sources continue to use profile 9 and agricultural sources continue to use profile 19.

Figure 3-25. Example Nonroad Day-of-week Temporal Profiles

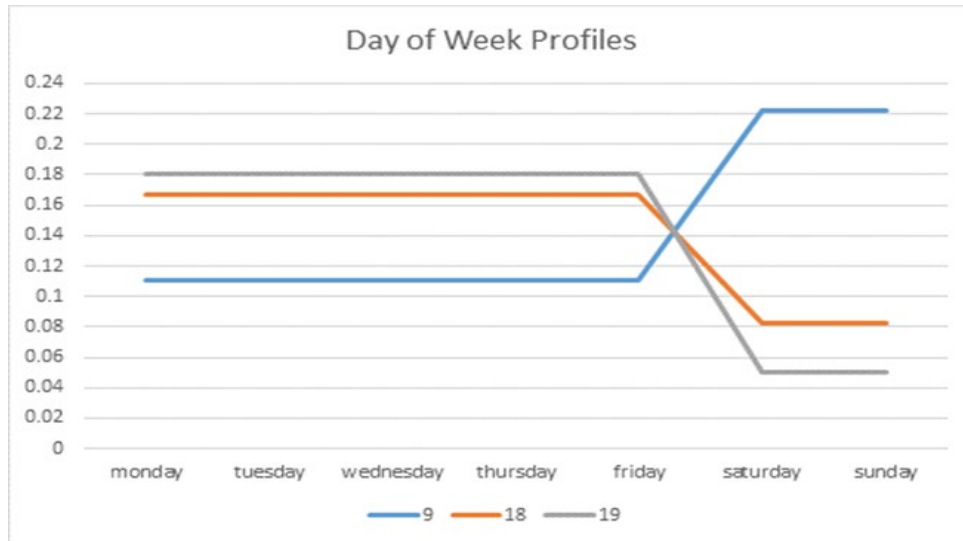
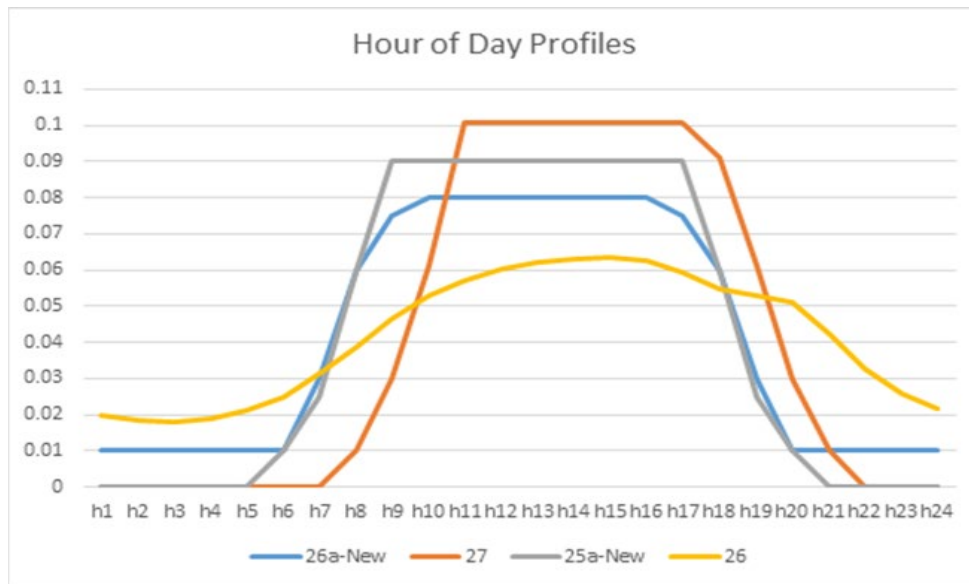


Figure 3-26 shows the previously existing temporal profiles 26 and 27 along with newer temporal profiles (25a and 26a) which have lower emissions overnight. In this platform, construction sources use profile 26a. Commercial lawn and garden and agriculture sources use the profiles 26a and 25a, respectively. Residential lawn and garden sources use profile 27.

Figure 3-26. Example Nonroad Diurnal Temporal Profiles



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

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

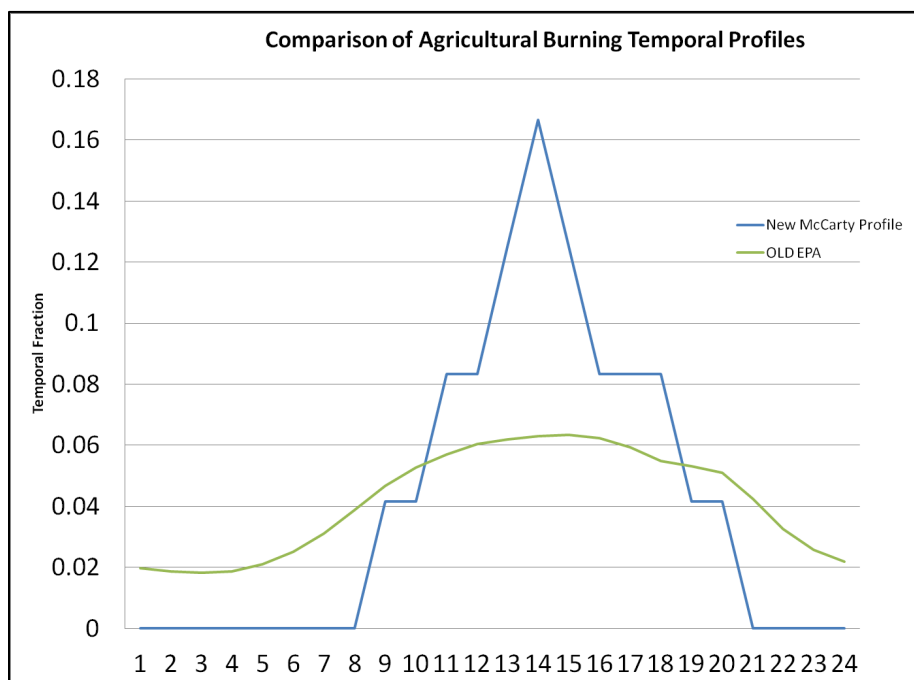
ground. The land use data used to reduce the NEI emissions explains the amount of emissions that are subject to transport. This methodology is discussed in (Pouliot et al., 2010), and in “Fugitive Dust Modeling for the 2008 Emissions Modeling Platform” (Adelman, 2012). The precipitation adjustment is applied to remove all emissions for hours where measurable rain occurs, or where there is snow cover. Therefore, the afdust emissions vary day-to-day based on the precipitation and/or snow cover for each grid cell and hour. 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 from the BEIS model vary each 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 rail sector, new monthly profiles were developed for the 2016 platform. Monthly temporal allocation for rail freight emissions is based on AAR Rail Traffic Data, Total Carloads and Intermodal, for 2016. For passenger trains, monthly temporal allocation is flat for all months. Rail passenger miles data is available by month for 2016 but it is not known how closely rail emissions track with passenger activity since passenger trains run on a fixed schedule regardless of how many passengers are aboard, and so a flat profile is chosen for passenger trains. Rail emissions are allocated with flat day of week profiles, and most emissions are allocated with flat hourly profiles.

For the ptagfire sector, the inventories are in the daily point fire format FF10 PTDAY. The diurnal temporal profile for ag fires reflects the fact that burning occurs during the daylight hours - see Figure 3-27 (McCarty et al., 2009). This puts most of the emissions during the work-day and suppresses the emissions during the middle of the night.

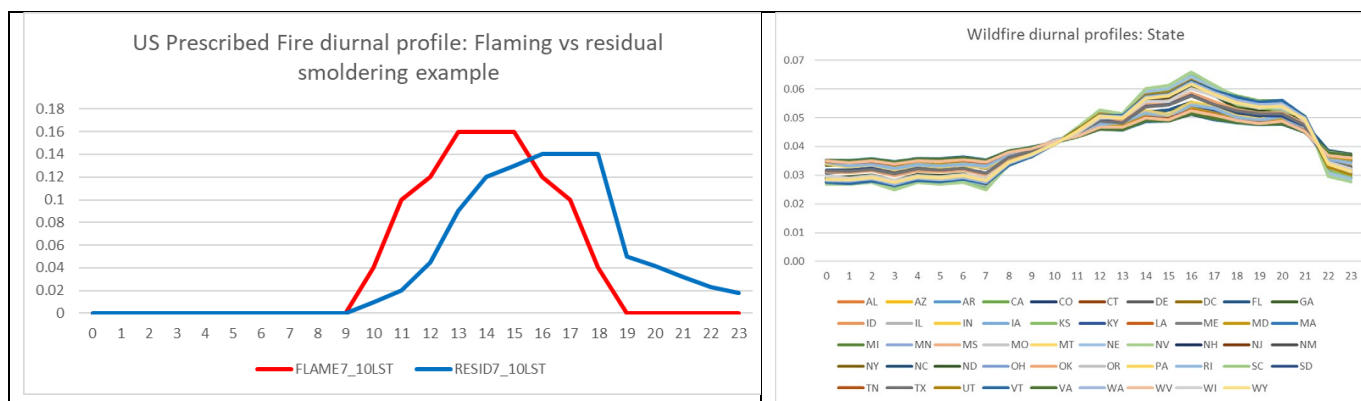
Figure 3-27. Agricultural burning diurnal temporal profile



Industrial processes that are not likely to shut down on Sundays, such as those at cement plants, use profiles that include emissions on Sundays, while those that would shut down on Sundays use profiles that reflect Sunday shutdowns.

