Technical Support Document (TSD): Preparation of Emissions Inventories for the 2018v2 North American Emissions Modeling Platform

EPA-454/B-23-003
September 2023

Technical Support Document (TSD): Preparation of Emissions Inventories for the 2018v2 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

List of Figures

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
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
NH_3	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
PFC	Portable Fuel Container
$PM_{2.5}$	Particulate matter less than or equal to 2.5 microns
PM_{10}	Particulate matter less than or equal to 10 microns
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
SO_2	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), has created a 2018 version 2 platform for use in air quality modeling analyses. This platform primarily draws on data from the 2017 National Emissions Inventory (NEI) (EPA, 2021b), although the emissions were updated to represent the year 2018 through the incorporation of 2018-specific data along with adjustment methods appropriate for each sector. The analytic year inventories were developed starting with the base year 2018 inventory using sector-specific methods as described below. This 2018 platform supports applications related to particulate matter (PM). An earlier version of a 2018 platform was developed in 2021 in support of ozone, PM and air toxics air quality modeling analyses (EPA, 2022a).

The full 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 data and techniques that comprise the emission modeling platform including the emission inventories, the ancillary data files, and the approaches used to transform inventories for use in air quality modeling.

This emissions modeling platform includes all criteria air pollutants (CAPs) and precursors, and a group of hazardous air pollutants (HAPs). The group of HAPs are those explicitly used by the chemical mechanism in the Community Multiscale Air Quality (CMAQ) model (Appel et al., 2018) for ozone/particulate matter (PM): chlorine (Cl), hydrogen chloride (HCl), benzene, acetaldehyde, formaldehyde, methanol, naphthalene. The modeling domain includes the lower 48 states and parts of Canada and Mexico. The modeling cases for this platform were developed for studies with both the CMAQ model and with the Comprehensive Air Quality Model with Extensions (CAMx). The emissions modeling process used first prepares outputs in the format used by CMAQ, after which those emissions data are converted to the formats needed by CAMx.

The 2018 platform consists of cases that represent the years 2018 and 2032 with the abbreviations **2018gg_18j** and **2032gg2_18j**, respectively. Derivatives of these cases that included source apportionment by state were also developed. This platform accounts for atmospheric chemistry and transport within a state-of-the-art photochemical grid model. In the case abbreviation 2018gg_18j, 2018 is the year represented by the emissions; the "g" represents the base year emissions modeling platform iteration, which here shows that g is for the 2018 platform which started with the 2017 NEI; and the "g" stands for the seventh configuration of emissions modeled for that modeling platform. In the script and data directories this platform is known as "em_v8.1." Data and summary reports for this platform are available from https://www.epa.gov/air-emissions-modeling/2018v2-emissions-modeling-platform. It is distinguished from the original 2018 platform used for 2018 AirToxScreen that is called "em_v8." Note that the original 2018 platform did not include analytic year emissions.

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 2018 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 (GHRSST) (see https://www.ghrsst.org/) and is given the EPA meteorological case label "18j." The full case abbreviation includes this suffix following the emissions portion of the case name to fully specify the abbreviation of the base year case as "2018gf_18j."

The emissions modeling platform includes point sources, nonpoint sources, commercial marine vessels (CMV), onroad and nonroad mobile sources, and fires for the U.S., Canada, and 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. A full NEI was not developed for the year 2018 because only point sources above a certain potential to emit must be submitted for years between the full triennial NEI years (e.g., 2014, 2017, 2020). Emissions from Canada and Mexico are used for the modeling platform but are not part of the NEI.

The primary emissions modeling tool used to create the air quality model-ready emissions was the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system (http://www.smoke-model.org/), version 4.8.1 (SMOKE 4.8.1). Emissions files were created for a 36-km national grid and for a 12-km national grid, both of which include the contiguous states and parts of Canada and Mexico as shown in Figure 3-1. Emissions at 36-km were only created for the inventory year 2018.

This document contains six sections. Section 2 describes the base year 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. Methods to develop analytic year emissions are described in Section 4. Data summaries are provided in Section 5. Section 6 provides references. Note that all tables of emissions totals in this document are in the units of short tons/year.

2 Base Year Emissions Inventories and Approaches

This section summarizes the emissions data that make up the 2018 base year emissions and provides details about the data contained in each of the platform sectors. The original starting point for the emission inventories was the original 2018 platform, which incorporated data and methods from the 2017 NEI. The base year emissions for many of the sectors in this platform are consistent with original platform, which had a case abbreviation of 2018gc.

Data and documentation for the 2017NEI, including a TSD, are available from https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data (EPA, 2021b). In addition to U.S. emissions from the NEI data categories of point, nonpoint, onroad, nonroad, and events (i.e., fires), emissions from the Canadian and Mexican inventories are included in the 2018v2 platform. The Canadian and Mexican inventories in the 2018v2 platform were not changed from those in the 2016v2 platform (EPA, 2022b), although they were reprocessed for the year 2018. The Canadian inventories were provided by Environment and Climate Change Canada (ECCC), and most of the inventories for Mexico are based on data provided by SEMARNAT.

The triennial year NEI data for CAPs are largely compiled from data submitted by state, local and tribal (S/L/T) air agencies. A large proportion of HAP emissions data in the NEI are also from the S/L/T agencies, but, are augmented by the EPA when not available from S/L/Ts. The EPA uses the Emissions Inventory System (EIS) to compile the NEI. EIS includes hundreds of automated quality assurance checks to help improve data quality, and also supports tracking release point (e.g., stack) coordinates separately from facility coordinates. The EPA collaborates extensively with S/L/T agencies to ensure a high quality of data in the NEI. Because 2018 is not a triennial NEI year, the inventories for most emissions modeling sectors were modified in some way to represent the year 2018 to the extent possible.

For interim years other than triennial NEI years, point source data are typically pulled forward from the most recent triennial NEI year for the sources that were not reported by S/L/Ts for the interim year. Thus, the 2018 point source emission inventories for the platform include emissions primarily from S/L/T-submitted data. Agricultural and wildland fire emissions represent the year 2018 and are consistent with those in 2018gc. In 2018gg, most anthropogenic emissions are consistent with those in 2018gc, although some had minor adjustments as described in Table 2-1. Onroad and nonroad mobile source emissions were developed using the Motor Vehicle Emission Simulator (MOVES). Onroad emissions were developed based on emissions factors output from MOVES3 for the year 2018. Nonroad emissions were consistent with those in 2018gc and were generated using MOVES3, including the spatial allocation factors made for the 2016v1 platform.

For the purposes of preparing the air quality model-ready emissions, emissions from the five NEI data categories (i.e., point, nonpoint, onroad, nonroad, and events) are split into finer-grained sectors used for emissions modeling. The significance of an emissions modeling or "platform sector" is that the data are run through the SMOKE programs independently from the other sectors except for the final merge. The final merge program (Mrggrid) combines the sector-specific gridded, speciated, hourly emissions together to create CMAQ-ready emission inputs.

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/2018v2-platform , The platform informational text file describes the particular zipped files associated with each platform sector and provides notes about how SMOKE should be run for each sector. Summary reports are available in addition to the data files for the 2018v2 platform. The types of reports include state summaries of inventory pollutants and model species by modeling platform sector and county totals by modeling platform sector.

Table 2-1 presents an overview of how base year emission for the sectors in the emissions modeling platform were developed and how they relate to the NEI as their starting point. The platform sector abbreviations are provided in italics. These abbreviations are used in the SMOKE modeling scripts, inventory file names, and throughout the remainder of this document. Additional details on the changes made in the 2018v2 platform for each sector are available in the sector-specific subsections that follow.

Other natural emissions are also merged in with the sectors in Table 2-1: ocean chlorine and sea salt, and lightning NOx. 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). In CMAQ, the species name is "CL2." For more information on the natural emissions, see Section 2.7.7.

Table 2-1. Platform sectors for the 2018gg emissions modeling case

Platform Sector: ***abbreviation***	**NEI Data Category**	**Description and resolution of the data input to SMOKE**
EGU units: ***ptegu***	Point	Point source electric generating units (EGUs) for 2018 from the Emissions Inventory System (EIS) based on the winter 2022 point flat file as was used for 2018 AirToxScreen. The inventory emissions are replaced with hourly 2018 Continuous Emissions Monitoring System (CEMS) values for nitrogen oxides (NO_X) and sulfur dioxide ($SO_{2)}$ for any units that are matched to the NEI, and other pollutants for matched units are scaled from the 2018 point inventory using CEMS heat input. Emissions for all sources not matched to CEMS data come from the annual inventory. Annual resolution for sources not matched to CEMS data, hourly for CEMS sources. EGUs closed in 2018 are not part of the inventory.
Point source oil and gas: ***pt_oilgas***	Point	Point sources for 2018 including S/L/T data for oil and gas production and related 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 from the 2017NEI Production-related sources without 2018 data were pulled forward from 2017 NEI and adjusted to 2018. In NM and UT, the WRAP inventory from the 2016v3 platform (EPA, 2023a) was used. Annual resolution.
Aircraft and ground support equipment: ***airports***	Point	2017 NEI point source emissions from aircraft up to 3,000 ft elevation and emissions from ground support equipment, adjusted to 2018 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: ***ptnonipm***	Point	All 2018 point source inventory records not matched to the ptegu, airports, or pt_oilgas sectors, including updates submitted by state and local agencies including some sources that were not operating in 2018 but did operate in later years use the winter 2022 inventory as was used for 2018 AirToxScreen. 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 2018 using same projection factors as the rail sector. Annual resolution.

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Agricultural fertilizer: ***fertilizer***	Nonpoint	Nonpoint agricultural fertilizer application emissions of ammonia computed inline within CMAQ for 2018 through the bidirectional ammonia flux process. Created an emissions inventory post-CMAQ to use for data summaries but did not run SMOKE. Ran inline, but used county and monthly resolution for the output inventory.
Agricultural Livestock: ***livestock***	Nonpoint	2017 NEI nonpoint agricultural livestock emissions including ammonia and other pollutants (except $PM_{2.5}$). Same as 2018gc except included a correction for Maryland. County and annual resolution.
Agricultural fires with point resolution: ***ptagfire***	Nonpoint	2018 agricultural fire sources based on EPA-developed data, represented as point source day-specific emissions. Same as 2018gc. They are in the NEI nonpoint data category, but in the platform, they are treated as point sources. Day-specific resolution.
Area fugitive dust: ***afdust***	Nonpoint	PM_{10} and $PM_{2.5}$ fugitive dust sources based on the 2017 NEI nonpoint inventory, including building construction, road construction, agricultural dust, and paved and unpaved road dust; with paved road dust adjusted to 2018 based on vehicle miles traveled (VMT). Emissions are reduced during modeling according to a transport fraction and a 2018 meteorology-based (precipitation and snow/ice cover) zero-out. Afdust emissions from the portion of southeast Alaska inside the 36US3 domain are processed in a separate sector called 'afdust_ak'. County and annual resolution.
Biogenic: ***beis***	Nonpoint	Year 2018, hour-specific, grid cell-specific emissions generated from a new B3GRD files for 12US1 and 36US3 based on a corrected version of the BEIS3.7 model within SMOKE, including emissions in Canada and Mexico using BELD5 land use data. Gridded and hourly resolution.
Category 1, 2 CMV: ***cmv_c1c2***	Nonpoint	2017 NEI Category 1 and category 2 (C1C2) commercial marine vessel (CMV) emissions based on Automatic Identification System (AIS) data, adjusted to 2018, including the county apportionment fix consistent with what was done for 2016v3. Same as 2018gc. Includes C1C2 CMV emissions in U.S. state and Federal waters along with non-U.S. C1C2 emissions within the modeling domains. Gridded and hourly resolution.
Category 3 CMV: ***cmv_c3***	Nonpoint	2017 NEI Category 3 (C3) CMV emissions converted to point sources based on the center of the grid cells and adjusted to 2018, including the county apportionment fix consistent with what was done for 2016v3. Includes C3 emissions in U.S. state and Federal waters, and also all non-U.S. C3 emissions within the modeling domains. Same as 2018gc. Gridded and hourly resolution.
Locomotives : ***rail***	Nonpoint	2017 NEI line haul rail locomotives emissions adjusted to 2018. Includes freight and commuter rail emissions. Same as 2018gc. County and annual resolution.
Solvents : ***np_solvents***	Nonpoint (some Point)	VOC emissions from solvents for the year 2018 derived using the January 2022 version of the VCPy framework (Seltzer et al., 2021). Includes household cleaners, personal care products, adhesives, architectural coatings, aerosol coatings, industrial coatings, allied paint products, printing inks, dry-cleaning emissions, and agricultural pesticides. County and annual resolution.
Nonpoint source oil and gas: ***np_oilgas***	Nonpoint	2018 nonpoint oil and gas emissions output from the oil and gas tool using 2018 activity data. For exploration the 2018 oil and gas tool output were used directly. For production used the WRAP inventory from the 2016v3 platform in New Mexico and North Dakota; the 2017 NEI in California, Colorado, Oklahoma, Texas, Utah, and Wyoming; and oil and gas tool outputs for 2018 in all other states. County and annual resolution

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Residential Wood Combustion: ***rwc***	Nonpoint	2017 NEI nonpoint sources from residential wood combustion (RWC) with no adjustments to 2018. Same as 2018gc. County and annual resolution.
Remaining nonpoint: ***nonpt***	Nonpoint	2017 NEI nonpoint sources that are not included in other platform sectors with no adjustments to 2018. Same as 2018gc. For 2018 used 2017 NEI for all sources. County and annual resolution.
Nonroad: ***nonroad***	Nonroad	2018 nonroad equipment emissions developed with MOVES3, including the updates made to spatial apportionment that were developed for the 2016v1 platform. MOVES3 was used for all states except California and Texas. California submitted emissions for 2017 and 2023 which were interpolated to 2018; Texas submitted emissions for 2017 and 2020, which were interpolated to 2018. Same as 2018gc. County and monthly resolution.
Onroad: ***onroad***	Onroad	2018 onroad mobile source gasoline and diesel vehicles from moving and non-moving vehicles that drive on roads, along with vehicle refueling. Includes the following modes: exhaust, extended idle, auxiliary power units, off network idling, starts, evaporative, permeation, refueling, and brake and tire wear. For all states except California, developed using SMOKE-MOVES with emission factor tables produced by MOVES3. Activity data were projected to 2018 using factors derived from data obtained from Federal Highway Administration and state departments of transportation. Same as 2018gc. County and hourly resolution.
Onroad California: ***onroad_ca_adj***	Onroad	California-provided CAP onroad mobile source gasoline and diesel vehicles based on the EMFAC2017 model interpolated to 2018 between 2017 and 2023. The 2018 data were gridded and temporalized using MOVES3 outputs. Volatile organic compound (VOC) HAP emissions derived from California-provided VOC emissions and MOVES-based speciation. Same as 2018gc. County and hourly resolution.
Point source fires- ***ptfire-rx*** ***ptfire-wild***	Events	Point source day-specific wildfires and prescribed fires for 2018 computed using Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2 (SMARTFIRE2) and BlueSky Pipeline for both flaming and smoldering processes (i.e., SCCs 281XXXX002). The ptfire-rx sectors includes Flint Hills grasslands fires; wildfires were run in a separate sector ptfire-wild. Smoldering emissions forced into layer 1 (by adjusting heat flux). Same as 2018gc. Daily resolution.
Non-US. Fires: ***ptfire_othna***	N/A	Point source day-specific wildfires and agricultural fires outside of the U.S. for 2018 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. Includes any prescribed fires although they are not distinguished from wildfires. Same as 2018gc. Daily resolution.
Other Area Fugitive dust sources not from the NEI: ***othafdust***	N/A	Area fugitive dust sources of particulate matter emissions excluding dust from livestock land tilling from agricultural activities, from Environment and Climate Change Canada (ECCC) for 2016. Transport fraction adjustments applied along with a 2018-specific meteorology-based (precipitation and snow/ice cover) zero-out. Same as 2018gc. County and annual resolution.