For the ptfire sectors, the inventories are in the daily point fire format FF10 PTDAY, so temporal profiles are only used to go from day-specific to hourly emissions. Separate hourly profiles for prescribed and wildfires were used. For ptfire, state-specific hourly profiles were used, with distinct profiles for prescribed fires and wildfires. Figure 3-28 below shows the profiles used for each state for the platform. The wildfire diurnal profiles are similar but vary according to the average meteorological conditions in each state.

Figure 3-28. Prescribed and Wildfire diurnal temporal profiles



For the nonroad sector, while the NEI only stores the annual totals, the modeling platform uses monthly inventories from output from MOVES. For California, CARB’s annual inventory was temporalized to monthly using monthly temporal profiles applied in SMOKE by SCC. This is an improvement over the 2011 platform, which applied monthly temporal allocation in California at the broader SCC7 level.

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. Spatial allocation was performed for each of the modeling grids shown in Section 3.1. 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 2016-2017 data wherever possible. For Mexico, updated spatial surrogates were used as described below. For Canada, updated surrogates were provided by Environment Canada for the 2016v7.2 platform. The U.S., Mexican, and Canadian 12-km surrogates cover the entire CONUS domain 12US1 shown in Figure 3-1.

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. As described in Section 3.4.2, an area-to-point approach overrides the use of surrogates for airport refueling sources.

Table 3-24 lists the codes and descriptions of the surrogates. Surrogate names and codes listed in *italics* are not directly assigned to any sources in the platform, but are sometimes used to gapfill other surrogates, or as an input for merging two surrogates to create a new surrogate that is assigned to sources. 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.

Many of the surrogates currently in use were developed for use in the 2014v7.0 platform using recently available data sets (Adelman, 2016). They include the use of the 2011 National Land Cover Database (the previous platform used 2006) and development of various development density levels such as open, low, medium high and various combinations of these. These landuse surrogates largely replaced the FEMA category surrogates that were used in the 2011 platform. Additionally, onroad surrogates were developed using more recent average annual daily traffic counts from the highway monitoring performance system (HPMS). Onroad surrogates for this platform do not distinguish between urban and rural road types, which prevents issues in areas where there are inconsistent urban and rural definitions between MOVES and the surrogate data.

Recent surrogate updates include:

- A public school surrogate (508) was developed for off-network school buses.
- Oil and gas surrogates were updated to represent 2019, including a new surrogate for total gas produced (689)
- Corrections were made to the rail surrogates (261/271).
- The transit bus terminal surrogate was re-gapfilled with the NLCD medium+high surrogate (306)
- Some gridding cross reference corrections / updates were made including the use of NLCD medium+high surrogate instead of intercity bus terminals for off network emissions from other buses.
- The 500 series surrogates are no longer used and SCCs that used them (e.g., cigarette smoke, accidental releases) were remapped to NLCD surrogates.
- Onroad surrogates were generated to incorporate 2017 Average Annual Daily Traffic (AADT);

Surrogates for the U.S. were generated using the Surrogate Tool to drive the Spatial Allocator with some surrogates were developed directly within ArcGIS or using the Surrogate Tools DB. The tool and documentation for the original Surrogate Tool are available at https://www.cmascenter.org/sa-tools/documentation/4.2/SurrogateToolUserGuide_4_2.pdf, and the tool and documentation for the Surrogate Tools DB is available from https://www.cmascenter.org/surrogate_tools_db/. The file `Surrogate_specifications_2019_platform_US_Can_Mex.xlsx` documents the configuration for generating the surrogates.

Table 3-24. U.S. Surrogates available for the 2019 modeling platforms

Code	Surrogate Description	Code	Surrogate Description
N/A	Area-to-point approach (see 3.6.2)	650	Refineries and Tank Farms
100	Population	670	Spud Count - CBM Wells
110	<i>Housing</i>	671	Spud Count - Gas Wells
150	Residential Heating - Natural Gas	672	<i>Gas Production at Oil Wells</i>
170	Residential Heating - Distillate Oil	673	<i>Oil Production at CBM Wells</i>
180	Residential Heating - Coal	674	Unconventional Well Completion Counts
190	Residential Heating - LP Gas	676	<i>Well Count - All Producing</i>
205	Extended Idle Locations	677	<i>Well Count - All Exploratory</i>
239	Total Road AADT	678	Completions at Gas Wells
240	Total Road Miles	679	Completions at CBM Wells
242	All Restricted AADT	681	Spud Count - Oil Wells
244	All Unrestricted AADT	683	<i>Produced Water at All Wells</i>
258	<i>Intercity Bus Terminals</i>	6831	Produced Water at CBM Wells
259	Transit Bus Terminals	6832	Produced Water at Gas Wells
260	<i>Total Railroad Miles</i>	6833	Produced Water at Oil Wells
261	NTAD Total Railroad Density	685	Completions at Oil Wells
271	NTAD Class 1 2 3 Railroad Density	686	<i>Completions at All Wells</i>
300	NLCD Low Intensity Development	687	Feet Drilled at All Wells
304	NLCD Open + Low	689	Gas Produced - Total
305	NLCD Low + Med	691	Well Counts - CBM Wells
306	NLCD Med + High	692	<i>Spud Count - All Wells</i>
307	NLCD All Development	693	<i>Well Count - All Wells</i>
308	NLCD Low + Med + High	694	Oil Production at Oil Wells
309	NLCD Open + Low + Med	695	Well Count - Oil Wells
310	NLCD Total Agriculture	696	Gas Production at Gas Wells
319	NLCD Crop Land	697	<i>Oil Production at Gas Wells</i>
320	NLCD Forest Land	698	Well Count - Gas Wells
321	NLCD Recreational Land	699	Gas Production at CBM Wells
340	<i>NLCD Land</i>	711	Airport Areas
350	NLCD Water	801	Port Areas
500	<i>Commercial Land</i>	805	<i>Offshore Shipping Area</i>
505	<i>Industrial Land</i>	806	<i>Offshore Shipping NEI2014 Activity</i>
506	<i>Education</i>	807	<i>Navigable Waterway Miles</i>
508	Public Schools	808	<i>2013 Shipping Density</i>
510	<i>Commercial plus Industrial</i>	820	<i>Ports NEI2014 Activity</i>
535	<i>Residential + Commercial + Industrial + Institutional + Government</i>	850	Golf Courses
560	<i>Hospital (COM6)</i>	860	Mines

For the onroad sector, the on-network (RPD) emissions were spatially allocated differently from other off-network processes (i.e. RPV, RPP, RPHO). Surrogates for on-network processes are based on AADT data and off network processes (including the off-network idling included in RPHO) are based on land use surrogates as shown in Table 3-25. Emissions from the extended (i.e., overnight) idling of trucks were assigned to surrogate 205, which is based on locations of overnight truck parking spaces. The underlying data for this surrogate were updated during the development of the 2016 platforms to include additional

data sources and corrections based on comments received and these updates were carried into this platform.

Table 3-25. Off-Network Mobile Source Surrogates

Source type	Source Type name	Surrogate ID	Description
11	Motorcycle	307	NLCD All Development
21	Passenger Car	307	NLCD All Development
31	Passenger Truck	307	NLCD All Development
32	Light Commercial Truck	308	NLCD Low + Med + High
41	Other Bus	306	NLCD Med + High
42	Transit Bus	259	Transit Bus Terminals
43	School Bus	508	Public Schools
51	Refuse Truck	306	NLCD Med + High
52	Single Unit Short-haul Truck	306	NLCD Med + High
53	Single Unit Long-haul Truck	306	NLCD Med + High
54	Motor Home	304	NLCD Open + Low
61	Combination Short-haul Truck	306	NLCD Med + High
62	Combination Long-haul Truck	306	NLCD Med + High

For the oil and gas sources in the np_oilgas sector, the spatial surrogates were updated to those shown in Table 3-26 using 2019 data consistent with what was used to develop the nonpoint oil and gas emissions.

The exploration and production of oil and gas has increased in terms of quantities and locations over the last seven years, primarily through the use of new technologies, such as hydraulic fracturing. Census-tract, 2-km, and 4-km sub-county Shapefiles were developed, from which the 2019 oil and gas surrogates were generated. All spatial surrogates for np_oilgas are developed based on known locations of oil and gas activity for year 2019.

The primary activity data source used for the development of the oil and gas spatial surrogates was data from Drilling Info (DI) Desktop’s HPDI database (Drilling Info, 2019). This database contains well-level location, production, and exploration statistics at the monthly level. Due to a proprietary agreement with DI Desktop, individual well locations and ancillary production cannot be made publicly available, but aggregated statistics are allowed. These data were supplemented with data from state Oil and Gas Commission (OGC) websites (Alaska, Arizona, Idaho, Illinois, Indiana, Kentucky, Louisiana, Michigan, Mississippi, Missouri, Nevada, Oregon and Pennsylvania, Tennessee). In cases when the desired surrogate parameter was not available (e.g., feet drilled), data for an alternative surrogate parameter (e.g., number of spudded wells) was downloaded and used. Under that methodology, both completion date and date of first production from HPDI were used to identify wells completed during 2019.

The spatial surrogates, numbered 670 through 699 and also 6831, 6832, and 6833, were processed at 12km resolution and gapfilled with the Surrogate Tool. The surrogates were first gapfilled using fallback surrogates. For each surrogate, the last two fallbacks were surrogate 693 (Well Count – All Wells) and 304 (NLCD Open + Low). Where appropriate, other surrogates were also part of the gapfilling procedure. For example, surrogate 670 (Spud Count – CBM Wells) was first gapfilled with 692 (Spud Count – All Wells), and then 693 and finally 304.

Table 3-26. Spatial Surrogates for Oil and Gas Sources

Surrogate Code	Surrogate Description
670	Spud Count - CBM Wells
671	Spud Count - Gas Wells
672	Gas Production at Oil Wells
673	Oil Production at CBM Wells
674	Unconventional Well Completion Counts
676	Well Count - All Producing
677	Well Count - All Exploratory
678	Completions at Gas Wells
679	Completions at CBM Wells
681	Spud Count - Oil Wells
683	Produced Water at All Wells
685	Completions at Oil Wells
686	Completions at All Wells
687	Feet Drilled at All Wells
689	Gas Produced – Total
691	Well Counts - CBM Wells
692	Spud Count - All Wells
693	Well Count - All Wells
694	Oil Production at Oil Wells
695	Well Count - Oil Wells
696	Gas Production at Gas Wells
697	Oil Production at Gas Wells
698	Well Count - Gas Wells
699	Gas Production at CBM Wells
6831	Produced water at CBM wells
6832	Produced water at gas wells
6833	Produced water at oil wells

Table 3-27 shows the CAP emissions (i.e., NH₃, NO_x, PM_{2.5}, SO₂, and VOC) by sector assigned to each spatial surrogate.

Table 3-27. Selected 2019 CAP emissions by sector for U.S. Surrogates (short tons in 12US1)

Sector	ID	Description	NH ₃	NO _x	PM _{2.5}	SO ₂	VOC
afdust	240	Total Road Miles	0	0	315,096	0	0
afdust	304	NLCD Open + Low	0	0	842,116	0	0
afdust	306	NLCD Med + High	0	0	52,278	0	0
afdust	308	NLCD Low + Med + High	0	0	117,047	0	0
afdust	310	NLCD Total Agriculture	0	0	791,881	0	0
livestock	310	NLCD Total Agriculture	2,602,279	0	0	0	227,985

Sector	ID	Description	NH ₃	NO _x	PM _{2.5}	SO ₂	VOC
nonpt	100	Population	34,304	0	0	0	208
nonpt	150	Residential Heating - Natural Gas	33,550	204,371	4,041	1,365	12,055
nonpt	170	Residential Heating - Distillate Oil	1,531	30,031	3,284	11,510	1,039
nonpt	180	Residential Heating - Coal	1	3	1	3	3
nonpt	190	Residential Heating - LP Gas	98	31,061	163	712	1,181
nonpt	239	Total Road AADT	0	22	541	0	297,798
nonpt	240	Total Road Miles	0	0	0	0	0
nonpt	244	All Unrestricted AADT	0	0	0	0	101,255
nonpt	271	NTAD Class 1 2 3 Railroad Density	0	0	0	0	2,203
nonpt	300	NLCD Low Intensity Development	4,823	19,093	94,548	2,882	72,599
nonpt	304	NLCD Open + Low	0	0	0	0	0
nonpt	306	NLCD Med + High	23,668	272,514	245,871	131,592	112,049
nonpt	307	NLCD All Development	85	25,798	110,610	8,169	69,262
nonpt	308	NLCD Low + Med + High	884	156,033	15,683	10,076	10,037
nonpt	310	NLCD Total Agriculture	0	0	38	0	0
nonpt	319	NLCD Crop Land	0	0	97	72	299
nonpt	320	NLCD Forest Land	3,953	68	273	0	279
nonpt	650	Refineries and Tank Farms	0	16	0	0	106,401
nonpt	711	Airport Areas	0	0	0	0	596
nonpt	801	Port Areas	0	0	0	0	6,730
nonroad	261	NTAD Total Railroad Density	3	1,807	184	1	356
nonroad	304	NLCD Open + Low	4	1,620	136	3	2,423
nonroad	305	NLCD Low + Med	96	14,661	3,879	77	105,749
nonroad	306	NLCD Med + High	335	160,244	9,947	265	89,188
nonroad	307	NLCD All Development	101	29,155	15,414	73	170,963
nonroad	308	NLCD Low + Med + High	565	262,271	21,894	231	45,811
nonroad	309	NLCD Open + Low + Med	122	21,080	1,240	99	46,015
nonroad	310	NLCD Total Agriculture	421	305,710	21,805	183	32,213
nonroad	320	NLCD Forest Land	15	3,281	522	8	3,675
nonroad	321	NLCD Recreational Land	83	13,038	5,523	57	203,840
nonroad	350	NLCD Water	192	113,237	4,467	160	268,186
nonroad	850	Golf Courses	13	2,087	119	10	5,738
nonroad	860	Mines	2	2,467	240	1	462
np_oilgas	670	Spud Count - CBM Wells	0	0	0	0	89
np_oilgas	671	Spud Count - Gas Wells	0	0	0	0	3,284
np_oilgas	674	Unconventional Well Completion Counts	27	20,730	496	26	870
np_oilgas	678	Completions at Gas Wells	0	7,874	193	2,968	20,964
np_oilgas	679	Completions at CBM Wells	0	9	0	400	1,159
np_oilgas	681	Spud Count - Oil Wells	0	0	0	0	38,758
np_oilgas	685	Completions at Oil Wells	0	377	0	1,361	42,017
np_oilgas	687	Feet Drilled at All Wells	0	75,545	1,995	107	3,318
np_oilgas	689	Gas Produced - Total	0	460	55	4	68,697

Sector	ID	Description	NH ₃	NO _x	PM _{2.5}	SO ₂	VOC
np_oilgas	691	Well Counts - CBM Wells	0	29,113	521	11	30,841
np_oilgas	694	Oil Production at Oil Wells	0	3,695	0	31,403	1,052,276
np_oilgas	695	Well Count - Oil Wells	0	129,122	3,032	1,465	676,769
np_oilgas	696	Gas Production at Gas Wells	0	211	0	1	50,268
np_oilgas	698	Well Count - Gas Wells	0	253,031	4,794	127	498,114
np_oilgas	699	Gas Production at CBM Wells	0	47	5	0	5,190
np_oilgas	6831	Produced water at CBM wells	0	0	0	0	3,695
np_oilgas	6832	Produced water at gas wells	0	0	0	0	38,515
np_oilgas	6833	Produced water at oil wells	0	0	0	0	46,549
np_solvents	100	Population	0	0	0	0	1,372,923
np_solvents	240	Total Road Miles	0	0	0	0	48,397
np_solvents	306	NLCD Med + High	33	27	300	1	409,967
np_solvents	307	NLCD All Development	24	6	19	5	527,883
np_solvents	308	NLCD Low + Med + High	0	0	129	0	7,970
np_solvents	310	NLCD Total Agriculture	0	0	0	0	149,185
onroad	205	Extended Idle Locations	342	34,291	780	18	4,084
onroad	242	All Restricted AADT	34,157	925,436	25,956	5,041	134,605
onroad	244	All Unrestricted AADT	63,200	1,496,382	55,842	10,503	374,603
onroad	259	Transit Bus Terminals	15	2,037	50	1	439
onroad	304	NLCD Open + Low	0	687	20	0	4,124
onroad	306	NLCD Med + High	921	95,906	3,529	76	20,258
onroad	307	NLCD All Development	3,576	204,352	7,433	960	594,388
onroad	308	NLCD Low + Med + High	204	19,149	569	56	29,121
onroad	508	Public Schools	16	2,189	81	1	544
rail	261	NTAD Total Railroad Density	14	35,834	1,061	31	1,822
rail	271	NTAD Class 1 2 3 Railroad Density	324	480,174	13,760	644	20,118
rwc	300	NLCD Low Intensity Development	16,369	33,925	297,877	7,937	322,528

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 Canadian emissions are based on the 2015 Canadian inventories and associated data. The spatial surrogate data came from ECCC, along with cross references. The shapefiles they provided were used in the Surrogate Tool (previously referenced) to create spatial surrogates. The Canadian surrogates used for this platform are listed in Table 3-15. The population

surrogate was updated for Mexico for the 2014v7.1 platform. Surrogate code 11, which uses 2015 population data at 1 km resolution, replaces the previous population surrogate code 10. The other surrogates for Mexico are circa 1999 and 2000 and were based on data obtained from the Sistema Municipal 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 3-29.