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Other Point Fugitive dust sources not from the NEI: ***othptdust***	N/A	2016 point source fugitive dust sources of particulate matter emissions including dust from livestock and land tilling from agricultural activities, provided by ECCC. Wind erosion emissions were not included. Transport fraction adjustments applied along with a 2018-specific meteorology-based (precipitation and snow/ice cover) zero-out. Same as 2018gc. Monthly resolution.
Other point sources not from the NEI: ***othpt***	N/A	2016 point source emissions from the ECCC including Canadian sources other than agricultural ammonia and low-level oil and gas sources, along with emissions from Mexico's 2016 inventory projected to 2018. Canada same as 2018gc, Mexico updated from 2018gc. Monthly resolution for Canada airport emissions, annual resolution for the remainder of Canada and all of Mexico.
Canada ag not from the NEI: ***canada_ag***	N/A	2016 agricultural point sources from the ECCC, including agricultural ammonia. Same as 2018gc, except with these emissions split out from the othpt sector. Monthly resolution.
Canada oil and gas 2D not from the NEI: ***canada_og2D***	N/A	2016 low-level point oil and gas sources with emissions forced into 2D low-level to reduce the size of the othpt sector. Point oil and gas sources subject to plume rise remain in the othpt sector. Same as 2018gc, except with these emissions split out from the othpt sector. Annual resolution.
Other non-NEI nonpoint and nonroad: ***othar***	N/A	2016 Canada emissions from the ECCC inventory, with nonroad emissions projected from 2016 to 2018 using US nonroad trends. Mexico (municipio resolution) emissions projected from 2016 to 2018. Canada same as 2018gc, Mexico updated from 2018gc. Resolution: Canada: province or sub-province resolution; monthly for nonroad sources and annual for rail and other nonpoint sectors; Mexico: municipio resolution; annual nonpoint and nonroad mobile inventories.
Other non-NEI onroad sources: ***onroad_can***	N/A	Year 2016 Canada from the ECCC onroad mobile inventory projected to 2018 using US onroad trends. Separate trends applied to refueling and non-refueling. Same as 2018gc. Province resolution or sub-province resolution, depending on the province; Monthly resolution.
Other non-NEI onroad sources: ***onroad_mex***	N/A	Year 2018 Mexico onroad mobile inventory from MOVES-Mexico. Same as from 2018gc. Municipio and monthly resolution.

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). This section describes NEI point sources within the contiguous U.S. and the offshore oil platforms which are processed by SMOKE as point source inventories.

A full NEI is compiled every three years including 2014, 2017 and 2020. In the intervening years, year-specific emissions for point sources that exceed the potential to emit threshold as defined in the Air Emissions Reporting Requirements (AERR)[1] must be submitted by the responsible state, local, or tribal

[1] 80 FR 8787 published 2/19/2015. See: https://www.federalregister.gov/documents/2015/02/19/2015-03470/revisions-to-the-air-emissions-reporting-requirements-revisions-to-lead-pb-reporting-threshold-and

agencies. These emissions, and any relevant closures, are submitted to the Emissions Inventory System (EIS) used to compile the NEI. Sources not updated by the responsible agencies for the interim year are either carried forward from the most recent triennial NEI if they have not been marked as closed. While point source emissions are available in EIS for the year 2018, a full set of documentation on how the 2018 point source inventory was compiled is not available. The methods for point source emissions estimation for the year of 2018 are similar to those used for the 2017 NEI. A comprehensive description of how point source emissions were characterized and estimated in the 2017 NEI is available in the 2017 NEI TSD (EPA, 2021).

The point source file used for the modeling platform was exported from EIS into the Flat File 2010 (FF10) format that is compatible with SMOKE (see https://www.cmascenter.org/smoke/documentation/4.9/html/ch06s02s08.html). The export of point source emissions specific to 2018, including stack parameters and locations from EIS, was done on March 22, 2022. The flat file was modified to remove sources without specific locations (i.e., their FIPS code ends in 777). Then the point source FF10 was divided into point source sectors used in the platform: the EGU sector (ptegu), point source oil and gas extraction-related emissions (pt_oilgas), airport emissions were put into the airports sector, and the remaining non-EGU sources into the non-IPM (ptnonipm) sector. The split was done at the unit level for ptegu and facility level for pt_oilgas such that a facility may have units and processes in both ptnonipm and ptegu, but units cannot be in both pt_oilgas and any other point sector.

The EGU emissions are split out from the other sources to facilitate the use of distinct SMOKE temporal processing and analytic-year projection techniques where the Integrated Planning Model (IPM) is used to project EGU emissions and other techniques are used to project non-EGU emissions. The oil and gas sector emissions (pt_oilgas) were processed separately for summary tracking purposes and distinct analytic-year 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.

While reviewing recent point source inventories it was determined that data submitted by some agencies used specific default values for certain stack parameters that are not necessarily appropriate to use for those sources. Defaulted values were noticed in data submissions for the states of Illinois, Louisiana, Michigan, Pennsylvania, Texas, Wisconsin, and others. Using these default values can impact modeling results, especially in fine scale modeling. When the stack parameters were substantially different from average values for that source type, the defaulted stack parameters were replaced with the value from the SMOKE PSTK file for that source classification code (SCC). The agencies and default values that were replaced are shown in Table 2-2. Comments for any impacted inventory records were appended in the FF10 inventory files with comments of the form “stktemp replaced with ptsk default” so the updated records could be identified. These updates impacted the ptnonipm and pt_oilgas inventories.

Table 2-2. Default stack parameter replacements

Agency abbreviation	Stkdiam	Stkhgt	Stktemp	Stkvel
CODPHE	0.1 ft	1 ft	70 degF or 72 degF	
PADEP	0.1 ft	1 ft	70 degF	0.1 ft/s or 1000 ft/s
LADEQ	0.3 ft		70 degF or 77 degF	0.1 ft/s
ILEPA	0.33 ft	33 ft or 35 ft	70 degF	
TXCEQ	1 ft or 3 ft	40 ft	72 degF	0.1 ft/s
NVBAQ		32.8 ft	72 degF	
WIDNR		20 ft		3.281 ft/s
MIDEQ			70 degF or 72 degF	
MNPCA			70 degF	
IADNR			68 degF or 70 degF	
ORDEQ			72 degF	
MSDEQ			72 degF	
SCDEQ			72 degF	1 ft/s
NCDAQ			72 degF	0.2 ft/s
INDEM			0 degF	0 ft/s
NEDEQ			350 degF	1.6666 ft/s
KYDAQ				0 ft/s
WYDEQ				11.46 ft/s

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.

The inventory pollutants processed through SMOKE for all point source sectors included carbon monoxide (CO), oxides of nitrogen (NO_X), volatile organic compounds (VOC), sulfur dioxide (SO_2), ammonia (NH_3), particles less than 10 microns in diameter (PM_{10}), and particles less than 2.5 microns in diameter ($PM_{2.5}$), and all of the hazardous air pollutants (HAPs) listed in Table 3-3. The pollutants naphthalene, benzene, acetaldehyde, formaldehyde, and methanol (NBAFM) species are based on speciation of VOCs. The resulting VOC in the modeling system may be higher or lower than the VOC emissions in the NEI; they would only be the same if the HAP inventory and speciation profiles were exactly consistent. For HAPs other than those in NBAFM, there is no concern for double-counting since CMAQ handles these outside of the CB6 chemical mechanism.

The ptnonipm and pt_oilgas sector emissions were provided to SMOKE as annual emissions. For those ptegu sources with CEMS data that could be matched to the point inventory from EIS, hourly CEMS NO_X and SO_2 emissions were used rather than the annual total NEI emissions. For all other pollutants at matched units, the annual emissions were used as-is from the NEI, but were allocated to hourly values using heat input from the CEMS data. For the sources in the ptegu sector not matched to CEMS data, daily emissions were created using an approach described in Section 2.1.1. For non-CEMS units other than municipal waste combustors and cogeneration units, region- and pollutant-specific diurnal profiles were applied to create hourly emissions.

2.1.1 EGU sector (ptegu)

The ptegu sector contains emissions from EGUs in the 2018 NEI point inventory that could be matched to units found in the National Electric Energy Data System (NEEDS) v6 database (https://www.epa.gov/airmarkets/national-electric-energy-data-system-needs-v6 dated 2/14/2023). NEEDS 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 projected by IPM are not properly matched to the units in the point source inventory

The matching of NEEDS to the NEI sources was prioritized according to the amount of the emissions produced by the source. In the SMOKE point flat file, emission records for sources that have been matched to the NEEDS database have a value filled into the IPM_YN column based on the matches stored within EIS. The 2018 NEI point inventory consists of data submitted by S/L/T agencies and EPA to the EIS for Type A (i.e., large) point sources. Those EGU sources in the 2017 NEI inventory that were not submitted or updated for 2018 and not identified as retired were retained in 2018, but for 2018v2 the emissions values were pulled from the 2017 NEI where possible.

When possible, units in the ptegu sector are matched to 2018 CEMS data from EPA's Clean Air Markets Division (CAMD) via ORIS facility codes and boiler ID (see https://campd.epa.gov/). For the matched units, SMOKE replaces the 2018 emissions of NO_X and SO_2 with the CEMS emissions, thereby ignoring the annual values specified in the NEI annual FF10 flat file. 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 NEI or updates provided by data submitters outside of EIS. Because these attributes are obtained from the NEI, the chemical speciation of VOC and $PM_{2.5}$ for the sources is selected based on the SCC or in some cases, based on unit-specific data. If CEMS data exists for a unit, but the unit is not matched to the NEI, the CEMS data for that unit 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. The EGU flat file inventory is split into a flat file with CEMS matches and a flat file without CEMS matches to support analysis and temporal allocation to hourly values.

In the SMOKE point FF10 file, emission records for point sources matched to CEMS data have values filled into the ORIS_FACILITY_CODE and ORIS_BOILER_ID columns. The CEMS data in SMOKE-ready format is available at https://gaftp.epa.gov/DMDnLoad/emissions/smoke/. Many smaller emitters in the CEMS program are not identified with ORIS facility or boiler IDs that can be matched to the NEI due to inconsistencies in the way a unit is defined between the NEI and CEMS datasets, or due to uncertainties in source identification such as inconsistent plant names in the two data systems. Also, the NEEDS database of units modeled by IPM includes many smaller emitting EGUs that do not have CEMS. Therefore, there will be more units in the NEEDS database than have CEMS data. The temporal allocation of EGU units matched to CEMS is based on the CEMS data, whereas regional profiles are used for most of the remaining units. More details can be found in Section 3.3.2.

Some EIS units match to multiple CAMD units based on cross-reference information in the EIS alternate identifier table. The multiple matches are used to take advantage of hourly CEMS data when a CAMD unit specific entry is not available in the inventory. Where a multiple match is made, the EIS unit is split and the ORIS facility and boiler IDs are replaced with the individual CAMD unit IDs. The split EIS unit NOX and SO2 emissions annual emissions are replaced with the sum of CEMS values for that respective unit. All other pollutants are scaled from the EIS unit into the split CAMD unit using the fraction of annual heat input from the CAMD unit as part of the entire EIS unit. The NEEDS ID in the "ipm_yn" column of the flat file is updated with a "_M_" between the facility and boiler identifiers to signify that the EIS unit had multiple CEMS matches. The inventory records with multiple matches had the EIS unit identifiers appended with the ORIS boiler identifier to distinguish each CEMS record in SMOKE.

For sources not matched to CEMS data, except for municipal waste combustors (MWCs) waste-to-energy and cogeneration units, daily emissions were computed from the NEI annual emissions using average CEMS data profiles specific to fuel type, pollutant,[2] and IPM region. To allocate emissions to each hour of the day, diurnal profiles were created using average CEMS data for heat input specific to fuel type and IPM region. See Section 3.3.2 for more details on the temporal allocation approach for ptegu sources.

[2] The year to day profiles use NOx and SO_2 CEMS for NOx and SO_2, respectively. For all other pollutants, they use heat input CEMS data.

MWC and cogeneration units without CEMS data available were specified to use uniform temporal allocation such that the emissions are allocated to constant levels for every hour of the year. These sources do not use hourly CEMs, and instead use a temporal profile that allocates the same emissions for each day, combined with a uniform hourly temporal profile applied by SMOKE.

2.1.2 Point source oil and gas sector (pt_oilgas)

The pt_oilgas sector consists of point source oil and gas emissions in United States, primarily pipeline-transportation and some upstream exploration and production. Sources in the pt_oilgas sector consist of sources which are not electricity generating units (EGUs) and which have a North American Industry Classification System (NAICS) code corresponding to oil and gas exploration, production, pipeline-transportation or distribution. The pt_oilgas sector was separated from the ptnonipm sector by selecting sources with specific NAICS codes shown in Table 2-3. The use of NAICS to separate out the point oil and gas emissions forces all sources within a facility to be in this sector, as opposed to ptegu where sources within a facility can be split between ptnonipm and ptegu sectors.

Table 2-3. 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

The starting point for most states in the 2018v2 emissions platform pt_oilgas inventory was the 2018 point source NEI. The 2018 inventory includes data submitted by S/L/T agencies and EPA to the EIS for Type A (i.e., large) point sources. For the federally-owned offshore point inventory of oil and gas platforms, a 2017 inventory was used that was developed by the U.S. Department of the Interior, Bureau of Ocean and Energy Management, Regulation, and Enforcement (BOEM). For 2018, New Mexico and Utah used the WRAP oil and gas inventory from 2016v3 platform.

The NEI year that the data was submitted for is indicated by the calc_year field in the FF10 inventory files. Sources in the 2018NEI in which the calc_year is 2017 were projected to 2018. Each state/SCC/NAICS combination in the inventory was classified as either an oil source, a natural gas source, a combination of oil and gas, or designated as a "no growth" source. Growth factors were based on historical state production data from the Energy Information Administration (EIA) and are listed in Table 2-4. These factors were applied to sources with NAICS = 2111, 21111, 211111, 211112, and 213111 and with production-related SCC processes in the pt_oilgas sector. States listed with N/A as values do not have oil and gas activity data from which projection factors could be developed and therefore were held flat with no change from 2017 to 2018.

For pipeline transportation, national projection factors of 17% for oil and 12% for gas were applied. The "no growth" sources include all offshore and tribal land emissions, and all emissions with a NAICS code associated with distribution, transportation, or support activities. The historical production data for years 2017 and 2018 for oil and natural gas were taken from the following websites:

- https://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm (Crude production)
- http://www.eia.gov/dnav/ng/ng_sum_lsum_a_epg0_fgw_mmcf_a.htm (Natural gas production)

Table 2-5 shows the national emissions for pt_oilgas following the projection to 2018; these numbers only reflect the portion of the inventory projected from 2017 to 2018.

Table 2-4. 2017-to-2018 projection factors for pt_oilgas sector

State	Natural Gas growth	Oil growth	Combination gas/oil growth
Alabama	-7.0%	-13.8%	-10.4%
Alaska	0.1%	-3.2%	-1.5%
Arizona	-25.0%	-15.4%	-20.2%
Arkansas	-15.1%	-5.4%	-10.2%
California	-4.6%	-2.4%	-3.5%
Colorado	8.3%	25.6%	17.0%
Florida	3.7%	-4.4%	-0.3%
Idaho	-50.8%	-3.3%	-27.0%
Illinois	15.6%	1.3%	8.5%
Indiana	-14.5%	-5.3%	-9.9%
Kansas	-8.3%	-3.1%	-5.7%
Kentucky	-5.3%	-8.6%	-6.9%
Louisiana	32.2%	-8.0%	12.1%
Maryland	-59.4%	#N/A	-59.4%
Michigan	-7.1%	-1.6%	-4.4%
Mississippi	-7.5%	-4.7%	-6.1%
Missouri	0.0%	-17.2%	-8.6%
Montana	-4.8%	4.0%	-0.4%
Nebraska	-4.8%	-3.2%	-4.0%
Nevada	0.0%	-10.8%	-5.4%
New Mexico	16.5%	44.6%	30.5%

State	Natural Gas growth	Oil growth	Combination gas/oil growth
New York	-6.5%	20.1%	6.8%
North Dakota	25.0%	17.9%	21.4%
Ohio	34.2%	13.8%	24.0%
Oklahoma	14.4%	20.2%	17.3%
Oregon	-24.3%	#N/A	-24.3%
Pennsylvania	14.9%	-1.3%	6.8%
South Dakota	-6.1%	-2.4%	-4.2%
Tennessee	10.1%	-22.5%	-6.2%
Texas District 1	4.1%	8.0%	6.1%
Texas District 10	-5.2%	-0.8%	-3.0%
Texas District 2	9.7%	10.4%	10.1%
Texas District 3	10.8%	21.2%	16.0%
Texas District 4	-5.8%	0.8%	-2.5%
Texas District 5	-6.9%	-5.8%	-6.3%
Texas District 6	19.1%	-2.2%	8.4%
Texas District 7B	-4.8%	-4.7%	-4.8%
Texas District 7C	15.4%	15.0%	15.2%
Texas District 8	45.9%	51.3%	48.6%
Texas District 8A	5.5%	2.9%	4.2%
Texas District 9	-7.5%	-5.7%	-6.6%
Utah	-6.1%	7.8%	0.8%
Virginia	-3.4%	-28.6%	-16.0%
West Virginia	17.0%	34.7%	25.8%
Wyoming	0.3%	16.2%	8.2%

Table 2-5. 2017 NEI-based sources in pt_oilgas (excluding offshore) before and after projections to 2018

Pollutant	Before projections	After projections	% change 2017 to 2018
CO	67,208	73,687	+9.6%
NH3	259.3	258.7	-0.3%
NOX	104,804	114,595	+9.3%
PM10-PRI	4,730	5,028	+6.3%
PM25-PRI	4,441	4,737	+6.7%
SO2	2,725	2,847	+4.5%
VOC	64,152	71,193	+11.0%

2.1.3 Non-IPM sector (ptnonipm)

With minor exceptions, the ptnonipm sector contains point sources that are not in the airport, ptegu or pt_oilgas sectors. For the most part, the ptnonipm sector reflects the non-EGU sources of the NEI point inventory; however, it is likely that some small low-emitting EGUs not matched to the NEEDS database or to CEMS data are present in the ptnonipm sector. The ptnonipm emissions in the 2018v2 platform have been updated from the 2018gc inventory by using a March 22, 2022 export from EIS.