Table 3-28. Canadian Spatial Surrogates

Code	Canadian Surrogate Description	Code	Description
100	Population	921	Commercial Fuel Combustion
101	total dwelling	923	TOTAL INSTITUTIONAL AND GOVERNEMNT
104	capped total dwelling	924	Primary Industry
106	ALL INDUST	925	Manufacturing and Assembly
113	Forestry and logging	926	Distribution and Retail (no petroleum)
200	Urban Primary Road Miles	927	Commercial Services
210	Rural Primary Road Miles	932	CANRAIL
211	Oil and Gas Extraction	940	PAVED ROADS NEW
212	Mining except oil and gas	946	Construction and mining
220	Urban Secondary Road Miles	948	Forest
221	Total Mining	951	Wood Consumption Percentage
222	Utilities	955	UNPAVED ROADS AND TRAILS
230	Rural Secondary Road Miles	960	TOTBEEF
233	Total Land Development	970	TOTPOUL
240	capped population	980	TOTSWIN
308	Food manufacturing	990	TOTFERT
321	Wood product manufacturing	996	urban area
323	Printing and related support activities	1251	OFFR_TOTFERT
324	Petroleum and coal products manufacturing	1252	OFFR_MINES
326	Plastics and rubber products manufacturing	1253	OFFR Other Construction not Urban
327	Non-metallic mineral product manufacturing	1254	OFFR Commercial Services
331	Primary Metal Manufacturing	1255	OFFR Oil Sands Mines
350	Water	1256	OFFR Wood industries CANVEC
412	Petroleum product wholesaler-distributors	1257	OFFR UNPAVED ROADS RURAL
448	clothing and clothing accessories stores	1258	OFFR Utilities
482	Rail transportation	1259	OFFR total dwelling
562	Waste management and remediation services	1260	OFFR_water
901	AIRPORT	1261	OFFR_ALL INDUST
902	Military LTO	1262	OFFR Oil and Gas Extraction
903	Commercial LTO	1263	OFFR_ALLROADS

Code	Canadian Surrogate Description	Code	Description
904	General Aviation LTO	1265	OFFR CANRAIL
945	Commercial Marine Vessels	9450	Commercial Marine Vessel Ports

Table 3-29. 2019 CAPs Allocated to Mexican and Canadian Spatial Surrogates for 12US1 (short tons)

Code	Mexican or Canadian Surrogate Description	NH ₃	NO _x	PM _{2.5}	SO ₂	VOC
11	MEX 2015 Population	0	85,151	465	178	223,016
14	MEX Residential Heating - Wood	0	2,333	6,512	190	17,541
16	MEX Residential Heating - Distillate Oil	1	28	0	0	1
22	MEX Total Road Miles	2,983	359,738	12,086	6,647	71,102
24	MEX Total Railroads Miles	0	19,518	408	185	732
26	MEX Total Agriculture	115,677	18,186	16,239	473	3,847
32	MEX Commercial Land	0	75	1,631	0	27,763
34	MEX Industrial Land	92	2,036	1,257	6	34,866
36	MEX Commercial plus Industrial Land	5	7,049	305	15	101,386
40	MEX Residential (RES1-4)+Comercial+Industrial+Institutional+Government	0	15	61	2	21,041
42	MEX Personal Repair (COM3)	0	0	0	0	5,130
44	MEX Airports Area	0	3,420	48	241	1,294
48	MEX Brick Kilns	0	266	5,297	470	130
50	MEX Mobile sources - Border Crossing	3	58	2	0	45
100	CAN Population	776	51	604	14	219
101	CAN total dwelling	0	0	0	0	147,322
104	CAN capped total dwelling	347	30,961	2,282	2,473	1,614
106	CAN ALL INDUST			583		
113	CAN Forestry and logging	117	1,392	7,471	29	3,938
200	CAN Urban Primary Road Miles	1,572	66,863	2,365	232	7,134
210	CAN Rural Primary Road Miles	628	39,000	1,297	98	3,023
211	CAN Oil and Gas Extraction	1	39	424	41	1,657
212	CAN Mining except oil and gas	0	0	3,051	0	0
220	CAN Urban Secondary Road Miles	2,951	105,604	4,764	482	18,852
221	CAN Total Mining	0	0	13,221	0	0
222	CAN Utilities	55	3,344	2,859	453	63
230	CAN Rural Secondary Road Miles	1,652	71,811	2,515	257	8,255
240	CAN capped population	327	44,524	1,385	52	95,157
308	CAN Food manufacturing	0	0	18,982	0	17,387
321	CAN Wood product manufacturing	785	4,450	1,543	328	15,455

Code	Mexican or Canadian Surrogate Description	NH₃	NO_x	PM_{2.5}	SO₂	VOC
323	CAN Printing and related support activities	0	0	0	0	11,693
324	CAN Petroleum and coal products manufacturing	0	1,179	1,599	462	9,154
326	CAN Plastics and rubber products manufacturing	0	0	0	0	24,027
327	CAN Non-metallic mineral product manufacturing	0	0	6,449	0	0
331	CAN Primary Metal Manufacturing	0	156	5,561	29	72
412	CAN Petroleum product wholesaler-distributors	0	0	0	0	43,724
448	CAN clothing and clothing accessories stores	0	0	0	0	140
482	CAN Rail transportation	1	4,062	88	1	256
562	CAN Waste management and remediation services	240	1,924	2,620	2,483	9,199
901	CAN AIRPORT	0	93	9	0	9
921	CAN Commercial Fuel Combustion	187	24,020	2,379	1,414	1,224
923	CAN TOTAL INSTITUTIONAL AND GOVERNMENT	0	0	0	0	14,458
924	CAN Primary Industry	0	0	0	0	38,858
925	CAN Manufacturing and Assembly	0	0	0	0	69,488
926	CAN Distribution and Retail (no petroleum)	0	0	0	0	7,285
927	CAN Commercial Services	0	0	0	0	31,311
932	CAN CANRAIL	48	83,844	1,662	43	3,559
940	CAN PAVED ROADS NEW			27,751		
946	CAN Construction and mining	0	0	0	0	9,850
951	CAN Wood Consumption Percentage	957	10,634	107,554	1,519	152,072
955	CAN UNPAVED ROADS AND TRAILS			383,147		
990	CAN TOTFERT	48	4,047	265	6,827	152
996	CAN urban area	0	0	2,994	0	0
1251	CAN OFFR TOTFERT	73	50,505	3,421	48	4,585
1252	CAN OFFR MINES	1	563	38	1	82
1253	CAN OFFR Other Construction not Urban	68	28,864	3,601	41	10,186
1254	CAN OFFR Commercial Services	43	14,335	2,235	26	35,468
1255	OFFR Oil Sands Mines	0	0	0	0	0
1256	CAN OFFR Wood industries CANVEC	7	2,103	214	4	853
1257	CAN OFFR UNPAVED ROADS RURAL	24	10,272	574	14	24,333
1258	CAN OFFR Utilities	8	3,727	176	5	824
1259	CAN OFFR total dwelling	17	5,844	588	10	12,557

Code	Mexican or Canadian Surrogate Description	NH₃	NO_x	PM_{2.5}	SO₂	VOC
1260	CAN OFFR water	19	5,604	264	22	20,367
1261	CAN OFFR ALL INDUST	4	5,065	145	2	1,068
1262	CAN OFFR Oil and Gas Extraction	1	570	42	0	168
1263	CAN OFFR ALLROADS	3	1,361	129	2	438
1265	CAN OFFR CANRAIL	0	489	15	0	37

4 Emission Summaries

Tables 4-1 through 4-3 summarize emissions by sector for the 2019 platform. 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 larger 12km domain (12US1) discussed in Section 3.1. Note that totals for the 12US2 domain are not available here, but the sum of the U.S. sectors would be essentially the same and only the Canadian and Mexican emissions would change according to the extent of the grids to the north and south of the continental United States. The afdust sector emissions here represent the emissions *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. Emissions from the cmv sectors include separate totals for the U.S., which includes emissions within state waters only; these extend to roughly 3-5 miles offshore and includes CMV emissions at U.S. ports. CMV emissions from outside U.S. state waters, including those within Canadian waters, Mexican waters, and offshore areas, are summarized in the non-U.S. section of the table. The total of all US sectors is listed as “Con U.S. Total.”

State totals and other summaries are available in the reports area on the FTP site for the 2019 platform (<https://gaftp.epa.gov/Air/emismod/2019/>).

Table 4-1. National by-sector CAP emissions for the 2019 platform, 12US1 grid (tons/yr)

Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
afdust_adj				5,391,767	753,763		
airports	494,906	0	135,054	9,899	8,661	16,907	55,888
cmv_c1c2	17,699	60	117,678	3,191	3,092	596	4,264
cmv_c3	9,509	30	95,659	1,683	1,549	3,864	4,418
fertilizer		1,202,914					
livestock		2,602,279					227,985
nonpt	1,927,267	102,898	739,250	572,589	475,154	166,399	818,185
nonroad	10,464,693	1,953	930,665	90,623	85,372	1,168	974,635
np_oilgas	629,304	27	520,213	11,180	11,091	37,872	2,581,373
np_solvents	36	58	34	469	448	5	2,516,324
onroad	16,637,063	102,432	2,780,428	215,217	94,256	16,657	1,162,167
ptegu	479,731	20,734	999,436	116,793	98,046	1,017,892	29,201
ptagfire	687,701	146,655	27,373	104,474	66,053	10,683	99,156
ptfire-rx	9,176,460	150,531	163,988	986,337	842,244	80,673	2,200,144
ptfire-wild	2,121,948	34,930	34,299	220,638	186,981	17,581	502,126
ptnonipm	1,359,439	68,482	855,115	380,052	241,176	500,592	760,023
pt_oilgas	174,426	3,759	354,632	13,514	13,190	36,934	143,335
rail	108,825	339	516,008	15,304	14,821	675	21,940
rwc	2,152,689	16,369	33,925	298,738	297,877	7,937	322,528
Con. U.S. Total	46,441,694	4,454,448	8,303,756	8,432,468	3,193,775	1,916,436	12,423,693
beis	3,695,221		942,563				25,450,181
CONUS + beis	50,136,915	4,454,448	9,246,319	8,432,468	3,193,775	1,916,436	37,873,874
Can./Mex./Offshore							
Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
Canada ag		492,799					105,147
Canada oil and gas 2D	666	7	3,232	185	185	3,933	509,228
Canada othafdust				500,478	77,863		
Canada othptdust				124,644	43,736		
Canada othar	2,180,838	3,818	298,213	222,283	173,889	16,299	721,690
Canada onroad_can	1,587,108	7,125	327,671	24,783	12,312	1,121	132,251
Canada othpt	1,115,145	19,471	650,682	90,031	43,039	989,862	148,178
Canada ptfire_othna	1,503,071	30,374	63,142	210,958	178,315	12,143	439,097
Canada cmv	11,009	31	101,469	1,749	1,633	2,997	4,623
Mexico othar	109,035	115,777	50,564	101,331	32,933	1,576	348,466
Mexico onroad_mex	1,812,455	2,983	447,355	16,112	11,380	6,832	159,395
Mexico othpt	154,181	1,154	172,530	47,798	33,325	345,440	37,488
Mexico ptfire_othna	367,565	7,109	14,666	48,343	41,333	3,026	106,475
Mexico cmv	8,243	185	90,456	10,460	9,625	84,307	3,827
Offshore cmv	49,677	551	499,240	31,100	28,647	225,408	22,602
Offshore pt_oilgas	51,866	8	49,959	636	635	462	38,803
Can/Mex/offshore total	8,950,860	681,393	2,769,180	1,430,892	688,848	1,693,406	2,777,271

Table 4-2. National by-sector VOC HAP emissions for the 2019 platform, 12US1 grid (tons/yr)

Sector	Acetaldehyde	Benzene	Formaldehyde	Methanol	Naphthalene	Acrolein	1,3-Butadiene
airports	2,138	956	6,186	893	603	1,213	861
cmv_c1c2	42	20	182	0	12	8	4
cmv_c3	43	21	189	0	12	8	4
livestock	1,546	458		16,102	0		
nonpt	5,105	9,269	5,921	5,262	490	223	779
nonroad	9,153	26,147	22,895	1,254	1,607	1,591	4,179
np_oilgas	1,215	35,055	13,239	582	36	655	122
np_solvents	56	307	6	40,441	4,053		0
onroad	11,111	22,791	13,937	1,887	1,856	1,095	3,070
ptegu	293	390	2,712	102	22	235	4
ptagfire	7,394	1,612	6,271	930	29	584	679
ptfire-rx	70,282	22,255	135,979	104,320	17,922	28,313	16,906
ptfire-wild	17,345	5,248	31,188	30,989	5,035	5,300	2,639
ptnonipm	5,798	2,929	6,803	52,092	1,039	957	608
pt_oilgas	2,849	1,180	14,044	2,056	28	2,093	282
rail	1,593	458	4,536	0	57	325	38
rwc	11,227	15,902	18,584	0	2,695	892	2,119
Con. U.S. Total	147,190	144,997	282,672	256,909	35,497	43,492	32,295
beis	386,933		527,645	2,055,435			
CONUS + beis	534,123	144,997	810,317	2,312,343	35,497	43,492	32,295
Canada ag	1,126	149	0	25,776	0	0	0
Canada oil and gas 2D	0	42,586	0	0	0	0	0
Canada othafdust	0	0	0	0	0	0	0
Canada othar	21,509	14,034	17,104	4,586	3,651	0	0
Canada onroad can	2,157	5,892	2,866	0	46	0	0
Canada othpt	1,486	1,667	5,221	15,927	12	0	0
Canada ptfire othna	13,088	9,952	44,692	38,508	0		
Canada cmv	45	22	197	0	13	9	5
Mexico othar	2,905	5,861	2,250	2,720	404	0	0
Mexico onroad mex	674	3,885	1,616	665	232	114	576
Mexico othpt	77	846	3,070	474	12	0	0
Mexico ptfire othna	4,664	2,048	9,202	6,504	0		
Mexico cmv	37	18	163	0	10	7	4
Offshore cmv	221	107	965	0	62	42	23
Offshore pt_oilgas	0	0	0	0	0	0	0

Non-U.S. total	47,991	87,068	87,346	95,160	4,442	172	608
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Table 4-3. National by-sector Diesel PM and metal emissions for the 2019 platform, 12US1 grid (tons/yr)

Sector	Diesel PM ₁₀	Diesel PM _{2.5}	Chromium Hex	Arsenic	Cadmium	Nickel	Manganese	Ethylene Oxide
airports	80	78	--	--	--	--	--	--
cmv_c1c2	3,191	3,092	0.00002	0.08	0.73	2.12	0.010	--
cmv_c3	1,683	1,549	0.00001	0.04	0.37	1.06	0.005	--
nonpt	--	--	0.3571	5.95	3.77	26.27	15.54	0.95
nonroad	50,589	48,894	0.004	0.89	--	1.13	0.68	--
np_oilgas	--	--	0.00002	0.03	0.10	0.09	0.05	--
onroad	58,015	53,446	0.04	8.09	--	5.94	33.70	--
ptegu	--	--	4.02	14.60	7.81	71.49	119.12	0.0006
ptnonipm	1,105	991	36.30	33.81	12.33	204.86	718.87	115.15
pt_oilgas	--	--	0.02	0.02	0.30	6.14	2.54	--
rail	15,304	14,821	0.07	14.56	0.03	54.71	31.29	--
rwc	--	--	--	--	0.08	0.07	0.62	--
Con. U.S. Total	129,969	122,870	41	78	26	374	922	116
Canada CMV	1,749	1,633	0.000012	0.04	0.39	1.12	0.01	--
Mexico CMV	10,460	9,625	0.00007	0.25	2.27	6.61	0.03	--
Offshore CMV	12,209	11,258	0.00008	0.29	2.66	7.73	0.04	--

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Appendix A: CB6 Assignment for Species

September 27, 2016

MEMORANDUM

To: Alison Eyth and Madeleine Strum, OAQPS, EPA
From: Ross Beardsley and Greg Yarwood, Ramboll Environ
Subject: Species Mappings for CB6 and CB05 for use with SPECIATE 4.5

Summary

Ramboll Environ (RE) reviewed version 4.5 of the SPECIATE database, and created CB05 and CB6 mechanism species mappings for newly added compounds. In addition, the mapping guidelines for Carbon Bond (CB) mechanisms were expanded to promote consistency in current and future work.

Background

The Environmental Protection Agency's SPECIATE repository contains gas and particulate matter speciation profiles of air pollution sources, which are used in the generation of emissions data for air quality models (AQM) such as CMAQ (<http://www.cmascenter.org/cmaq/>) and CAMx (<http://www.camx.com>). However, the condensed chemical mechanisms used within these photochemical models utilize fewer species than SPECIATE to represent gas phase chemistry, and thus the SPECIATE compounds must be assigned to the AQM model species of the condensed mechanisms. A chemical mapping is used to show the representation of organic chemical species by the model compounds of the condensed mechanisms.

This memorandum describes how chemical mappings were developed from SPECIATE 4.5 compounds to model species of the CB mechanism, specifically CB05 (http://www.camx.com/publ/pdfs/CB05_Final_Report_120805.pdf) and CB6 (http://aqrp.ceer.utexas.edu/projectinfoFY12_13/12-012/12-012%20Final%20Report.pdf).

Methods

CB Model Species

Organic gases are mapped to the CB mechanism either as explicitly represented individual compounds (e.g. ALD2 for acetaldehyde), or as a combination of model species that represent common structural groups (e.g. ALDX for other aldehydes, PAR for alkyl groups). Table 1 lists all of the explicit and structural model species in CB05 and CB6 mechanisms, each of which represents a defined number of carbon atoms allowing for carbon to be conserved in all cases. CB6 contains four more explicit model species than CB05 and an additional structural group to represent ketones. The CB05 representation of the five additional CB6 species is provided in the 'Included in CB05' column of Table 1.

In addition to the explicit and structural species, there are two model species that are used to represent organic gases that are not treated by the CB mechanism:

NVOL – Very low volatility SPECIATE compounds that reside predominantly in the particle phase and should be excluded from the gas phase mechanism. These compounds are mapped by setting NVOL equal to the molecular weight (e.g. decabromodiphenyl oxide is mapped as 959.2 NVOL), which allows for the total mass of all NVOL to be determined.

UNK – Compounds that are unable to be mapped to CB using the available model species. This approach should be avoided unless absolutely necessary, and will lead to a warning message in the speciation tool.

Table 1. Model species in the CB05 and CB6 chemical mechanisms.

Model Species Name	Description	Number of Carbons	Included in CB05 (structural mapping)	Included in CB6
Explicit model species				
ACET	Acetone (propanone)	3	No (3 PAR)	Yes
ALD2	Acetaldehyde (ethanal)	2	Yes	Yes
BENZ	Benzene	6	No (1 PAR, 5 UNR)	Yes
CH4	Methane	1	Yes	Yes
ETH	Ethene (ethylene)	2	Yes	Yes
ETHA	Ethane	2	Yes	Yes
ETHY	Ethyne (acetylene)	2	No (1 PAR, 1 UNR)	Yes
ETOH	Ethanol	2	Yes	Yes
FORM	Formaldehyde (methanal)	1	Yes	Yes
ISOP	Isoprene (2-methyl-1,3-butadiene)	5	Yes	Yes
MEOH	Methanol	1	Yes	Yes
PRPA	Propane	3	No (1.5 PAR, 1.5 UNR)	Yes
Common Structural groups				
ALDX	Higher aldehyde group (-C-CHO)	2	Yes	Yes
IOLE	Internal olefin group ($R_1R_2>C=C<R_3R_4$)	4	Yes	Yes
KET	Ketone group ($R_1R_2>C=O$)	1	No (1 PAR)	Yes
OLE	Terminal olefin group ($R_1R_2>C=C$)	2	Yes	Yes
PAR	Paraffinic group ($R_1-C<R_2R_3$)	1	Yes	Yes
TERP	Monoterpenes	10	Yes	Yes
TOL	Toluene and other monoalkyl aromatics	7	Yes	Yes
UNR	Unreactive carbon groups (e.g., halogenated carbons)	1	Yes	Yes
XYL	Xylene and other polyskyl aromatics	8	Yes	Yes
Not mapped to CB model species				
NVOL	Very low volatility compounds	*	Yes	Yes
UNK	Unknown	*	Yes	Yes

*Each NVOL represents 1 g mol⁻¹ and low volatility compounds are assigned to NVOL based on molecular weight. UNK is unmapped and thus does not represent any carbon.

Mapping guidelines for non-explicit organic gases using CB model species

SPECIATE compounds that are not treated explicitly are mapped to CB model species that represent common structural groups. Table 2 lists the carbon number and general mapping guidelines for each of the structure model species.

Table 2. General Guidelines for mapping using CB6 structural model species.

CB6 Species Name	Number of Carbons	Represents
ALDX	2	Aldehyde group. ALDX represents 2 carbons and additional carbons are represented as alkyl groups (mostly PAR), e.g. propionaldehyde is ALDX + PAR.
IOLE	4	Internal olefin group. IOLE represents 4 carbons and additional carbons are represented as alkyl groups (mostly PAR), e.g. 2-pentene isomers are IOLE + PAR. Exceptions: <ul style="list-style-type: none"> IOLE with 2 carbon branches on both sides of the double bond are downgraded to OLE
KET	1	Ketone group. KET represents 1 carbon and additional carbons are represented as alkyl groups (mostly PAR), e.g. butanone is 3 PAR + KET.
OLE	2	Terminal olefin group. OLE represents 2 carbons and additional carbons are represented as alkyl groups (mostly PAR), e.g. propene is OLE + PAR. Alkyne group, e.g. butyne isomers are OLE + 2 PAR.
PAR	1	Alkanes and alkyl groups. PAR represents 1 carbon, e.g. butane is 4 PAR. See UNR for exceptions.
TERP	10	All monoterpenes are represented as 1 TERP.
TOL	7	Toluene and other monoalkyl aromatics. TOL represents 7 carbons and any additional carbons are represented as alkyl groups (mostly PAR), e.g. ethylbenzene is TOL + PAR. Cresols are represented as TOL and PAR. Styrenes are represented using TOL, OLE and PAR.
UNR	1	Unreactive carbons are 1 UNR such as quaternary alkyl groups (e.g., neo-pentane is 4 PAR + UNR), carboxylic acid groups (e.g., acetic acid is PAR + UNR), ester groups (e.g., methyl acetate is 2 PAR + UNR), halogenated carbons (e.g., trichloroethane isomers are 2 UNR), carbons of nitrile groups (-CEN).
XYL	8	Xylene isomers and other polyalkyl aromatics. XYL represents 8 carbons and any additional carbons are represented as alkyl groups (mostly PAR), e.g. trimethylbenzene isomers are XYL + PAR.

Some compounds that are multifunctional and/or include hetero-atoms lack obvious CB mappings. We developed guidelines for some of these compound classes to promote consistent representation in this work and future revisions. Approaches for several compound classes are explained in Table 3. We developed guidelines as needed to address newly added species in SPECIATE 4.5 but did not systematically review existing mappings for "difficult to assign" compounds that could benefit from developing a guideline.

Table 3. Mapping guidelines for some difficult to map compound classes and structural groups

Compound Class/Structural group	CB model species representation
Chlorobenzenes and other halogenated benzenes	<p>Guideline:</p> <ul style="list-style-type: none"> • 3 or less halogens – 1 PAR, 3 UNR • 4 or more halogens – 6 UNR <p>Examples:</p> <ul style="list-style-type: none"> • 1,3,5-Chlorobenzene – 1 PAR, 3 UNR • Tetrachlorobenzenes – 6 UNR
Cycloalkenes	<p>Guideline:</p> <ul style="list-style-type: none"> • 1 IOLE with additional carbons represented as alkyl groups (generally PAR) <p>Examples:</p> <ul style="list-style-type: none"> • Methylcyclopentadiene – 1 IOLE, 2 PAR • Methylcyclohexadiene – 1 IOLE, 3 PAR
Furans/Pyrrroles	<p>Guideline:</p> <ul style="list-style-type: none"> • 2 OLE with additional carbons represented as alkyl groups (generally PAR) <p>Examples:</p> <ul style="list-style-type: none"> • 2-Butylfuran – 2 OLE, 4 PAR • 2-Pentylfuran – 2 OLE, 5 PAR • Pyrrole – 2 OLE • 1-Methylpyrrole – 2 OLE, 1 PAR
Heterocyclic aromatic compounds containing 2 non-carbon atoms	<p>Guideline:</p> <ul style="list-style-type: none"> • 1 OLE with remaining carbons represented as alkyl groups (generally PAR) <p>Examples:</p> <ul style="list-style-type: none"> • Ethylpyrazine – 1 OLE, 4 PAR • 1-methylpyrazole – 1 OLE, 2 PAR • 4,5-Dimethyloxazole – 1 OLE, 3 PAR
Triple bond(s)	<p>Guideline:</p> <ul style="list-style-type: none"> • Triple bonds are treated as PAR unless they are the only reactive functional group. If a compound contains more than one triple bond and no other reactive functional groups, then one of the triple bonds is treated as OLE with additional carbons treated as alkyl groups. <p>Examples:</p> <ul style="list-style-type: none"> • 1-Penten-3-yne – 1 OLE, 3 PAR • 1,5-Hexadien-3-yne – 2 OLE, 2 PAR • 1,6-Heptadiyne – 1 OLE, 5 PAR

These guidelines were used to map the new species from SPECATE4.5, and also to revise some previously mapped compounds. Overall, a total of 175 new species from SPECATEv4.5 were mapped and 7 previously mapped species were revised based on the new guidelines.

Recommendation

1. Complete a systematic review of the mapping of all species to ensure conformity with current mapping guidelines. The assignments of existing compounds that are similar to new species were reviewed and revised to promote consistency in mapping approaches, but the majority of existing species mappings were not reviewed as it was outside the scope of this work.
2. Develop a methodology for classifying and tracking larger organic compounds based on their volatility (semi, intermediate, or low volatility) to improve support for secondary organic aerosol (SOA) modeling using the volatility basis set (VBS) SOA model, which is available in both CMAQ and CAMx. A preliminary investigation of the possibility of doing so has been performed, and is discussed in a separate memorandum.

Appendix B: Profiles (other than onroad) that are new or revised in SPECIATE versions 4.5 and later that were used in the 2016 and later platforms

Table B-1 Profiles first used in 2016beta, 2016v1, and 2016v2 platforms

Sector	Pollutant	Profile code	Profile description	SPECIATE version
np_oilgas, pt_oilgas	VOC	CMU01	Oil and Gas - Produced Gas Composition from Gas Wells - Central Montana Uplift – Montana	5.1
np_oilgas, pt_oilgas	VOC	WIL01	Oil and Gas - Flash Gas Composition from Tanks at Oil Wells - Williston Basin North Dakota	5.1
np_oilgas, pt_oilgas	VOC	WIL02	Oil and Gas - Flash Gas Composition from Tanks at Oil Wells - Williston Basin Montana	5.1
np_oilgas, pt_oilgas	VOC	WIL03	Oil and Gas - Produced Gas Composition from Oil Wells - Williston Basin North Dakota	5.1
np_oilgas, pt_oilgas	VOC	WIL04	Oil and Gas - Produced Gas Composition from Oil Wells - Williston Basin Montana	5.1
cmv_c1c2, cmv_c3	VOC	95331NEIHP	Marine Vessel - 95331 blend with CMV HAP	5.1