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.

For 2018v2, A review of stack parameters (i.e., height, diameter, velocity, temperature) was performed to look for default values submitted for many stacks for the same type of source in the inventory. When these parameters were substantially different from average values for that source type, the defaulted stack parameters were replaced with the value from the SMOKE PSTK file for that SCC as shown in Table 2-2.

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

2.1.4 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. Terminal Area Forecast (TAF) data were used to project 2017 NEI emissions to 2018. 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 2018 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 2-6.

Table 2-6. SCCs for the airports sector

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2265008005	Mobile Sources	Off-highway Vehicle Gasoline, 4-stroke	Airport Ground Support Equipment	Airport Ground Support Equipment
2267008005	Mobile Sources	LPG	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

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2275060011	Mobile Sources	Aircraft	Air Taxi	Piston
2275060012	Mobile Sources	Aircraft	Air Taxi	Turbine
2275070000	Mobile Sources	Aircraft	Aircraft Auxiliary Power Units	Total

2.2 Nonpoint sources (afdust, fertilizer, livestock, np_oilgas, np_solvents, rwc, 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.

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 (afdust)

The area-source fugitive dust (afdust) sector contains PM_{10} 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 2-7 is a listing of the Source Classification Codes (SCCs) in the afdust sector. For 2018v2 no changes were made from the year 2018 afdust inventory in 2018gc.

Table 2-7. Afdust sector SCCs

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
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

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2325020000	Industrial Processes	Mining and Quarrying: SIC 14	Crushed and Broken Stone	Total
2325030000	Industrial Processes	Mining and Quarrying: SIC 14	Sand and Gravel	Total
2325060000	Industrial Processes	Mining and Quarrying: SIC 10	Lead Ore Mining and Milling	Total
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
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
2805001010	Miscellaneous Area Sources	Ag. Production – Livestock	Dairy Cattle	Dust Kicked-up by Hooves
2805001020	Miscellaneous Area Sources	Ag. Production – Livestock	Broilers	Dust Kicked-up by Feet
2805001030	Miscellaneous Area Sources	Ag. Production – Livestock	Layers	Dust Kicked-up by Feet
2805001040	Miscellaneous Area Sources	Ag. Production – Livestock	Swine	Dust Kicked-up by Hooves
2805001050	Miscellaneous Area Sources	Ag. Production – Livestock	Turkeys	Dust Kicked-up by Feet

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 2018 based on county-level VMT trends. For the data compiled into the 2017 NEI, meteorological adjustments are applied to paved and unpaved road SCCs but not transport adjustments. The meteorological adjustments that were applied (to paved and unpaved road SCCs) were backed out so that the entire sector could be processed consistently in SMOKE and the same grid-specific transport fractions and meteorological adjustments could be applied sector-wide. Thus, 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. The total impacts of the transport fraction and meteorological adjustments are shown in Table 2-8. Note that while totals from AK, HI, PR, and VI are included at the bottom of the table, they are from non-continental U.S. (non-CONUS) modeling domains and are not included in this modeling.

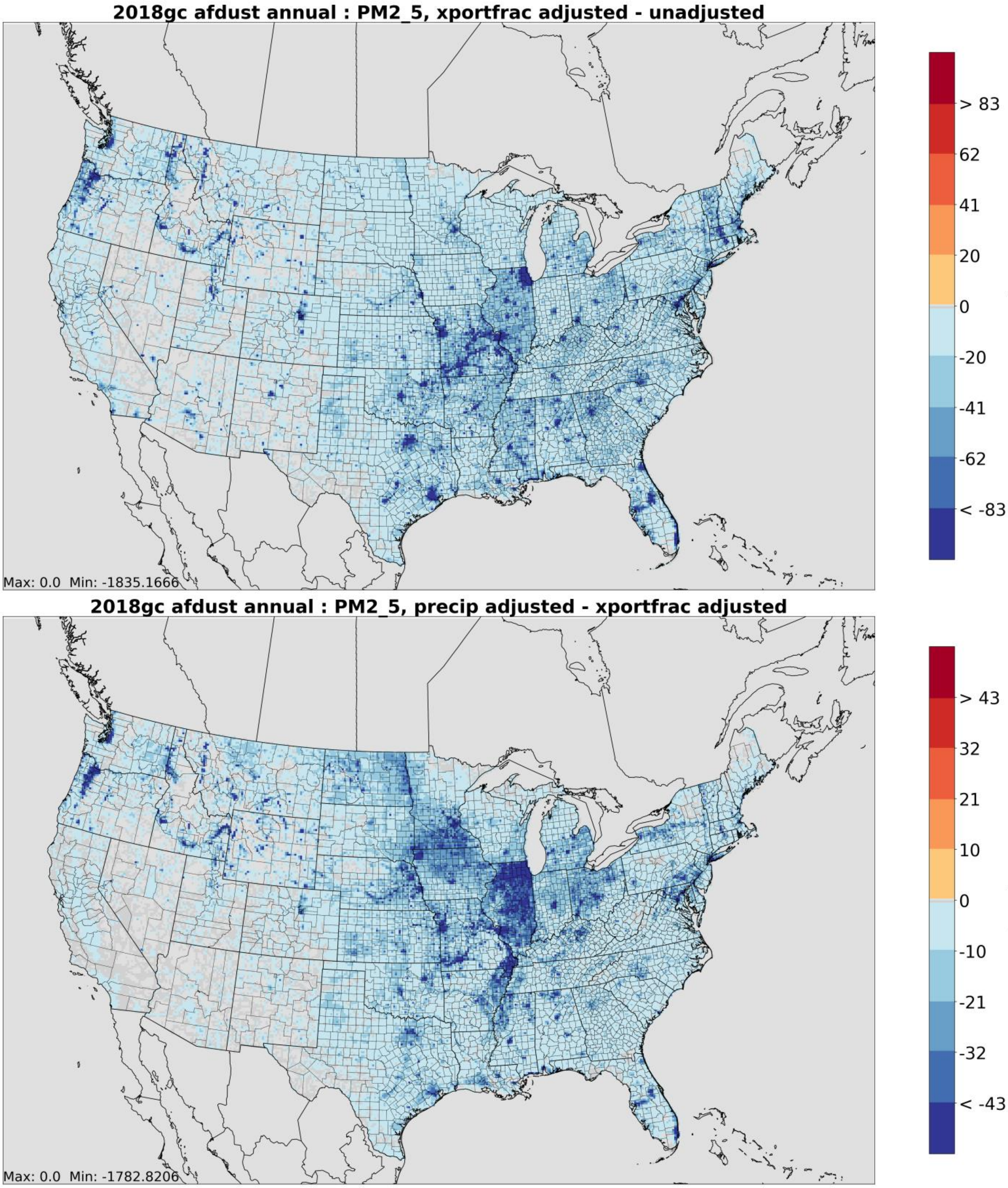
Table 2-8. Total impact of fugitive dust adjustments to the unadjusted 2018 inventory

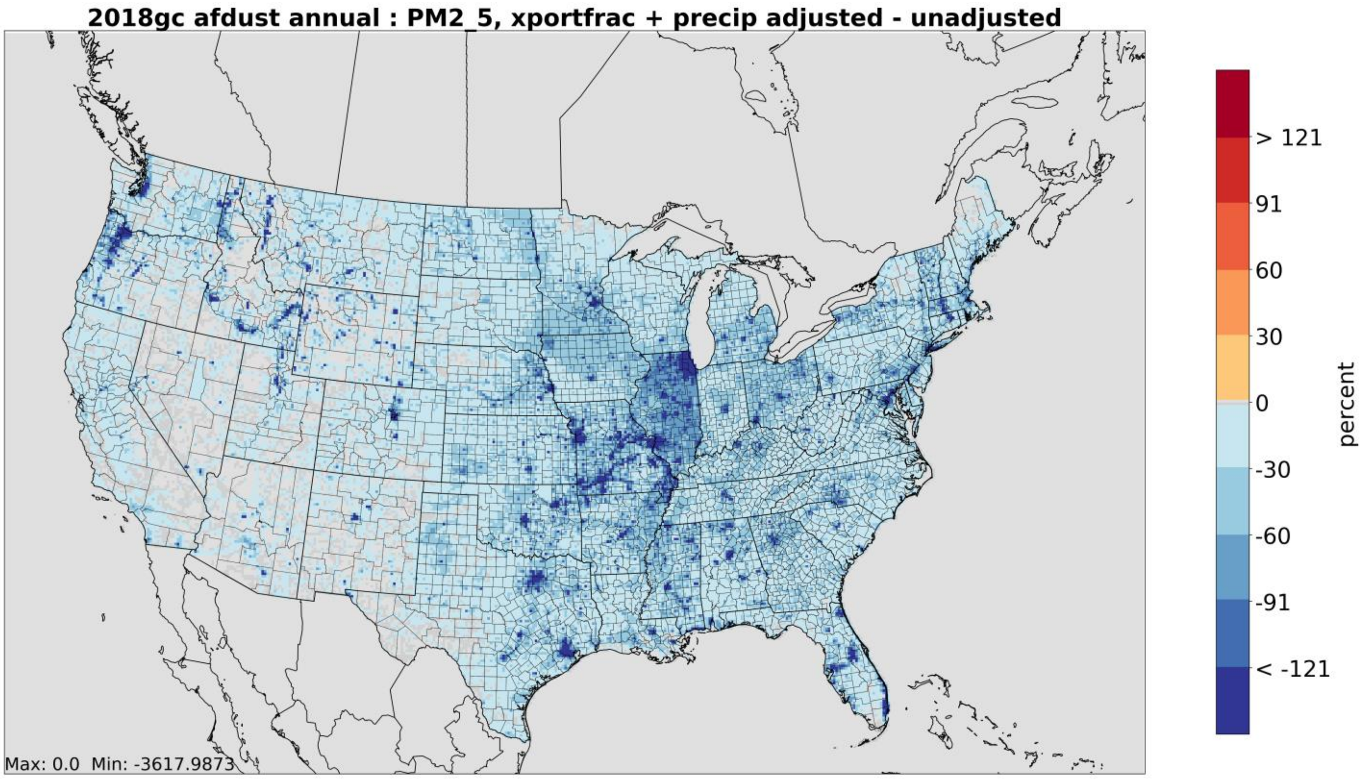
State	Unadjusted PM_{10}	Unadjusted $PM_{2.5}$	Change in PM_{10}	Change in $PM_{2.5}$	PM_{10} Reduction	$PM_{2.5}$ Reduction
Alabama	305,367	41,144	-230,323	-31,003	75%	75%
Arizona	181,909	24,406	-66,546	-8,746	37%	36%
Arkansas	394,141	54,562	-291,744	-39,859	74%	73%
California	310,409	39,283	-129,849	-15,926	42%	41%
Colorado	282,333	41,177	-138,166	-19,575	49%	48%
Connecticut	24,373	4,018	-20,564	-3,402	84%	85%
Delaware	15,399	2,363	-10,975	-1,698	71%	72%
District of Columbia	2,904	408	-2,045	-287	70%	70%
Florida	399,417	55,840	-232,626	-32,611	58%	58%
Georgia	296,293	42,313	-221,055	-31,383	75%	74%
Idaho	566,157	65,518	-293,324	-32,981	52%	50%
Illinois	1,113,448	160,670	-743,938	-106,939	67%	67%
Indiana	145,326	27,135	-104,222	-19,547	72%	72%
Iowa	388,521	57,174	-272,484	-40,050	70%	70%
Kansas	671,159	89,522	-326,621	-43,144	49%	48%
Kentucky	177,791	29,057	-143,563	-23,399	81%	81%
Louisiana	180,054	27,493	-124,363	-18,843	69%	69%
Maine	71,361	8,748	-62,096	-7,617	87%	87%
Maryland	75,016	12,001	-55,750	-8,968	74%	75%
Massachusetts	63,362	9,769	-53,378	-8,193	84%	84%
Michigan	295,317	38,890	-226,158	-29,569	77%	76%
Minnesota	426,574	60,081	-322,412	-45,022	76%	75%
Mississippi	450,394	55,051	-334,736	-40,639	74%	74%
Missouri	1,343,746	159,274	-923,739	-109,115	69%	69%
Montana	503,637	66,766	-315,146	-40,657	63%	61%
Nebraska	518,777	71,853	-287,865	-39,258	55%	55%
Nevada	137,960	18,342	-45,995	-6,095	33%	33%
New Hampshire	20,797	4,369	-18,572	-3,901	89%	89%
New Jersey	32,650	6,098	-25,454	-4,715	78%	77%
New Mexico	212,784	26,470	-81,954	-10,159	39%	38%
New York	235,609	33,253	-196,117	-27,572	83%	83%
North Carolina	237,482	32,163	-177,764	-24,084	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
North Dakota	392,449	60,817	-249,067	-38,155	63%	63%
Ohio	273,606	42,727	-208,705	-32,606	76%	76%
Oklahoma	606,070	82,689	-324,863	-43,387	54%	52%
Oregon	611,834	69,018	-391,320	-43,250	64%	63%
Pennsylvania	136,244	24,437	-114,081	-20,670	84%	85%
Rhode Island	4,674	780	-3,735	-624	80%	80%
South Carolina	120,222	16,728	-85,592	-11,963	71%	72%
South Dakota	216,781	38,647	-127,869	-22,524	59%	58%
Tennessee	142,420	26,141	-109,301	-20,163	77%	77%
Texas	1,345,665	195,743	-683,391	-96,971	51%	50%
Utah	170,178	21,730	-84,218	-10,590	49%	49%
Vermont	76,848	8,552	-68,663	-7,617	89%	89%
Virginia	126,183	20,340	-101,285	-16,401	80%	81%
Washington	233,671	38,073	-127,588	-20,758	55%	55%
West Virginia	85,562	11,078	-77,773	-10,070	91%	91%
Wisconsin	184,558	31,386	-138,771	-23,555	75%	75%
Wyoming	545,710	61,315	-285,547	-31,827	52%	52%
Domain Total (12km CONUS)	**15,353,146**	**2,115,413**	**-9,661,314**	**-1,326,091**	**63%**	**63%**
Alaska	107,706	11,726	-99,218	-10,749	92%	92%
Hawaii	18,243	2,381	-10,203	-1,359	56%	57%
Puerto Rico	1,138,725	152,073	-1,079,286	-144,873	95%	95%
Virgin Islands	1,777	245	-860	-120	48%	49%

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 and precipitation





2.2.2 Agricultural Livestock (livestock)

The livestock sector includes NH3 emissions from fertilizer and emissions of all pollutants other than $PM_{2.5}$ from livestock in the nonpoint (county-level) data category of the 2017NEI. $PM_{2.5}$ from livestock are in the Area Fugitive Dust (afdust) sector. Combustion emissions from agricultural equipment, such as tractors, are in the nonroad sector.

The SCCs included in the livestock sector are shown in Table 2-9. 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 NH_3 emissions, as there is a very small amount of NH_3 emissions from livestock in the ptnonipm inventory (as point sources). In addition to $NH_{3,}$ the sector includes livestock emissions from all pollutants other than $PM_{2.5}$. $PM_{2.5}$ from livestock are in the afdust sector. For 2018v2, corrections were made to the livestock emissions in Maryland and Illinois. Otherwise, the livestock emissions are unchanged from those in 2018gc.

Table 2-9. 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
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

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
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 2018 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 2018 was used to create projection factors (https://quickstats.nass.usda.gov/). The resulting projections factors are shown in Table 2-10. Livestock emissions utilized improved animal population data. VOC livestock emissions, new for this sector, were estimated by multiplying a national VOC/NH_3 emissions ratio by the county NH_3 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. The livestock sector includes VOC and HAP VOC in addition to NH3.