Table B-2 Profiles first used in 2016 alpha platform

Sector	Pollutant	Profile code	Profile description	SPECIATE version	Comment
nonpt	VOC	G95223TOG	Poultry Production - Average of Production Cycle with gapfilled methane and ethane	5.0	Replacement for v4.5 profile 95223; Used 70% methane, 20% ethane, and the 10% remaining VOC is from profile 95223
Nonpt, ptnonipm	VOC	G95240TOG	Beef Cattle Farm and Animal Waste with gapfilled methane and ethane	5.0	Replacement for v4.5 profile 95240. Used 70% methane, 20% ethane; the 10% remaining VOC is from profile 95240.
nonpt	VOC	G95241TOG	Swine Farm and Animal Waste	5.0	Replacement for v4.5 profile 95241. Used 70% methane, 20% ethane; the 10% remaining VOC is from profile 95241
nonpt, ptnonipm, pt_oilgas, ptegu	PM2.5	95475	Composite -Refinery Fuel Gas and Natural Gas Combustion	5.0	Composite of AE6-ready versions of SPECIATE4.5 profiles 95125, 95126, and 95127
nonroad	VOC	95328	Spark-Ignition Exhaust Emissions from 2-stroke off-road engines - E10 ethanol gasoline	4.5	
nonroad	VOC	95330	Spark-Ignition Exhaust Emissions from 4-stroke off-road engines - E10 ethanol gasoline	4.5	

Sector	Pollutant	Profile code	Profile description	SPECIATE version	Comment
nonroad	VOC	95331	Diesel Exhaust Emissions from Pre-Tier 1 Off-road Engines	4.5	
nonroad	VOC	95332	Diesel Exhaust Emissions from Tier 1 Off-road Engines	4.5	
nonroad	VOC	95333	Diesel Exhaust Emissions from Tier 2 Off-road Engines	4.5	
np_oilgas	VOC	95087a	Oil and Gas - Composite - Oil Field - Oil Tank Battery Vent Gas	4.5	
np_oilgas	VOC	95109a	Oil and Gas - Composite - Oil Field - Condensate Tank Battery Vent Gas	4.5	
np_oilgas	VOC	95398	Composite Profile - Oil and Natural Gas Production - Condensate Tanks	4.5	
np_oilgas	VOC	95403	Composite Profile - Gas Wells	4.5	
np_oilgas	VOC	95417	Oil and Gas Production - Composite Profile - Untreated Natural Gas, Uinta Basin	4.5	
np_oilgas	VOC	95418	Oil and Gas Production - Composite Profile - Condensate Tank Vent Gas, Uinta Basin	4.5	
np_oilgas	VOC	95419	Oil and Gas Production - Composite Profile - Oil Tank Vent Gas, Uinta Basin	4.5	
np_oilgas	VOC	95420	Oil and Gas Production - Composite Profile - Glycol Dehydrator, Uinta Basin	4.5	
np_oilgas	VOC	DJVNT_R	Oil and Gas -Denver-Julesburg Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
np_oilgas	VOC	FLR99	Natural Gas Flare Profile with DRE >98%	4.5	
np_oilgas	VOC	PNC01_R	Oil and Gas -Piceance Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
np_oilgas	VOC	PNC02_R	Oil and Gas -Piceance Basin Produced Gas Composition from Oil Wells	4.5	
np_oilgas	VOC	PNC03_R	Oil and Gas -Piceance Basin Flash Gas Composition for Condensate Tank	4.5	
np_oilgas	VOC	PNC04_R	Oil and Gas Production - Composite Profile - Glycol Dehydrator, Piceance Basin	4.5	
np_oilgas	VOC	PRBCB_R	Oil and Gas -Powder River Basin Produced Gas Composition from CBM Wells	4.5	
np_oilgas	VOC	PRBCO_R	Oil and Gas -Powder River Basin Produced Gas Composition from Non-CBM Wells	4.5	
np_oilgas	VOC	PRM01_R	Oil and Gas -Permian Basin Produced Gas Composition for Non-CBM Wells	4.5	
np_oilgas	VOC	SSJCB_R	Oil and Gas -South San Juan Basin Produced Gas Composition from CBM Wells	4.5	
np_oilgas	VOC	SSJCO_R	Oil and Gas -South San Juan Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
np_oilgas	VOC	SWFLA_R	Oil and Gas -SW Wyoming Basin Flash Gas Composition for Condensate Tanks	4.5	
np_oilgas	VOC	SWVNT_R	Oil and Gas -SW Wyoming Basin Produced Gas Composition from Non-CBM Wells	4.5	
np_oilgas	VOC	UNT01_R	Oil and Gas -Uinta Basin Produced Gas Composition from CBM Wells	4.5	

Sector	Pollutant	Profile code	Profile description	SPECIATE version	Comment
np_oilgas	VOC	WRBCO_R	Oil and Gas -Wind River Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
pt_oilgas	VOC	95325	Chemical Manufacturing Industry Wide Composite	4.5	
pt_oilgas	VOC	95326	Pulp and Paper Industry Wide Composite	4.5	
pt_oilgas, ptnonipm	VOC	95399	Composite Profile - Oil Field - Wells	4.5	
pt_oilgas	VOC	95403	Composite Profile - Gas Wells	4.5	
pt_oilgas	VOC	95417	Oil and Gas Production - Composite Profile - Untreated Natural Gas, Uinta Basin	4.5	
pt_oilgas	VOC	DJVNT_R	Oil and Gas -Denver-Julesburg Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
pt_oilgas, ptnonipm	VOC	FLR99	Natural Gas Flare Profile with DRE >98%	4.5	
pt_oilgas	VOC	PNC01_R	Oil and Gas -Piceance Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
pt_oilgas	VOC	PNC02_R	Oil and Gas -Piceance Basin Produced Gas Composition from Oil Wells	4.5	
pt_oilgas	VOC	PNCDH	Oil and Gas Production - Composite Profile - Glycol Dehydrator, Piceance Basin	4.5	
pt_oilgas, ptnonipm	VOC	PRBCO_R	Oil and Gas -Powder River Basin Produced Gas Composition from Non-CBM Wells	4.5	
pt_oilgas, ptnonipm	VOC	PRM01_R	Oil and Gas -Permian Basin Produced Gas Composition for Non-CBM Wells	4.5	
pt_oilgas, ptnonipm	VOC	SSJCO_R	Oil and Gas -South San Juan Basin Produced Gas Composition from Non-CBM Gas Wells	4.5	
pt_oilgas, ptnonipm	VOC	SWVNT_R	Oil and Gas -SW Wyoming Basin Produced Gas Composition from Non-CBM Wells	4.5	
ptfire	VOC	95421	Composite Profile - Prescribed fire southeast conifer forest	4.5	
ptfire	VOC	95422	Composite Profile - Prescribed fire southwest conifer forest	4.5	
ptfire	VOC	95423	Composite Profile - Prescribed fire northwest conifer forest	4.5	
ptfire	VOC	95424	Composite Profile - Wildfire northwest conifer forest	4.5	
ptfire	VOC	95425	Composite Profile - Wildfire boreal forest	4.5	
ptnonipm	VOC	95325	Chemical Manufacturing Industry Wide Composite	4.5	
ptnonipm	VOC	95326	Pulp and Paper Industry Wide Composite	4.5	
onroad	PM2.5	95462	Composite - Brake Wear	4.5	Used in SMOKE-MOVES
onroad	PM2.5	95460	Composite - Tire Dust	4.5	Used in SMOKE-MOVES

Appendix C: Mapping of Fuel Distribution SCCs to BTP, BPS and RBT

The table below provides a crosswalk between fuel distribution SCCs and classification type for portable fuel containers (PFC), fuel distribution operations associated with the bulk-plant-to-pump (BTP), refinery to bulk terminal (RBT) and bulk plant storage (BPS).

SCC	Type	Description
40301001	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 13: Breathing Loss (67000 Bbl. Tank Size)
40301002	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 10: Breathing Loss (67000 Bbl. Tank Size)
40301003	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 7: Breathing Loss (67000 Bbl. Tank Size)
40301004	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 13: Breathing Loss (250000 Bbl. Tank Size)
40301006	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 7: Breathing Loss (250000 Bbl. Tank Size)
40301007	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Fixed Roof Tanks (Varying Sizes); Gasoline RVP 13: Working Loss (Tank Diameter Independent)
40301101	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Floating Roof Tanks (Varying Sizes); Gasoline RVP 13: Standing Loss (67000 Bbl. Tank Size)
40301102	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Floating Roof Tanks (Varying Sizes); Gasoline RVP 10: Standing Loss (67000 Bbl. Tank Size)
40301103	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Floating Roof Tanks (Varying Sizes); Gasoline RVP 7: Standing Loss (67000 Bbl. Tank Size)
40301105	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Floating Roof Tanks (Varying Sizes); Gasoline RVP 10: Standing Loss (250000 Bbl. Tank Size)
40301151	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Floating Roof Tanks (Varying Sizes); Gasoline: Standing Loss - Internal
40301202	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Variable Vapor Space; Gasoline RVP 10: Filling Loss
40301203	RBT	Petroleum and Solvent Evaporation; Petroleum Product Storage at Refineries; Variable Vapor Space; Gasoline RVP 7: Filling Loss
40400101	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Breathing Loss (67000 Bbl Capacity) - Fixed Roof Tank
40400102	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Breathing Loss (67000 Bbl Capacity) - Fixed Roof Tank
40400103	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Breathing Loss (67000 Bbl. Capacity) - Fixed Roof Tank
40400104	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Breathing Loss (250000 Bbl Capacity)-Fixed Roof Tank
40400105	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Breathing Loss (250000 Bbl Capacity)-Fixed Roof Tank
40400106	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Breathing Loss (250000 Bbl Capacity) - Fixed Roof Tank
40400107	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Working Loss (Diam. Independent) - Fixed Roof Tank
40400108	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Working Loss (Diameter Independent) - Fixed Roof Tank
40400109	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Working Loss (Diameter Independent) - Fixed Roof Tank
40400110	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss (67000 Bbl Capacity)-Floating Roof Tank

SCC	Type	Description
40400111	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss (67000 Bbl Capacity)-Floating Roof Tank
40400112	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss (67000 Bbl Capacity)- Floating Roof Tank
40400113	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss (250000 Bbl Cap.) - Floating Roof Tank
40400114	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss (250000 Bbl Cap.) - Floating Roof Tank
40400115	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss (250000 Bbl Cap.) - Floating Roof Tank
40400116	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13/10/7: Withdrawal Loss (67000 Bbl Cap.) - Float Rf Tnk
40400117	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13/10/7: Withdrawal Loss (250000 Bbl Cap.) - Float Rf Tnk
40400118	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space
40400119	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space
40400120	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space
40400130	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: Standing Loss - External Floating Roof w/ Primary Seal
40400131	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss - Ext. Floating Roof w/ Primary Seal
40400132	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss - Ext. Floating Roof w/ Primary Seal
40400133	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss - External Floating Roof w/ Primary Seal
40400140	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: Standing Loss - Ext. Float Roof Tank w/ Secondary Seal
40400141	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss - Ext. Floating Roof w/ Secondary Seal
40400142	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss - Ext. Floating Roof w/ Secondary Seal
40400143	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss - Ext. Floating Roof w/ Secondary Seal
40400148	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13/10/7: Withdrawal Loss - Ext. Float Roof (Pri/Sec Seal)
40400149	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: External Floating Roof (Primary/Secondary Seal)
40400150	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Miscellaneous Losses/Leaks: Loading Racks
40400151	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Valves, Flanges, and Pumps
40400152	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Vapor Collection Losses
40400153	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Vapor Control Unit Losses
40400160	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: Standing Loss - Internal Floating Roof w/ Primary Seal
40400161	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss - Int. Floating Roof w/ Primary Seal
40400162	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss - Int. Floating Roof w/ Primary Seal

SCC	Type	Description
40400163	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss - Internal Floating Roof w/ Primary Seal
40400170	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400171	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400172	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 10: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400173	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 7: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400178	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Gasoline RVP 13/10/7: Withdrawal Loss - Int. Float Roof (Pri/Sec Seal)
40400179	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals; Specify Liquid: Internal Floating Roof (Primary/Secondary Seal)
40400199	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Terminals;
40400201	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Breathing Loss (67000 Bbl Capacity) - Fixed Roof Tank
40400202	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Breathing Loss (67000 Bbl Capacity) - Fixed Roof Tank
40400203	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Breathing Loss (67000 Bbl. Capacity) - Fixed Roof Tank
40400204	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Working Loss (67000 Bbl. Capacity) - Fixed Roof Tank
40400205	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Working Loss (67000 Bbl. Capacity) - Fixed Roof Tank
40400206	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Working Loss (67000 Bbl. Capacity) - Fixed Roof Tank
40400207	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Standing Loss (67000 Bbl Cap.) - Floating Roof Tank
40400208	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Standing Loss (67000 Bbl Cap.) - Floating Roof Tank
40400210	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13/10/7: Withdrawal Loss (67000 Bbl Cap.) - Float Rf Tnk
40400211	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space
40400212	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space
40400213	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Filling Loss (10500 Bbl Cap.) - Variable Vapor Space

SCC	Type	Description
40400230	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: Standing Loss - External Floating Roof w/ Primary Seal
40400231	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Standing Loss - Ext. Floating Roof w/ Primary Seal
40400232	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Standing Loss - Ext. Floating Roof w/ Primary Seal
40400233	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Standing Loss - External Floating Roof w/ Primary Seal
40400240	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: Standing Loss - Ext. Floating Roof w/ Secondary Seal
40400241	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Standing Loss - Ext. Floating Roof w/ Secondary Seal
40400248	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10/13/7: Withdrawal Loss - Ext. Float Roof (Pri/Sec Seal)
40400249	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: External Floating Roof (Primary/Secondary Seal)
40400250	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Loading Racks
40400251	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Valves, Flanges, and Pumps
40400252	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Miscellaneous Losses/Leaks: Vapor Collection Losses
40400253	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Miscellaneous Losses/Leaks: Vapor Control Unit Losses
40400260	RBT	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: Standing Loss - Internal Floating Roof w/ Primary Seal
40400261	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Standing Loss - Int. Floating Roof w/ Primary Seal
40400262	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Standing Loss - Int. Floating Roof w/ Primary Seal
40400263	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Standing Loss - Internal Floating Roof w/ Primary Seal
40400270	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400271	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 13: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400272	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10: Standing Loss - Int. Floating Roof w/ Secondary Seal

SCC	Type	Description
40400273	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 7: Standing Loss - Int. Floating Roof w/ Secondary Seal
40400278	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Gasoline RVP 10/13/7: Withdrawal Loss - Int. Float Roof (Pri/Sec Seal)
40400279	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Bulk Plants; Specify Liquid: Internal Floating Roof (Primary/Secondary Seal)
40400401	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 13: Breathing Loss
40400402	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 13: Working Loss
40400403	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 10: Breathing Loss
40400404	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 10: Working Loss
40400405	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 7: Breathing Loss
40400406	BTP /BPS	Petroleum and Solvent Evaporation; Petroleum Liquids Storage (non-Refinery); Petroleum Products - Underground Tanks; Gasoline RVP 7: Working Loss
40600101	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Splash Loading
40600126	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Submerged Loading
40600131	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Submerged Loading (Normal Service)
40600136	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Splash Loading (Normal Service)
40600141	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Submerged Loading (Balanced Service)
40600144	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Splash Loading (Balanced Service)
40600147	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Submerged Loading (Clean Tanks)
40600162	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Loaded with Fuel (Transit Losses)
40600163	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Gasoline: Return with Vapor (Transit Losses)

SCC	Type	Description
40600199	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Tank Cars and Trucks; Not Classified
40600231	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Tankers: Cleaned and Vapor Free Tanks
40600232	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Tankers
40600233	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Barges: Cleaned and Vapor Free Tanks
40600234	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Tankers: Ballasted Tank
40600235	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Ocean Barges Loading - Ballasted Tank
40600236	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Tankers: Uncleaned Tanks
40600237	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Ocean Barges Loading - Uncleaned Tanks
40600238	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Barges: Uncleaned Tanks
40600239	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Tankers: Ballasted Tank
40600240	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Loading Barges: Average Tank Condition
40600241	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Gasoline: Tanker Ballasting
40600299	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Marine Vessels; Not Classified
40600301	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Splash Filling
40600302	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Submerged Filling w/o Controls
40600305	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Unloading
40600306	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Balanced Submerged Filling
40600307	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Underground Tank Breathing and Emptying
40600399	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Gasoline Retail Operations - Stage I; Not Classified **
40600401	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Filling Vehicle Gas Tanks - Stage II; Vapor Loss w/o Controls
40600501	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Pipeline Petroleum Transport - General - All Products; Pipeline Leaks

SCC	Type	Description
40600502	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Pipeline Petroleum Transport - General - All Products; Pipeline Venting
40600503	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Pipeline Petroleum Transport - General - All Products; Pump Station
40600504	RBT	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Pipeline Petroleum Transport - General - All Products; Pump Station Leaks
40600602	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Consumer (Corporate) Fleet Refueling - Stage II; Liquid Spill Loss w/o Controls
40600701	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Consumer (Corporate) Fleet Refueling - Stage I; Splash Filling
40600702	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Consumer (Corporate) Fleet Refueling - Stage I; Submerged Filling w/o Controls
40600706	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Consumer (Corporate) Fleet Refueling - Stage I; Balanced Submerged Filling
40600707	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Consumer (Corporate) Fleet Refueling - Stage I; Underground Tank Breathing and Emptying
40688801	BTP /BPS	Petroleum and Solvent Evaporation; Transportation and Marketing of Petroleum Products; Fugitive Emissions; Specify in Comments Field
2501050120	RBT	Storage and Transport; Petroleum and Petroleum Product Storage; Bulk Terminals: All Evaporative Losses; Gasoline
2501055120	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Bulk Plants: All Evaporative Losses; Gasoline
2501060050	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Stage 1: Total
2501060051	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Stage 1: Submerged Filling
2501060052	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Stage 1: Splash Filling
2501060053	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Stage 1: Balanced Submerged Filling
2501060200	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Underground Tank: Total
2501060201	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; Gasoline Service Stations; Underground Tank: Breathing and Emptying
2501995000	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Storage; All Storage Types: Working Loss; Total: All Products
2505000120	RBT	Storage and Transport; Petroleum and Petroleum Product Transport; All Transport Types; Gasoline
2505020120	RBT	Storage and Transport; Petroleum and Petroleum Product Transport; Marine Vessel; Gasoline

SCC	Type	Description
2505020121	RBT	Storage and Transport; Petroleum and Petroleum Product Transport; Marine Vessel; Gasoline - Barge
2505030120	BTP /BPS	Storage and Transport; Petroleum and Petroleum Product Transport; Truck; Gasoline
2505040120	RBT	Storage and Transport; Petroleum and Petroleum Product Transport; Pipeline; Gasoline
2660000000	BTP /BPS	Waste Disposal, Treatment, and Recovery; Leaking Underground Storage Tanks; Leaking Underground Storage Tanks; Total: All Storage Types

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