Table 2-10. National projection factors for livestock: 2017 to 2018

beef	+0.74%
swine	+2.66%
broilers	+2.18%
turkeys	-1.37%
layers	+2.19%
dairy	+0.55%

2.2.3 Agricultural Fertilizer (fertilizer)

Using the same method described in the 2017 NEI TSD, fertilizer emissions for 2018 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 (NH_3) 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.

Fertilizer emissions are associated with the SCC 2801700099 (Miscellaneous Area Sources; Ag. Production – Crops; Fertilizer Application; Miscellaneous Fertilizers).

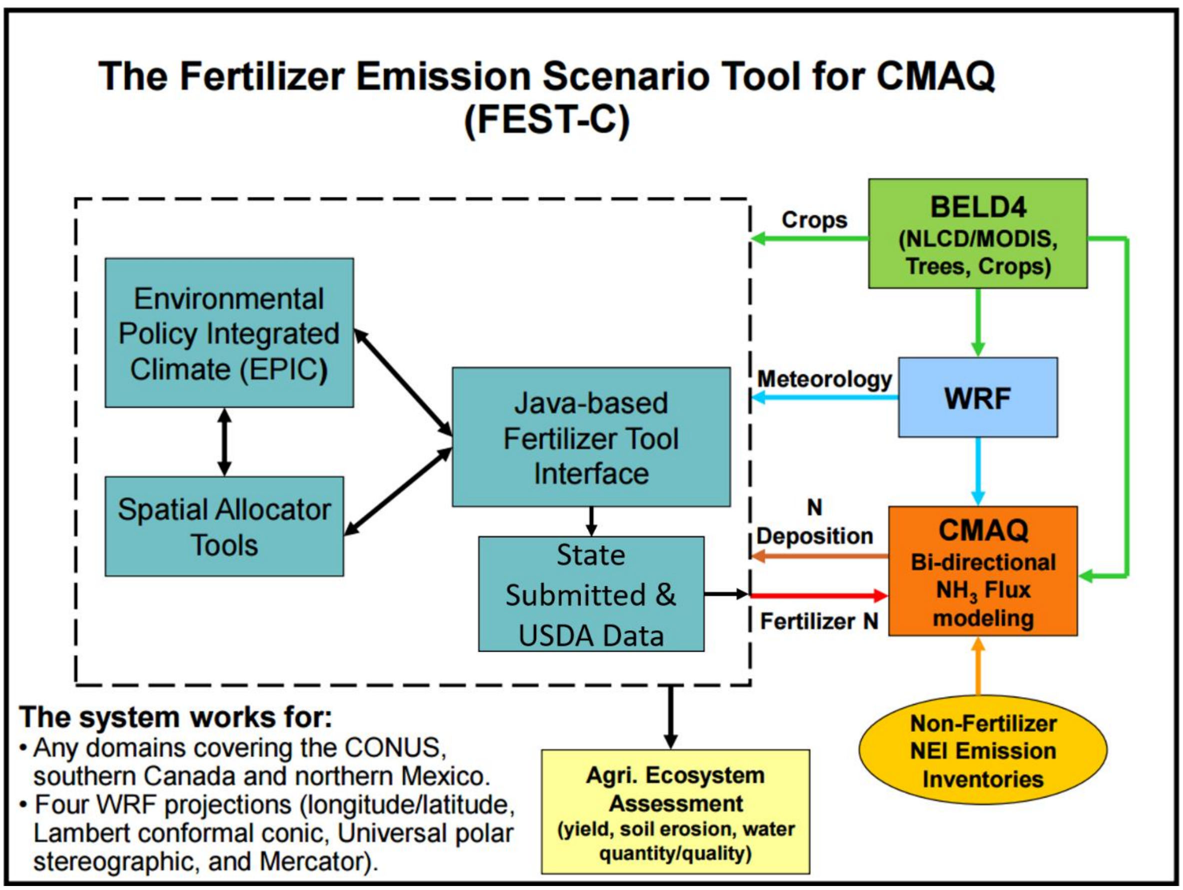
The approach to estimate year-specific fertilizer emissions consists of these steps:

- Run FEST-C to produce nitrate (NO3), Ammonium (NH4+, including Urea), and organic (manure) nitrogen (N) fertilizer usage estimates.
- Run the CMAQ model with bidirectional ("bidi") NH3 exchange to generate gaseous ammonia NH3 emission estimates.
- Calculate county-level emission factors as the ratio of bidirectional CMAQ NH3 fertilizer emissions to FEST-C total N fertilizer application.

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.

As illustrated in Figure 2-2, an iterative calculation was applied to estimate fertilizer emissions for the platform. 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 fertilizer application emissions



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 the base year using a national 12-km rectangular grid covering the continental U.S. The meteorological parameters in Table 2-11 were used as EPIC model inputs.

Table 2-11. 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 was then run for 25 years using current fertilization and agricultural cropping techniques to estimate soil nutrient content and pH.

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 (np_oilgas)

While the major emissions sources associated with oil and gas collection, processing, and distribution have traditionally been included in the National Emissions Inventory (NEI) as point sources (e.g., gas processing plants, pipeline compressor stations, and refineries), the activities occurring "upstream" of these types of facilities have not been as well characterized in the NEI. Here, upstream activities refer to emission units and processes associated with the exploration and drilling of oil and gas wells, and the equipment used at the wellsite to then extract the product from the well and deliver it to a central collection point or processing facility. The types of unit processes found at upstream sites include separators, dehydrators, storage tanks, and compressor engines.

The nonpoint oil and gas (np_oilgas) sector, which consists of oil and gas exploration and production sources, both onshore and offshore (state-owned only). For many states, these emissions are mostly based on the EPA Oil and Gas Tool run with data specific to the year 2018. Because of the growing importance of these emissions, 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.

EPA Oil and Gas Tool

EPA developed the 2018 non-point oil and gas inventory for the 2018v2 platform using the 2017NEI version of the Oil and Gas Emission Estimation Tool (the "Tool") with year 2018 oil and gas production and exploration activity as input into the Tool. The Tool was previously used to estimate emissions for the 2017 NEI. Year 2018 oil and gas activity data were supplied to EPA by some state air agencies, and where state data were not supplied to EPA, EPA populated the 2018v2 inventory with the best available data. 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 creates a CSV-formatted emissions dataset covering all national nonpoint oil and gas emissions. This dataset is then converted to FF10 format for use in SMOKE modeling. A separate report named "2017 Nonpoint Oil and Gas Emission Estimation Tool Revisions_V1 4_11_2019.docx" (ERG, 2019a) was generated that provides technical details of how the tool was applied for the 2017NEI. The 2017 NEI Tool document can be found at: https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/nonpoint/.

Nonpoint Oil and Gas Alternative Datasets

Some states provided, or recommended use of, a separate emissions inventory for use in 2018v2 platform instead of emissions derived from the EPA Oil and Gas Tool. The 2017NEI oil and gas emissions for production-related sources were used for the states of California, Colorado, Oklahoma, Texas, Utah and Wyoming. New Mexico and North Dakota used the WRAP inventory used in the 2016v3 modeling for production-related sources. Emissions from exploration-related sources can vary year to year more so than production-related sources, so the 2018 Oil and Gas Tool emissions for exploration-related sources were used for every state for the 2018v2 modeling platform.

In Pennsylvania for the 2018v2 modeling platform, the emissions associated with unconventional wells for year 2018 were supplied by the Pennsylvania Department of Environmental Protection (PA DEP). The Oil and Gas Tool was used to produce the conventional well emissions for 2018. Together these unconventional and conventional well emissions represent the total non-point oil and gas emissions for Pennsylvania.

2.2.5 Residential Wood Combustion (rwc)

The RWC sector includes residential wood burning devices such as fireplaces, fireplaces with inserts, free standing woodstoves, pellet stoves, outdoor hydronic heaters (also known as outdoor wood boilers), indoor furnaces, and outdoor burning in firepits and chimneys. 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, the conventional units were constructed prior to 1988. Units constructed after 1988 had to meet EPA emission standards and they are either catalytic or non-catalytic.

The 2018 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 2018. 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

The source classification codes (SCCs) in the RWC sector are listed in Table 2-12. For both 2018gc and 2018v2, the emissions use the 2017 NEI.

Table 2-12. SCCs for the residential wood combustion sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
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

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2104008230	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: fireplace inserts; EPA certified; catalytic
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
2104008610	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: outdoor
2104008700	Stationary Source Fuel Combustion	Residential	Wood	Outdoor wood burning device, NEC (fire-pits, chimineas, etc)
2104009000	Stationary Source Fuel Combustion	Residential	Firelog	Total: All Combustor Types

2.2.6 Solvents (np_solvents)

The np_solvents sector includes a diverse collection of sources for which 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 (i.e., VOCs) with 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); as such, these emissions are frequently described as volatile chemical products (VCPs).

The types of sources in the np_solvents sector include, but are not limited to, solvent utilization for the following:

- surface coatings such as architectural coatings, auto refinishing, traffic marking, textile production, furniture finishing, and coating of paper, plastic, metal, appliances, and motor vehicles;
- degreasing of furniture, metals, auto repair, electronics, and manufacturing;
- dry cleaning, graphic arts, plastics, industrial processes, personal care products, household products, adhesives and sealants; and
- asphalt application, roofing asphalt, and pesticide application.

For the 2018v2 platform, emissions for the np_solvents sector are derived using the 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, 2021), 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 and are retrieved from the Federal Reserve Bank of St. Louis (U.S. Bureau of Labor Statistics, 2020).

When national product usage data are unavailable, default usage estimates were 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 (CARB, 2007; CARB, 2012; CARB 2014; CARB, 2018; CARB, 2019) and 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). All methods are thoroughly documented in Section 32 of the 2020 NEI Technical Source Document.

National-level emissions estimates were allocated to the county-level using several proxies. Most emissions are allocated using population as an allocation surrogate. This includes all cleaners, personal care products, adhesives, architectural coatings, and aerosol coatings. Industrial coatings, 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, 2018) and follow the same mapping scheme used in the EPA's 2020 National Emissions Inventory (EPA, 2023b). Agricultural pesticides are allocated using county-level agricultural pesticide use, as taken from the 2017 NEI and traffic marking coatings are allocated using estimates of vehicular lane miles traveled on paved roads from the Federal Highway Administration and MOVES model. All activity data reflects the most recently available dataset.

In addition, point and nonpoint emissions for which SCCs overlap are reconciled using point source subtraction. Point source subtraction was performed at the county-level using estimates of uncontrolled point source emissions. Uncontrolled point source emission calculations were calculated, as necessary, using the submitted point source emissions, engineering judgement, and an assumed control efficiency.

2.2.7 Nonpoint (nonpt)

The 2018 platform nonpt sector inventory is mostly unchanged from the January 2021 version of the 2017 NEI, aside from the removal of emissions from accidental releases in a few states. The nonpt sector includes all nonpoint sources that are not included in the sectors afdust, livestock, fertilizer, cmv_c1c2, cmv_c3, np_oilgas, rail, rwc, or np_solvents. The types of sources in the nonpt sector include, but are not limited to:

- stationary source fuel combustion, including industrial, commercial, and residential and orchard heaters;
- commercial sources such as commercial cooking;
- industrial processes such as chemical manufacturing, metal production, mineral processes, petroleum refining, wood products, fabricated metals, and refrigeration;
- storage and transport of petroleum for uses such as gasoline service stations, aviation, and marine vessels;
- storage and transport of chemicals;

- waste disposal (including composting);
- miscellaneous non-industrial sources such as cremation, hospitals, lamp breakage, and automotive repair shops;
- bulk gasoline terminals;
- portable fuel containers (i.e., gas cans);
- cellulosic biorefining;
- biomass fuel combustion;
- stage 1 refueling emissions at gas stations;
- and any construction agricultural dust that is not part of the area fugitive dust or livestock sectors.

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 2018 modeling platform, VMT were projected from 2017 to 2018 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 2018 VMT. In addition, a number of states submitted 2017-specific activity data for incorporation into this platform. Finally, a new MOVES run for 2018 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 2018 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, NOx, 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 2-13. 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. For the portion of Southeast Alaska which lies inside the 36US3 modeling domain, SMOKE-MOVES was run using meteorology for the 36US3 domain; this extra run is included in the onroad_nonconus sector. In some summary reports these non-CONUS emissions are aggregated with emissions from the onroad sector.

Table 2-13. 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 2018-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 291 representative counties in the continental U.S. and a total of

329 including the non-CONUS areas. The representative counties that were used for the 2018 platform are very close to what was used in EPA's Air QUAlity TimE Series (EQUATES) project for the years 2016 and 2017 (EPA 2023c). 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, vehicle population (VPOP) is used for many off-network processes, 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 2018 platform are based on the 2017 NEI, development of which is 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 2018. 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 2018 modeling platform, VMT were projected from 2017 to 2018 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.

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 2018; 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). New Jersey's submittal of hoteling activity specified a 30% APU split, and this was used throughout NJ. For the rest of the country, a 12.4% APU split was used, meaning that during 12.4% 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.

2018 STARTS = 2018 VMT * (2017 STARTS/ 2017 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.

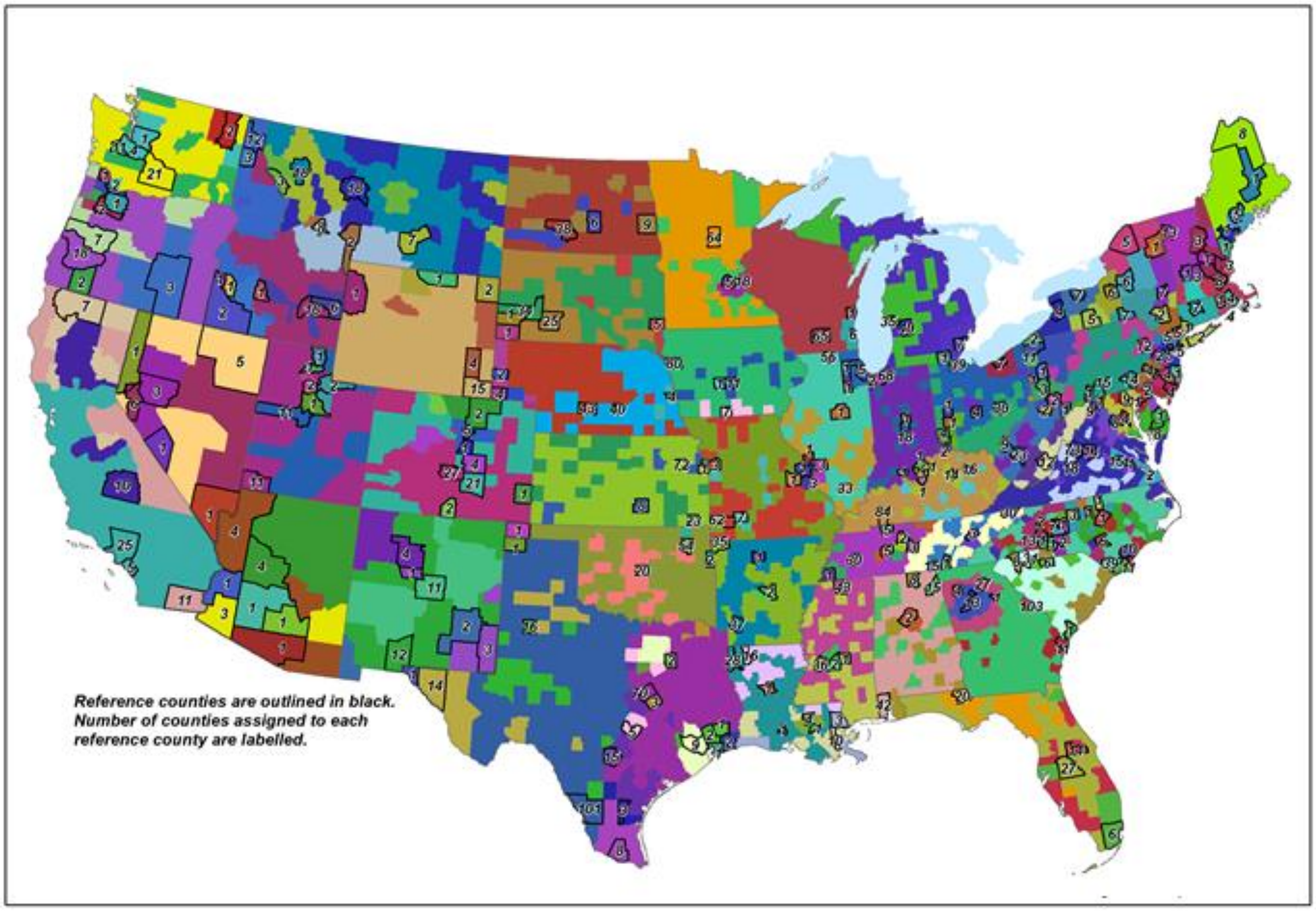
ONI activity hours were calculated based on VMT. For each representative county, the ratio of ONI hours to onroad VMT (on all road types) was calculated using the MOVES ONI Tool by source type, fuel type, and month. These ratios are then multiplied by each county's total VMT (aggregated by source type, 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 2018, 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 2018. The range of temperatures run along with the average humidities used were specific to the year 2018. 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 2018. 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, although no air quality modeling was done for these areas outside the contiguous US.

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, and the mean light-duty age. A binning algorithm was executed to identify "like counties." The result was 291 representative counties for CONUS and 38 for Alaska, Hawaii, Puerto Rico, and the US Virgin Islands, similar to the one shown in Figure 2-3 except for a few changes in North Carolina and Nebraska. In North Carolina there are 12 representative counties for 2018, while the figure shows 16. In Nebraska, Loop County (31115) is a separate representative county but that is not shown in the figure.

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 2-14 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 2-14. Fraction of IHS Vehicle Populations to Retain

Model	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 2018. 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 2018. 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 2018. In addition, the range of temperatures run along with the average humidities used were specific to the year 2018. 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 emissions for 2023 as part of the 2016v1 platform development. EPA interpolated between the 2017 and 2023 emissions to calculate the 2018 onroad emissions for California. The California inventory had CAPs only and did not have NH_3 or refueling emissions. The EPA added NH_3 to the CARB inventory by using the state total NH_3 from MOVES and allocating it at the county level based on CO. Refueling emissions were projected from the 2017 NEI using county total refueling VOC from EQUATES 2017 and the 2018 MOVES3 onroad run for California. 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. All emissions in this sector are annual and at county-SCC resolution; however, in the NEI they are provided at the sub-county level (i.e., port shape ids, where applicable) and by SCC. For more information on CMV sources in the 2017 NEI, see Section 4.21 of the 2017 NEI TSD and the supplemental documentation for 2017 NEI CMV.[3] C1 and C2 emissions that occur outside of state waters are not assigned to states. For this modeling platform, all CMV emissions in the cmv_c1c2 sector were treated as hourly gridded point sources with stack parameters that should result in them being placed in layer 1. The C1C2 CMV emissions were projected from 2017 to 2018 by applying an adjustment factor of 1.012 to the 2017 NEI emissions values.

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.

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

[3] https://www.epa.gov/sites/default/files/2019-11/cmv_methodology_documentation.zip.

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 in the base year inventory are categorized as operating either in-port or underway and as main and auxiliary engines are encoded using the SCCs listed in Table 2-13.

Table 2-15. SCCs for cmv_c1c2 sector

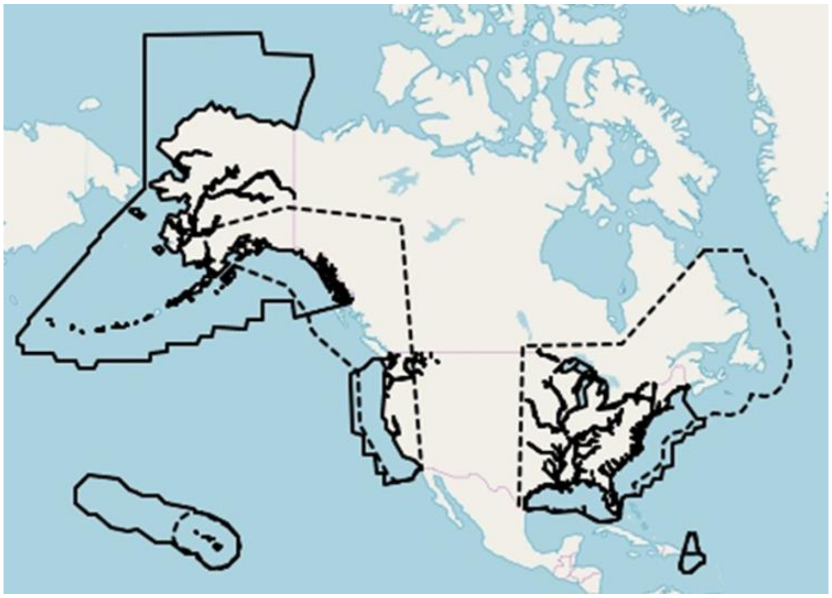
SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2280002101	C1/C2	Diesel	Port	Main
2280002102	C1/C2	Diesel	Port	Auxiliary
2280002201	C1/C2	Diesel	Underway	Main
2280002202	C1/C2	Diesel	Underway	Auxiliary

Category 1 and 2 CMV emissions were developed for the 2017 NEI,[4] The 2017 NEI 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) in order to quantify all ship activity which occurred between January 1 and December 31, 2017. The provided AIS data extends beyond 200 nautical miles from the U.S. coast (Figure 2-4). 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.

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 with excellent resolution in time and space. 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, 2018).

[4] Category 1 and 2 Commercial Marine Vessel 2017 Emissions Inventory (ERG, 2019b).

Figure 2-4. 2017NEI geographical extent of marine emissions (solid) and the U.S. ECA (dashed)



The engine bore and stroke data were used to calculate cylinder volume. Any vessel with a calculated cylinder volume greater than 30 liters was incorporated into the USEPA's 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). Following this, there were 422 million records remaining.

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**.

$$Emissions_{interval} = Time\ (hr)_{interval} \times Power(kW) \times EF(g/kWh) \times LLAF \qquad \textbf{Equation 2-1}$$

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 to determine their vessel type, and thus their vessel group, power rating, and engine tier information which are required for the emissions calculations. See the 2017 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 2-16. In total, 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 2-16. 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
Reefer	13
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 2-15.

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, PM_{10}, $PM_{2.5}$, CO, CO_2, SO_2 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.[5] Hazardous air pollutants and ammonia were added to the inventory according to multiplicative factors applied either to VOC or $PM_{2.5}$.

For more information on the emission computations for 2017, see the supporting documentation for the 2017 NEI C1C2 CMV emissions. The emissions from the 2017 NEI were adjusted to represent 2018 in the cmv_c1c2 sector by applying a factor of 1.012 to all pollutants (based on EIA fuel use data). For consistency, the same methods were used for California, Canadian, and other non-U.S. emissions. The 2017 emissions were mapped to 2018 dates so that the activity occurred on the same day of the week in the same sequential week of the year in both years. Holidays and days of the week were mapped from the dates in 2017 to the corresponding dates in 2018 to preserve weekday-weekend and holiday-centered fluctuations in emissions in each of the years. Individual vessels that released emissions within the same grid cell for over 400 hours were flagged as hoteling. The emissions from the hoteling vessels were scaled to the 400-hour cap. Both the annual and hourly inventory files were projected to 2018 using the same projection factor of 1.012.

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.[6] 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 CMV sources in the 2017 NEI, see Section 4.21 of the 2017 NEI TSD and the supplemental documentation for 2017 NEI CMV.[7]

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 2018 inventory but are in separate files from the emissions around the continental United States (CONUS). The cmv_c3 sources in the 2018 inventory are categorized as operating either in-port or underway and are encoded using the SCCs listed in Table 2-17. and distinguish between diesel and residual fuel, in port areas versus underway, and main and auxiliary engines. In addition to C3 sources in state and federal waters, the cmv_c3 sector includes emissions in waters not covered by the NEI (FIPS = 98) and taken from the "ECA-IMO-based" C3 CMV inventory.[8]

---

[5] 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.

[6] https://www.epa.gov/regulations-emissions-vehicles-and-engines/regulations-emissions-marine-vessels.

[7] https://www.epa.gov/sites/default/files/2019-11/cmv_methodology_documentation.zip.

[8] https://www.epa.gov/sites/production/files/2017-08/documents/2014v7.0_2014_emismod_tsdv1.pdf.

The ECA-IMO inventory is also used for allocating the FIPS-level emissions to geographic locations for regions within the domain not covered by the AIS selection boxes as described in the next section.

Table 2-17. SCCs for cmv_c3 sector

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2280002103	C3	Diesel	Port	Main
2280002104	C3	Diesel	Port	Auxiliary
2280002203	C3	Diesel	Underway	Main
2280002204	C3	Diesel	Underway	Auxiliary
2280003103	C3	Residual	Port	Main
2280003104	C3	Residual	Port	Auxiliary
2280003203	C3	Residual	Underway	Main
2280003204	C3	Residual	Underway	Auxiliary

Prior to creation of the 2017 NEI, 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, 2017. 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 2017 NEI CMV emissions were computed based on the AIS data from the USCG for the year of 2017. 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.

Prior to their 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.

[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.

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**.

$$Emissions_{interval} = Time\ (hr)_{interval} \times Power(kW) \times EF(g/kWh) \times LLAF \qquad \textbf{Equation 2-2}$$

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. 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.

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 those files were also generated for each year.

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.

There were some areas needed for modeling that the AIS request boxes did not cover (see Figure 2-4). These include a portion of the St. Lawrence Seaway transit to the Great Lakes, a small portion of the Pacific Ocean far offshore of Washington State, portions of the southern Pacific Ocean around off the coast of Mexico, and the southern portion of the Gulf of Mexico that is within the 36-km domain used for air quality modeling. In addition, a determination had to be made regarding whether to use the existing Canadian CMV inventory or the more detailed AIS-based inventory. The AIS-based inventory was used in the areas for which data were available, and the areas not covered were gap-filled with inventory data from the 2016beta platform, which included data from ECCC and the 2011 ECA-IMO C3 inventory.

For the gap-filled areas not covered by AIS selected data areas or the ECCC inventory, the 2016 nonpoint C3 inventory provided by ECCC was converted to a point inventory to support plume rise calculations for C3 vessels. The nonpoint emissions were allocated to point sources using a multi-step allocation process because not all of the inventory components had a complete set of county-SCC combinations. In the first step, the county-SCC sources from the nonpoint file were matched to the county-SCC points in the 2011

[10] Ammonia (NH_3) was also added by SMOKE in the speciation step.

ECA-IMO C3 inventory. The ECA-IMO inventory contains multiple point locations for each county-SCC. The nonpoint emissions were allocated to those points using the $PM_{2.5}$ emissions at each point as a weighting factor.

For cmv_c3 underway emissions without a matching FIPS in the ECA-IMO inventory were allocated using the 12 km 2014 offshore shipping activity spatial surrogate (surrogate code 806). Each county with underway emissions in the area inventory was allocated to the centroids of the cells associated with the respective county in the surrogate. The emissions were allocated using the weighting factors in the surrogate.

The resulting point emissions centered on each grid cell were converted to an annual point 2010 flat file format (FF10). A 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.

<u>Adjustment of the 2017 NEI CMV C3 to 2018</u>

Both the annual and hourly Category 3 (C3) CMV emissions were projected from 2017 to 2018 using factors derived from an EPA report on projected bunker fuel demand (See Table 2-18). The report projects bunker fuel consumption by region out to the year 2030. Bunker fuel usage was used as a surrogate for marine vessel activity. Factors based on the report were used for all pollutants except NOx. Growth factors for NOx emissions were handled separately to account for the phase in of Tier 3 vessel engines. The projection factors are shown in Table 2-18.

Table 2-18. Projection Factors for 2017 to 2018 for Category 3 Vessels

Region	NOx	All other pollutants
US East Coast	0.9869	1.0346
US South Pacific	0.9494	1.0153
US North Pacific	0.9926	1.0246
US Gulf of Mexico	0.9910	1.0253
US Great Lakes	1.0051	1.0173

The cmv_c3 projection factors were pollutant-specific and region-specific. Most states are mapped to a single region with a few exceptions. Pennsylvania and New York were split between the East Coast and Great Lakes, Florida was split between the Gulf Coast and East Coast, and Alaska was split between Alaska East and Alaska West. The non-federal factors listed in this table were applied to sources outside of U.S. federal waters (FIPS 98). Volatile Organic Compound (VOC) Hazardous Air Pollutant (HAP) emissions were projected using the VOC factors. NH3 emissions were computed by multiplying PM2.5 by 0.019247.

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 2-19. More detailed information on the development of the 2017 NEI rail inventory for this study is available in the 2017 NEI TSD. The 2017 NEI rail inventory was projected to 2018 using activity-based factors shown in Table 2-20. This activity-based factor was based on AEO fuel data.

Table 2-19. 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 2-20. 2017-to-2018 projection factors for the rail sector

NO_x	PM	VOC	Other pollutants
+2.44%	-3.29%	-2.95%	+6.63%

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)

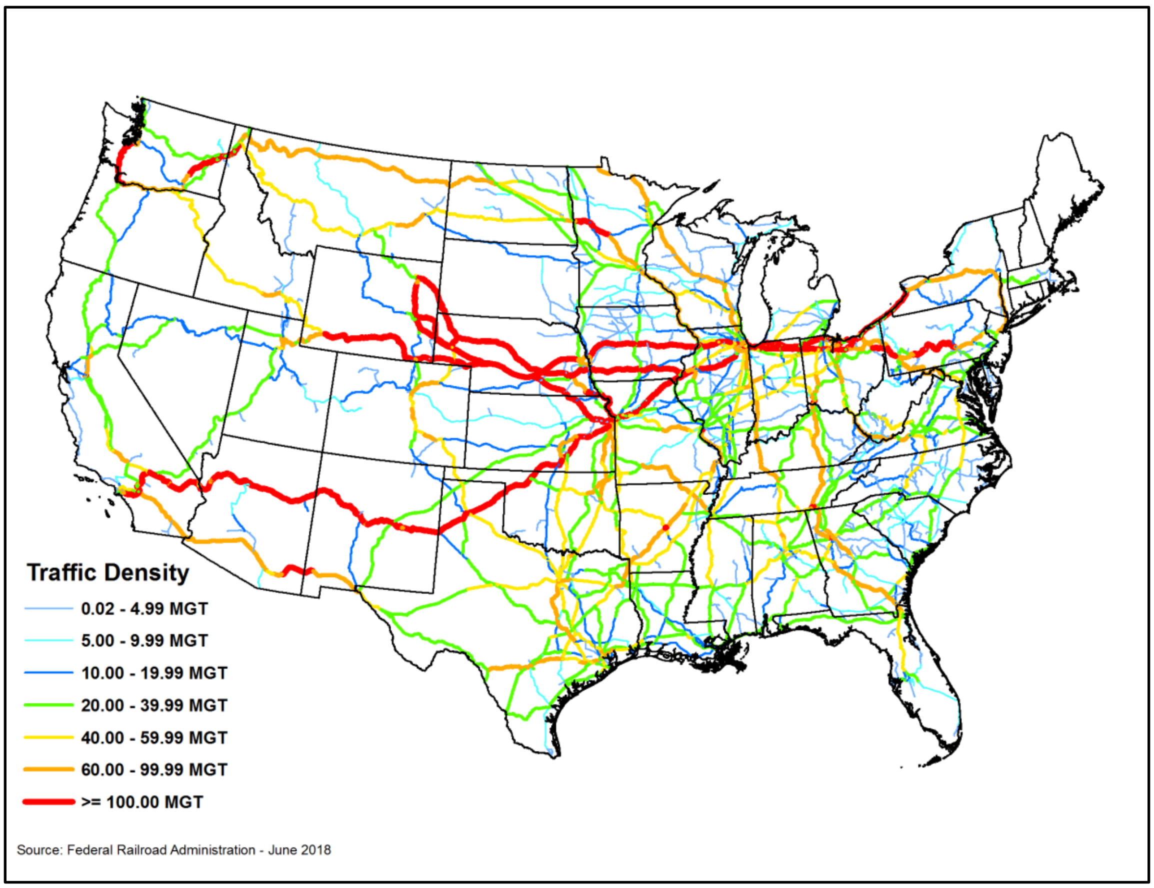
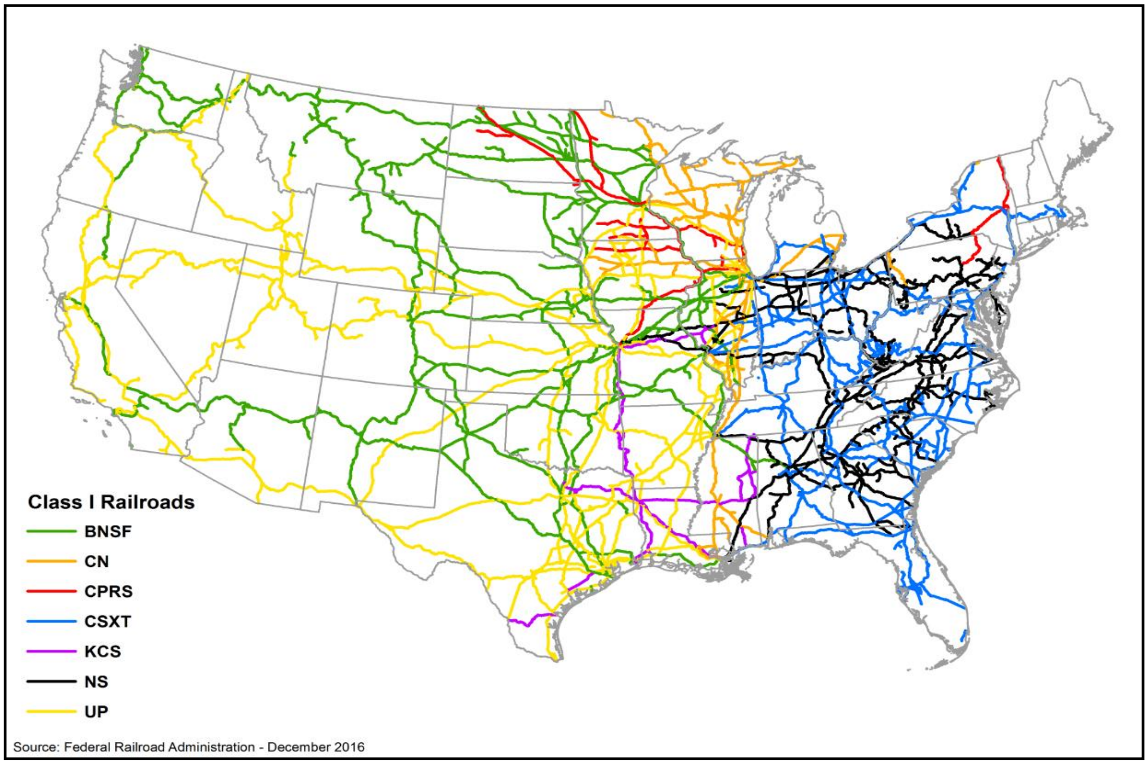


Figure 2-6. Class I Railroads in the United States

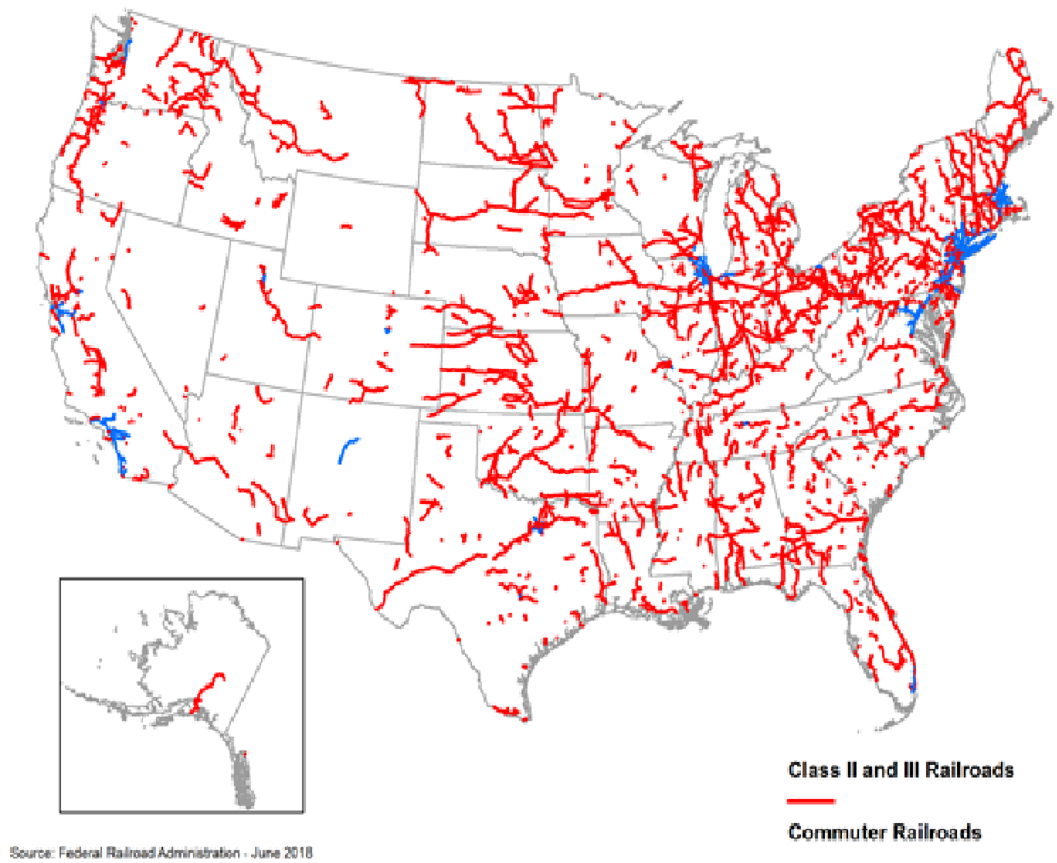


Class II and III Methodology

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.

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



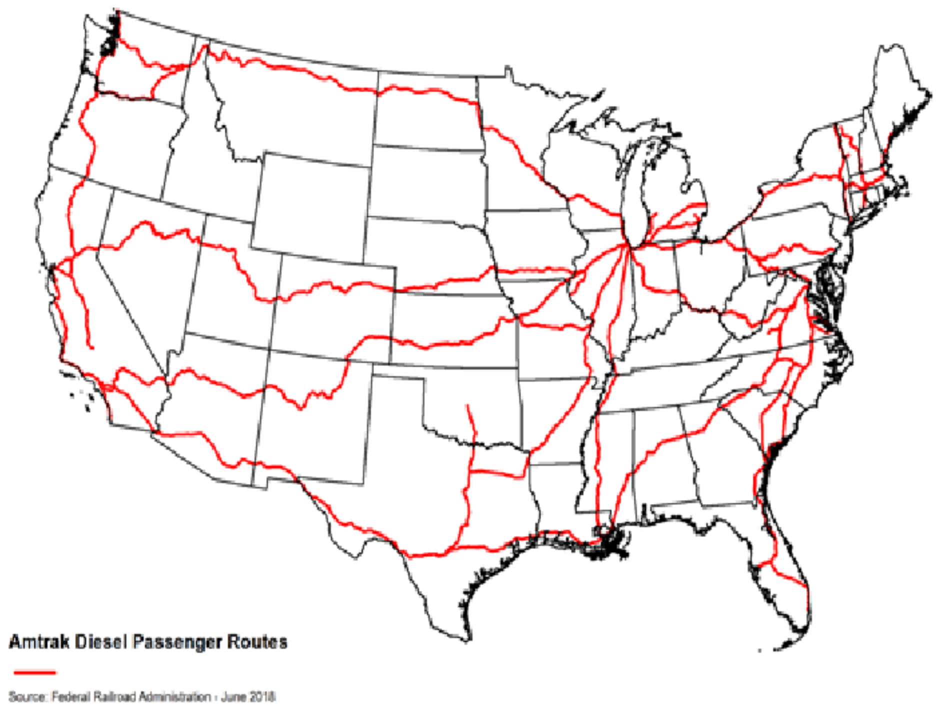
Commuter Rail Methodology

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 it 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.

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 off-road 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 2018 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 2018 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 available as part of the 2017 NEI.
- 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 created at this stage of the process to facilitate the calculation of PMC within SMOKE and for the development of emissions summaries.
- 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 and Texas emissions from MOVES were deleted and replaced with CARB- and TCEQ-supplied emissions, respectively.

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). EPA updated the construction equipment allocation data used in MOVES for the 2016v1 platform ad those updates are retained for use in this platform. Updated *nrsurrogate*, *nrstatesurrogate*, and *nrbaseyearequippopulation* tables that implement these updates, 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 updates are not included in MOVES3.

More information on the development of the updates to agricultural and construction equipment allocations is available in Section 2.4.4 of the 2016v3 platform TSD (EPA, 2023a).

Emissions Inside California and Texas

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 2018. 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 2018. 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 2018 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 2018 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 2-21). Note that this is only relevant for the 36km grid used in this study because Alaska does not overlap the 12km grid.

Table 2-21. Alaska counties/census areas for which specific nonroad emissions were removed

Nonroad Equipment Sector	Counties/Census Areas (FIPS) for which equipment sector emissions are removed
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-wild, ptfire-rx, 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 2-22. 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 for the Flint Hills in Kansas have their own SCC (2811021000) in the inventory. These wild grassland fires were assigned the standard wildfire SCCs shown in Table 2-22.

Table 2-22. SCCs included in the ptfire sector

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 2018 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
- Incident reports including dates of fire activity, acres burned, and fire locations from the National Association of State Foresters (NASF)
- 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)
- Wildfire and prescribed date, location, and locations from a few S/L/T activity submitters (includes Georgia, Florida and Kanas(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 2018 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.

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 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.

The National Association of State Foresters (NASF) is a non-profit organization composed of the directors of forestry agencies in the states, U.S. territories, and District of Columbia to manage and protect state and private forests, which encompass nearly two-thirds of the nation's forests. The NASF compiles fire incident reports from agencies in the organization and makes them publicly available. The NASF fire information includes dates of fire activity, acres burned, and fire location information.

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 2018 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 2018 data were acquired from USFWS through direct communication with USFWS staff and were used for 2018 platform development. The USFWS fire information provided fire type, acres burned, latitude-longitude, and start and ending times.

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 2018 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). For the purposes of the inventory the residual smoldering emissions were allocated to the smoldering SCCs listed in Table 2-20, while the lofted smoldering emissions were assigned to the flaming emissions SCCs.

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 2018 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

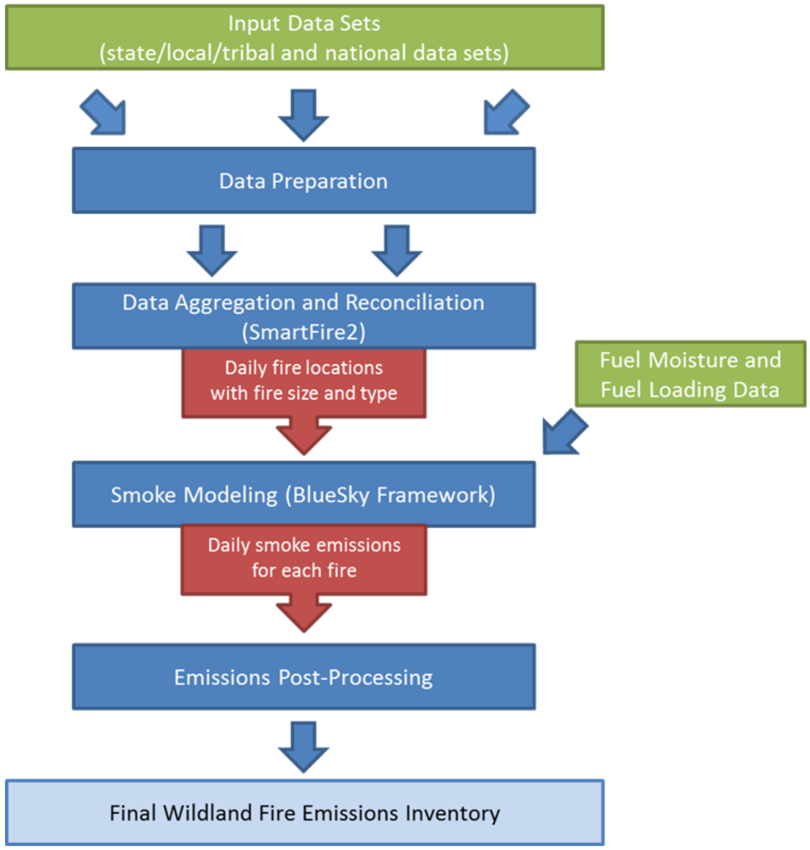
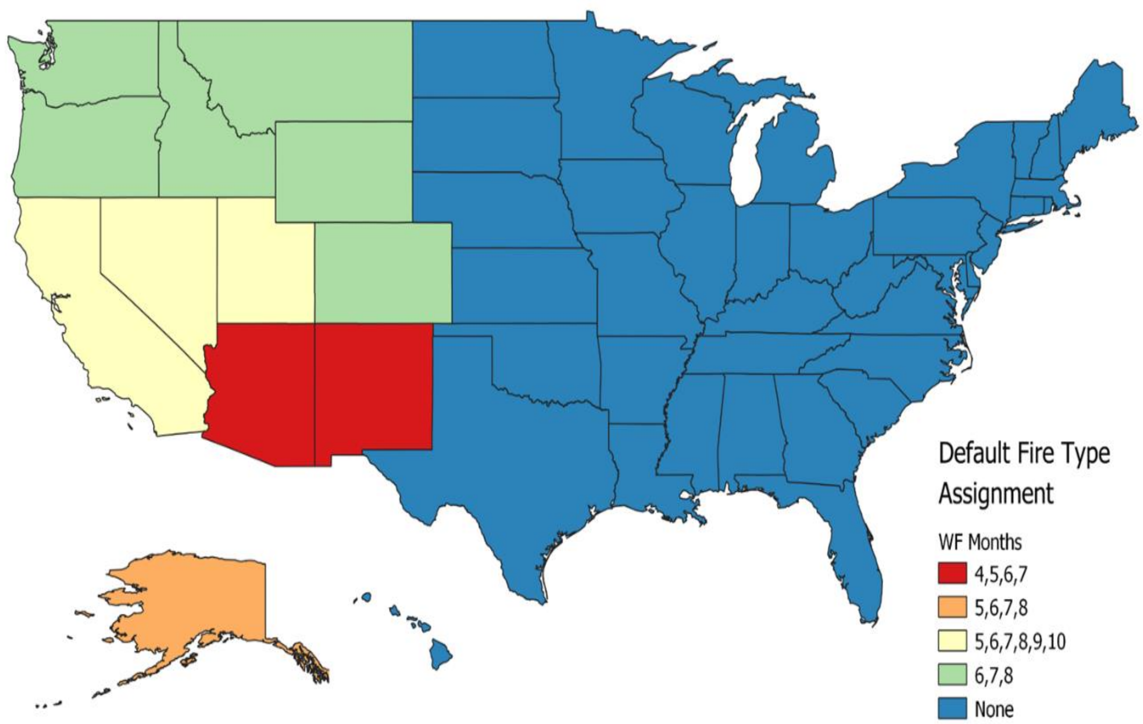


Figure 2-10. Default fire type assignment by state and month where data are only from satellites.

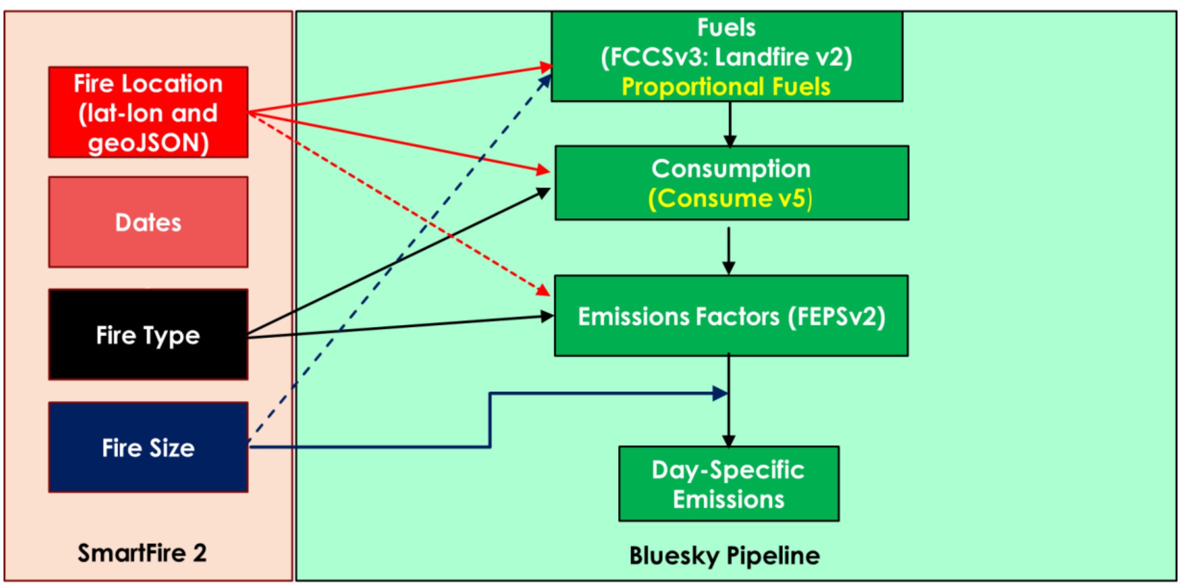


The second system used to estimate emissions is the BlueSky Modeling Pipeline. The framework supports the calculation of fuel loading and consumption, and emissions using various models depending on the available inputs as well as the desired results. The contiguous United States and Alaska, where Fuel Characteristic Classification System (FCCS) fuel loading data are available, were processed using the modeling chain described in Figure 2-11. The Fire Emissions Production Simulator (FEPS) in the BlueSky Pipeline generates all the CAP emission factors for wildland fires used in the 2018 study. HAP emission factors were obtained from Urbanski's (2014) work and applied by region and by fire type.

The FCCSv3 cross-reference was implemented along with the LANDFIREv1 (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 reprojection 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).

Figure 2-11. Blue Sky Pipeline



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 2018 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 2018 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 were moved to the ptfire sectors for this 2018 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 2-23.

Table 2-23. 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 2018 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 2018 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 2018 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 18j version of the 2018 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 2-24.

Table 2-24. 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/).

A minor bug correction was implemented in BEIS3 to correctly use a few agricultural landuse types in BELD5 that resulted in a minor increase of 1.6% in nitric oxide emissions from soils for the CONUS region. Additionally, a minor map projections issue was found in the BELD5 data used in 2018v1. This was corrected in 2018v2 and resulted in a 0.1% increase in VOC in the CONUS region and a 2.3% increase in VOC emissions in the Canadian provinces.

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 biogenic emissions 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. 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.

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 (othpt 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)
- Other area sources (othar sector)

Canadian CMV inventories that had been included in this sector in past modeling platforms are included in the cmv_c1c2 and cmv_c3 sectors as hourly point sources. The 2017 NEI CMV included most coastal waters of Canada and Mexico with emissions derived from AIS data. These NEI emissions were used for all areas of Canada and Mexico in which they were available and are included in the cmv_c1c2 and cmv_c3 sectors. Both the C1C2 and C3 emissions were developed in a point source format with point locations at the center of the 12km grid cells. Activity and corresponding emissions along the St. Lawrence Seaway were not included in the NEI. This region was gapfilled with emissions provided by ECCC that were apportioned to point sources on the centroids of 12km grid cells using the Canadian commercial marine vessel surrogate (CA 945). The Canadian emissions were held flat from 2017 to 2018.

In addition to emissions inventories, the ECCC 2015 dataset also included temporal profiles, and shapefiles for creating spatial surrogates. These profiles and surrogates were used 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 2018. 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 to from the Inventario Nacional de Emisiones de Mexico, 2016 (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)). As in the EQUATES project, the 2016 Mexico emissions were projected to 2018 using trends from the Community Emissions Data System (CEDS) dataset. The point source emissions were converted to English units and into the FF10 format that could be read by SMOKE, missing stack parameters were gapfilled using SCC-based defaults, and latitude and longitude coordinates were verified and adjusted if they were not consistent with the reported municipality. Only CAPs are covered in the Mexico point source inventory.

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 2018 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 2018 using US MOVES-based trends. For Mexico, 2016 Mexico nonpoint and nonroad inventories at the municipio resolution provided by SEMARNAT were used, and were projected to 2018 using trends from the Community Emissions Data System (CEDS) dataset. 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 2018 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 2018 for this study.

2.7.5 Fires in Canada and Mexico (*ptfire_othna*)

Annual 2018 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 Fires in Canada and Mexico (*ptfire_othna*)

Annual 2018 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.

2.7.7 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 36 km and 12 km resolution were available and were not modified other than the model-species name “CHLORINE” was changed to “CL2” to support CMAQ modeling.

For mercury, the same volcanic mercury emissions were used as in the last several modeling platforms. 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).

Because of mercury bidirectional flux within the latest version of CMAQ, the only natural mercury emissions included in the merge are from volcanoes.

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 discussed 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, which were then converted to CAMx. 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 biogenic speciation is done within the Tmpbeis4 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	
afdust_ak_adj (36US3 only)	Surrogates	Yes	Annual	
airports	Point	Yes	Annual	None
beis	Pre-gridded land use and biomass data	in BEIS3.7	computed hourly	
canada_ag	Point	Yes	monthly	None
canada_og2D	Point	Yes	Annual	None
cmv_c1c2	Point	Yes	hourly	in-line
cmv_c3	Point	Yes	hourly	in-line
fertilizer	Surrogates	No	monthly	
livestock	Surrogates	Yes	Annual	
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_nonconus (36US3 only)	Surrogates	Yes	monthly activity, computed hourly	
onroad_can	Surrogates	Yes	monthly	
onroad_mex	Surrogates	Yes	monthly	
othafdust_adj	Surrogates	Yes	annual	

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
othar	Surrogates	Yes	annual & monthly	
othpt	Point	Yes	annual & monthly	in-line
othptdust_adj	Point	Yes	monthly	None
ptagfire	Point	Yes	daily	in-line
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	

Biogenic emissions can be modeled two different ways in the CMAQ model. The BEIS model within 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 platform, biogenic emissions were processed in SMOKE and included in the gridded CMAQ-ready emissions. When CAMx is the targeted air quality model, BEIS is run within SMOKE and the resulting emissions are included with the ground-level emissions input to CAMx.

In 2018v2, SMOKE was run in such a way that it produced both diesel and non-diesel outputs for onroad and nonroad emissions that later get merged into the low-level emissions fed into the air quality model. This facilitates advanced speciation treatments that are sometimes used in CMAQ. The onroad emissions were processed in a single sector and were not split between gas and diesel for the 2032 case.

SMOKE has the option of grouping sources so that they are treated as a single stack when computing plume rise. For this platform, no grouping was performed because grouping combined with "in-line" processing will not give identical results as "offline" processing (i.e., when SMOKE creates 3-dimensional files). This occurs when stacks with different stack parameters or latitudes/longitudes are grouped, thereby changing the parameters of one or more sources. The most straightforward way to get the same results between in-line and offline is to avoid the use of grouping.

For 2018gg, SMOKE was run for two modeling domains: a 36-km resolution CONtinental United States "CONUS" modeling domain (36US3), and a 12-km resolution domain. For 2032, SMOKE was only run at 12-km resolution. The domains are shown in Figure 3-1. More specifically, for each of the 12-km resolution runs, SMOKE was run on the 12US1 domain and emissions were extracted from the 12US1 data files to create emissions for 12US2. Following the CMAQ run for 2018gg, the CMAQ outputs on the 36US3 grid were used to create boundary conditions for the 12US2 domain used for both 2018 and 2032. All grids use a Lambert-Conformal projection, with Alpha = 33º, Beta = 45º and Gamma = -97º, with a center of X = -97º and Y = 40º. Table 3-2 describes the grids for each of the domains.

Figure 3-1. Air quality modeling domains

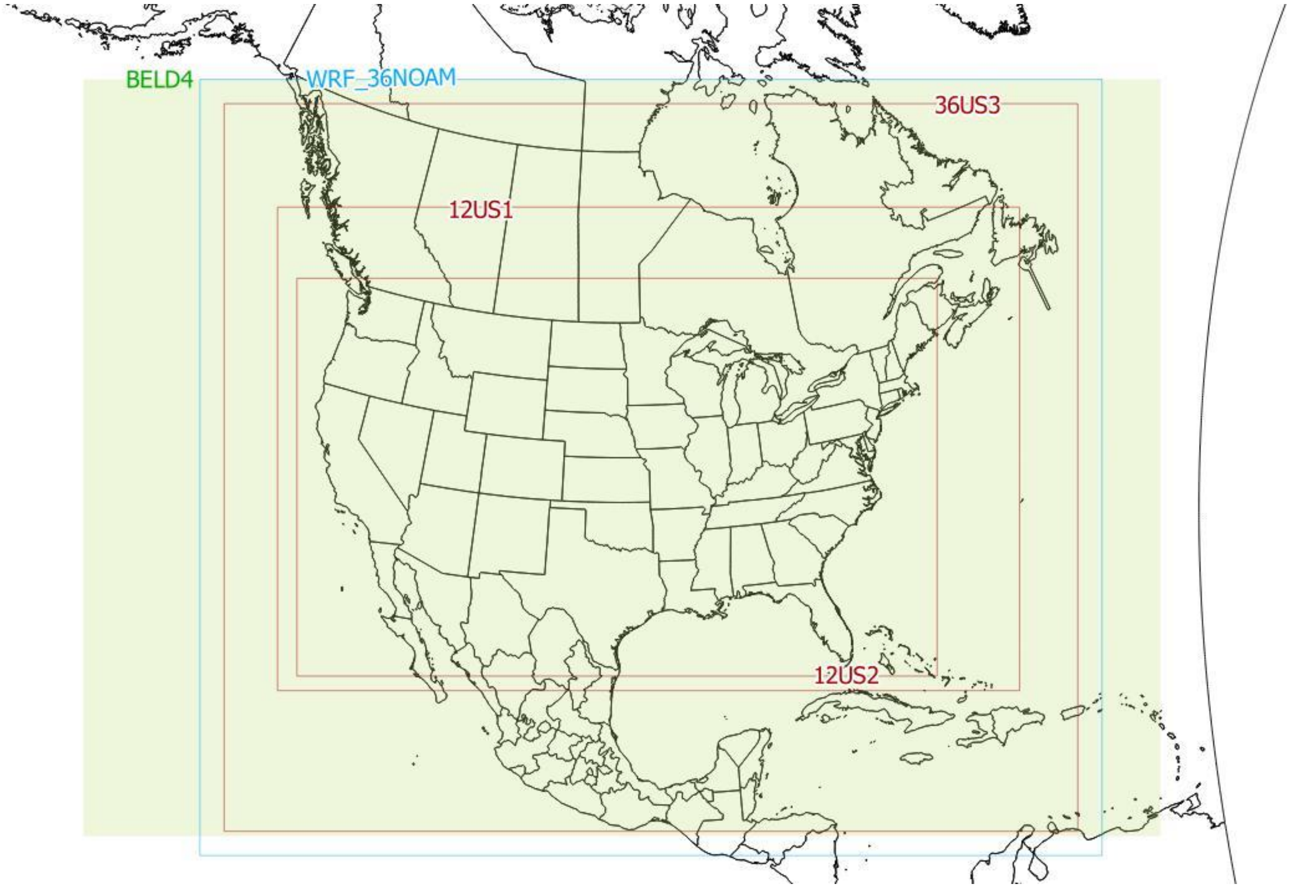


Table 3-2. Descriptions of the platform grids

Common Name	Grid Cell Size	Description (see Figure 3-1)	Grid name	Parameters listed in SMOKE grid description (GRIDDESC) file: projection name, xorig, yorig, xcell, ycell, ncols, nrows, nthik
Continental 36km grid	36 km	Entire conterminous US, almost all of Mexico, most of Canada (south of 60°N)	36US3	'LAM_40N97W', -2952000, -2772000, 36.D3, 36.D3, 172, 148, 1
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

3.2 Chemical Speciation

The emissions modeling step for chemical speciation creates the "model species" needed by the air quality model for a specific chemical mechanism. These model species are either individual chemical compounds (i.e., "explicit species") or groups of species (i.e., "lumped species"). The chemical mechanism used for the 2018 platform is the CB6R3AE7 mechanism (Yarwood, 2010, Luecken, 2019). In CB6R3AE7, additional species that are not included in the CB6 chemical mechanism include acetic acid (ACET), alpha pinene (APIN), formic acid (FACD), and intermediate volatility organic compounds (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 (Ramboll, 2020) 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).

For 2018v2, the key changes to speciation involved updating some speciation cross references and using newly available speciation profiles for solvents, oil and gas, and some point source SCCs. In addition, the mapping for SOAALK species were updated to exclusively include linear and branched alkanes with more than 8 carbons or cyclic alkanes with more than 6 carbons (Pye, 2012).

Table 3-3 lists the model species produced by SMOKE in the platform used for this study. Updates to species assignments for CB05 and CB6 were made for the 2014v7.1 platform. These continue to be used in the 2018v2 platform and are described in Appendix A.

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

Inventory Pollutant	**Model Species**	**Model species description**
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
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
$PM_{2.5}$	PNCOM	Non-carbon organic matter
$PM_{2.5}$	PNH4	Ammonium
$PM_{2.5}$	PSI	Silica
$PM_{2.5}$	PTI	Titanium

One additional species in the emissions files but not in the above table is non-methane organic gases (NMOG). This facilitates ongoing advanced work in speciation and is created using an additional GSPRO component that creates NMOG for all TOG and NONHAPTOG profiles plus all integrate HAPs. This species is not used for traditional ozone and particulate matter-focused modeling applications.

The TOG and $PM_{2.5}$ speciation factors that are the basis of the chemical speciation approach for 2018v2 were developed from the SPECIATE 5.2 database (https://www.epa.gov/air-emissions-modeling/speciate-2), the EPA's repository of TOG and PM speciation profiles of air pollution sources. Noting that the 2016v2 platform used profiles from a draft of SPECIATE 5.2. 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 ECCC (EPA, 2016). 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 ECCC as pre-speciated emissions; although not all CB6 species are provided. These inventories were not supplemented with missing species due to the minimal impact of supplementation.

Speciation updates made for the 2016v3 platform that are also in the 2018v2 platform included:

- Updated assignments to VOC profiles for 6 SCCs (all pulp and paper) and PM2.5 profiles for 3 SCCs (2 pulp and paper, 1 natural gas).
- Updated profile assignments for solvents.
- Re-mapped the profile for SCC 2310010200 from 2487 to 95247.
- Remapped all point and nonpoint SCCs that were mapped to profile 1011 to 95404. The major SCCs mapped to this profile are associated with oil production processes related fugitive leaks/venting. Profile 95404 is a composite profile from untreated oil wells.
- Remapped all point and nonpoint SCCs that were mapped to profile 1207 to profile 95782 (a profile for produced water for non-coal bed methane). These are for non-CBM produced water. We note that CBM produced water is using a Wyoming profile and 95782 is a non-CBM produced water profile also sampled in Wyoming.

Updates to PM speciation cross references implemented in 2016v2 and carried into 2018v2 included:

- where the comment says the “Heat Treating” profile should be used, changed the profile code to 91123 which is the actual Heat Treating profile;
- for SCC 2801500250, changed to profile SUGP02 (a new sugar cane burning profile);
- for SCC 30400740, changed to profile 95475;
- used new fire profiles for fire PM. Note that all US states (not DC/HI/PR/VI) now use one of the new profiles for all fire SCCs, including grassland fires. The profiles themselves aren't entirely state-specific; there are four representative states for forest fires and two representative states for grass fires, and all states are mapped to one of the four representative forest states and one of the two representative grass states. The GSREFs still have a non-FIPS-specific assignment to the previous profile 3766AE6 for fires outside of the United States.

For additional information on speciation updates made in the prior platforms, see the 2016v3 platform TSD (EPA, 2023a). Speciation profiles and cross references for this platform are available with the other SMOKE input files for the platform. Emissions of VOC and $PM_{2.5}$ 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.

3.2.1 VOC speciation

The speciation of VOC includes HAP emissions from the NEI in the speciation process. Instead of speciating VOC to generate all species listed in Table 3-3, emissions of five specific HAPs from the NEI were "integrated" with the NEI VOC. These HAPs include naphthalene, benzene, acetaldehyde, formaldehyde, and methanol (collectively known as "NBAFM"). 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 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 the CB6 chemical mechanism. 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 HAPs with VOC is a feature available in SMOKE for all inventory formats, including PTDAY (the format used for the ptfire and ptagfire sectors). The ability to use integration with the PTDAY format is used for the ptfire-rx and ptfire-wild sectors in this platform, but not for the ptagfire 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 particular sources to integrate via the NHAPEXCLUDE file (which actually provides the sources to be *excluded* from integration[11]). 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.[12] SMOKE computes NONHAPTOG and then applies the speciation profiles to allocate the NONHAPTOG to the remaining air quality model VOC species. 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. On the other hand, if certain sources do not have the necessary HAPs, then an NHAPEXCLUDE file must be provided based on the

[11] 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.

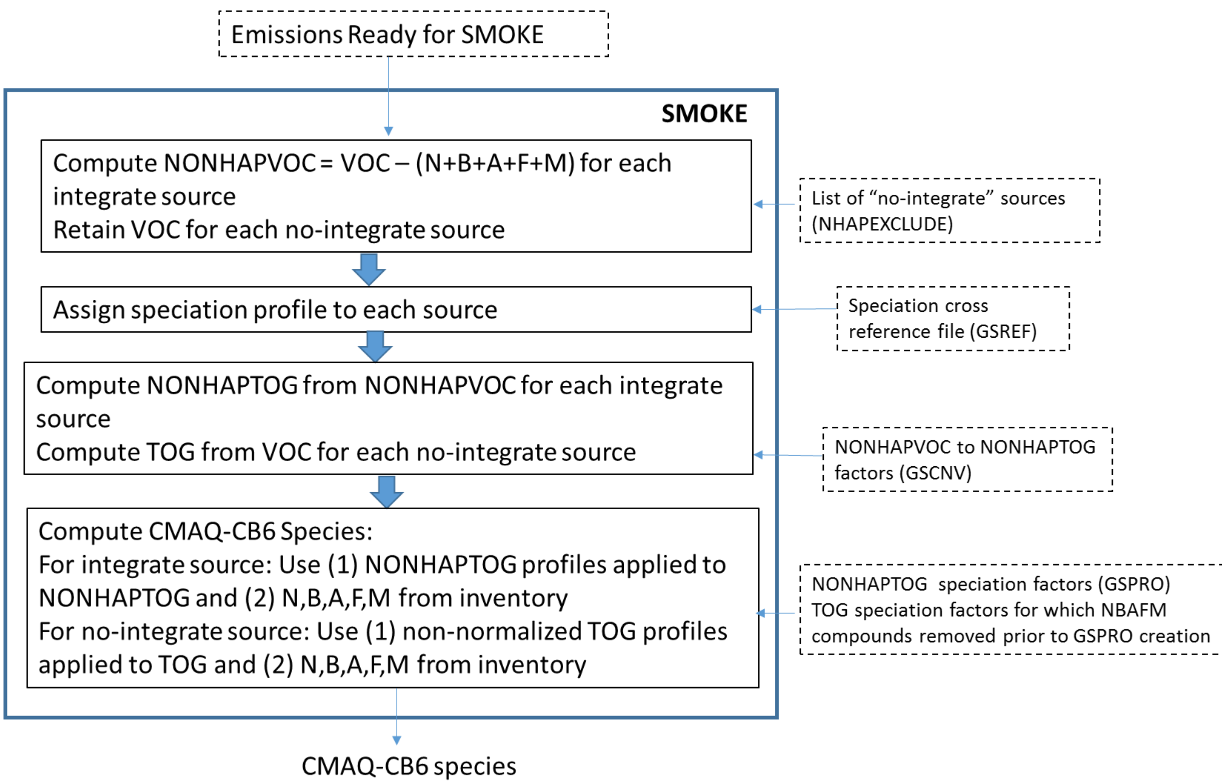
[12] These ratios and profiles are typically generated from the Speciation Tool when it is run with integration of a specified list of pollutants, for example NBAFM.

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.

In this platform, NBAFM species are created from the no-integrate source VOC emissions using speciation profiles and do not use HAPs from the inventory. Figure 3-2 illustrates the integrate and no-integrate processes for U.S. sources. 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 the NONHAPTOG 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."

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



In SMOKE, the INVTABLE allows the user to specify the HAPs to integrate. Two different INVTABLE files were used for different sectors of the platform. For sectors that had no integration across the entire sector (see Table 3-4), a "no HAP use" INVTABLE in which the "KEEP" flag was set to "N" for NBAFM pollutants was used. Thus, any NBAFM pollutants in the inventory input into SMOKE are automatically dropped. This approach avoids double-counting of these species and assumes that the VOC speciation is the best available approach for these species for sectors using this approach. The second

INVTABLE, used for sectors in which one or more sources are integrated, causes SMOKE to keep the inventory NBAFM pollutants and indicates that they are to be integrated with VOC. This is done by setting the “VOC or TOG component” field to “V” for all five HAP pollutants. For the onroad and nonroad sectors, “full integration” includes the integration of benzene, 1,3 butadiene, formaldehyde, acetaldehyde, naphthalene, acrolein, ethyl benzene, 2,2,4-Trimethylpentane, hexane, propionaldehyde, styrene, toluene, xylene, and methyl tert-butyl ether (MTBE).

Table 3-4. Integration of naphthalene, benzene, acetaldehyde, formaldehyde and methanol (NBAFM) for each sector

Platform Sector	Approach for Integrating NEI emissions of Naphthalene (N), Benzene (B), Acetaldehyde (A), Formaldehyde (F) and Methanol (M)
ptegu	No integration, create NBAFM from VOC speciation
ptnonipm	No integration, create NBAFM from VOC speciation
ptfire-rx	Partial integration (NBAFM)
ptfire-wild	Partial integration (NBAFM)
ptfire_othna	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
ptagfire	Full integration (NBAFM)
airports	No integration, create NBAFM from VOC speciation
afdust	N/A – sector contains no VOC
beis	N/A – sector contains no inventory pollutant “VOC”; but rather specific VOC species
cmv_c1c2	Full integration (NBAFM)
cmv_c3	Full integration (NBAFM)
fertilizer	N/A – sector contains no VOC
livestock	Partial integration (NBAFM)
rail	Full integration (NBAFM)
nonpt	Partial integration (NBAFM)
np_solvents	Partial integration (NBAFM)
nonroad	Full integration (internal to MOVES)
np_oilgas	Partial integration (NBAFM)
othpt	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
pt_oilgas	No integration, create NBAFM from VOC speciation
rwc	Full integration (NBAFM)
onroad	Full integration (internal to MOVES); however, MOVES2014a speciation was CB6-CAMx, not CB6-CMAQ, so post-SMOKE emissions were converted to CB6-CMAQ
onroad_can	No integration, no NBAFM in inventory, create NBAFM from speciation
onroad_mex	Full integration (internal to MOVES-Mexico); however, MOVES-MEXICO speciation was CB6-CAMx, not CB6-CMAQ, so post-SMOKE emissions were converted to CB6-CMAQ
othafdust	N/A – sector contains no VOC
othptdust	N/A – sector contains no VOC
othar	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
canada_ag	No integration, no NBAFM in inventory, create NBAFM from speciation
canada_og2D	No integration, no NBAFM in inventory, create NBAFM from speciation

Integration for the mobile sources estimated from MOVES (onroad and nonroad sectors, other than for California) 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. Following the run of SMOKE-MOVES, NMOG emissions were added to the data files through a post-SMOKE processor.

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

SMOKE can compute speciation profiles from mixtures of other profiles in user-specified proportions via two different methods. The first method, which uses a GSPRO_COMBO file, has been in use since the 2005 platform; the second method (GSPRO with fraction) was used for the first time in the 2014v7.0 platform. The GSPRO_COMBO method uses profile combinations specified in the GSPRO_COMBO ancillary file by pollutant (which can include emissions mode, e.g., EXH__VOC), state and county (i.e., state/county FIPS code) and time period (i.e., month). Different GSPRO_COMBO files can be used by sector, allowing for different combinations to be used for different sectors; but within a sector, different profiles cannot be applied based on SCC. The GSREF file indicates that a specific source uses a combination file with the profile code “COMBO.” SMOKE computes the resultant profile using the fraction of each specific profile assigned by county, month and pollutant.

A GSPRO_COMBO is used to specify a mix of E0 and E10 fuels in Canada. ECCC provided percentages of ethanol use by province, and these were converted into E0 and E10 splits. For example, Alberta has 4.91% ethanol in its fuel, so we applied a mix of 49.1% E10 profiles (4.91% times 10, since 10% ethanol would mean 100% E10), and 50.9% E0 fuel. Ethanol splits for all provinces in Canada are listed in Table 3-5. The Canadian onroad inventory includes four distinct FIPS codes in Ontario, allowing for application of different E0/E10 splits in Southern Ontario versus Northern Ontario. In Mexico, only E0 profiles are used.

Table 3-5. Ethanol percentages by volume by Canadian province

Province	Ethanol % by volume (E10 = 10%)
Alberta	4.91%
British Columbia	5.57%
Manitoba	9.12%
New Brunswick	4.75%
Newfoundland & Labrador	0.00%
Nova Scotia	0.00%
NW Territories	0.00%
Nunavut	0.00%
Ontario (Northern)	0.00%
Ontario (Southern)	7.93%
Prince Edward Island	0.00%
Québec	3.36%
Saskatchewan	7.73%
Yukon	0.00%

A new method to combine multiple profiles became available in SMOKE4.5. It allows multiple profiles to be combined by pollutant, state and county (i.e., state/county FIPS code) and SCC. This was used specifically for the oil and gas sectors (pt_oilgas and np_oilgas) because SCCs include both controlled and uncontrolled oil and gas operations which use different profiles.

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

The decision to integrate HAP emissions 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 3-4 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).[13] SMOKE essentially calculates the model-ready species by using the appropriate emission factor without further speciation.[14] 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 3-6. An additional run of the Speciation Tool was necessary to create the M-profiles that were then loaded into the MOVES default database. Fourth, for California, 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.

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

MOVES ID	Pollutant Name
5	Methane (CH4)
20	Benzene
21	Ethanol
22	MTBE
24	1,3-Butadiene
25	Formaldehyde

[13] 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.
[14] 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/.

MOVES ID	Pollutant Name
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 3-6. 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 state-provided emissions were used, MOVES-style speciation has been implemented in 2018gc and carried into 2018v2, 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 CA and TX. This means in 2018gc and 2018v2, onroad 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 3-6 was used. However, MOVES-MEXICO used an older version of the CB6 mechanism sometimes referred to as "CB6-CAMx." That mechanism is missing the model species XYLMN and SOAALK and were added post-SMOKE 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. BEIS4 includes the species (SESQ) that is mapped to the BEIS model species SESQT (Sesquiterpenes). The profile code associated with BEIS4 for use with CB05 is "B10C5," while the profile for use with CB6 is "B10C6." The main difference between the profiles is the explicit treatment of acetone emissions in B10C6. The biogenic speciation files are managed in the CMAQ Github repository. [15]

[15] https://github.com/USEPA/CMAQ/blob/main/CCTM/src/biog/beis4/gspro_biogenics.txt.

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. For example, SCC 2310030300 (Gas Well Water Tank Losses) in Colorado are controlled by a 95% efficient flare, so a profile (DJTFLR95) was developed to represent the composition of the VOC exiting the flare. Region-specific profiles were also available for several areas, some of which were included in SPECIATE v5.1 and others added to SPECIATE v5.2. These profiles are used in this platform and are listed in Appendix B. Additional documentation is available in the SPECIATE database.

For the profiles in SPECIATE v5.2:

- The Southern Ute profiles (SUIROGCT and SUIROGWT) applied to Archuleta and La Plata counties in southwestern Colorado were developed from data provided in Tables 19 and 20 of the report by Oakley Hayes, Matt Wampler, Danny Powers (December 2019), "Final Report for 2017 Southern Ute Indian Tribe Comprehensive Emissions Inventory for Criteria Pollutants, Hazardous Air Pollutants, and Greenhouse Gases."[16]
- A composite coal bed methane produced water profile, CBMPWWY, was developed by compositing a subset of the SPECIATE 5.0 pond profiles associated with coal bed methane wells. The SPECIATE 5.0 pond profiles were developed based on the publication: "Lyman, Seth N, Marc L Mansfield, Huy NQ Tran, Jordan D Evans, Colleen Jones, Trevor O'Neil, Ric Bowers, Ann Smith, and Cara Keslar. 2018. 'Emissions of Organic Compounds from Produced Water Ponds I: Characteristics and Speciation', Science of the Total Environment, 619: 896-905."[17] Note that the pond profiles from this publication are included in SPECIATE 5.0; but a composite to represent coal bed methane wells had not been developed for SPECIATE 5.0 and this new profile is in SPECIATE 5.2.
- The DJTFLR95 profile, DJ Condensate Flare Profile with DRE 95%, filled a need for the flared condensate and produced water tanks for Colorado's oil and gas operations. This profile was developed using the same approach as was used for the FLR99 (and other FLR**) SPECIATE 4.5 profiles, but instead of using profile 8949 for the uncombusted gas, it uses the Denver-Julesburg Basin Condensate composite (95398) and it quantifies the combustion by-products based on a 95% DRE. The approach for combining profile 95398 with combustion by-products based on the TCEQ's flare study (Allen, David T, and Vincent M Torres, University of Texas, Austin. 2011. 'TCEQ 2010 Flare Study Final Report', Texas Commission on Environmental Quality[18]) is the same as used in the workbook for the FLR** SPECIATE4.5 profiles and can be found in the flr99 zip file referenced in the SPECIATE database. The approach uses the analysis developed by Ramboll (Ramboll and EPA, 2017).

In addition to region-specific assignments, multiple profiles were assigned to select county/SCC combinations using the SMOKE feature discussed in Section 3.2.1.1. 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.

---

[16] https://www.southernute-nsn.gov/wp-content/uploads/sites/15/2019/12/191203-SUIT-CY2017-Emissions-Inventory-Report-FINAL.pdf.
[17] http://doi.org/10.1016/j.scitotenv.2017.11.161.
[18] https://downloads.regulations.gov/EPA-HQ-OAR-2012-0133-0047/attachment_32.pdf.

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. These fractions can vary by county FIPS, because they depend on the level of controls, which is an input to the Oil and Gas Tool. The basin or region-specific profiles for oil and gas sources used in this platform are shown in Table 3-7.

Table 3-7. 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	
PNC03_R	Piceance Basin Flash Gas Composition for Condensate Tank	
PNCDH	Piceance Basin, Glycol Dehydrator	
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 Gagres Composition from Non-CBM Gas Wells	
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
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	

Profile Code	Description	Region (if not in profile name)
UTUBOGF	Flash Gas from Condensate Tanks - including Carbonyls - Composite Uinta basin	
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	
CMU01	Oil and Gas - Produced Gas Composition from Gas Wells - Central Montana Uplift – Montana	
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 categories is customized to account for the impact of fuels, engine types, 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 other than for California are listed in Table 3-8. 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 3-8. TOG MOVES-SMOKE Speciation Profiles for Nonroad Emissions

Profile	Profile Description	Engine Type	Engine Technology	Engine Size	Horse-power category	Fuel	Fuel Sub-type	Emission Process
95327	SI 2-stroke E0	SI 2-stroke	All	All	All	Gasoline	E0	exhaust
95328	SI 2-stroke E10	SI 2-stroke	All	All	All	Gasoline	E10	exhaust
95329	SI 4-stroke E0	SI 4-stroke	All	All	All	Gasoline	E0	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

Profile	Profile Description	Engine Type	Engine Technology	Engine Size	Horse-power category	Fuel	Fuel Sub-type	Emission Process
95333a [19]	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
8753	E0 Evap	SI	all	all	All	Gasoline	E0	evaporative
8754	E10 Evap	SI	all	all	All	Gasoline	E10	evaporative
8766	E0 evap permeation	SI	all	all	All	Gasoline	E0	permeation
8769	E10 evap permeation	SI	all	all	All	Gasoline	E10	permeation
8869	E0 Headspace	SI	all	all	All	Gasoline	E0	headspace
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 the NEI TSD. 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 performed within 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 2018v2 platform, these sources get E10 speciation.

Table 3-9 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.

Table 3-9. Select mobile-related VOC profiles

Sector	Sub-category	Profile number	Profile Description
nonroad non-US	Gasoline exhaust	COMBO	Pre-Tier 2 E0 exhaust (8750a) and Pre-Tier 2 E10 exhaust (8751a)
nonpt / ptnonipm	PFC and BTP	COMBO	E0 headspace (8869) and E10 headspace (8870)
nonpt / ptnonipm	Bulk plant storage (BPS) and refine-to-bulk terminal (RBT) sources	8870	E10 Headspace

[19] 95333a replaced 95333. This correction was made to remove alcohols due to suspected contamination. Additional information is available in SPECIATE.

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 3-10 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 3-11 through Table 3-13 describe the meaning of these MOVES codes. For a specific representative county and analytic 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 3-10. 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
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[20]	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

[20] 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.

Profile	Profile Description	Model Years	ProcessID	FuelSubTypeID	RegClassID
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[21]	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). Other evaporative and refueling processes from diesel vehicles have zero emissions.

Table 3-11. MOVES process IDs

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

[21] 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 combination is already assigned to profile 8758.

Process ID	Process Name
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 3-12. 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 3-13. 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.[22]

The newest PM profile used in the 2018v2 platform is the Sugar Cane Pre-Harvest Burning Mexico profile (SUGP02). This profile falls under the sector ptagfire and are included in SPECIATE v5.2. Additionally, a series of regional fire profiles were added to SPECIATE 5.1 and are used in 2018v2. These fall under the sector ptfire and are as shown in Table 3-14.

Table 3-14. Regional fire PM speciation profiles used in ptfire sectors

Pollutant	Profile Code	Profile Description
PM	95793	Forest Fire-Flaming-Oregon AE6
PM	95794	Forest Fire-Smoldering-Oregon AE6
PM	95798	Forest Fire-Flaming-North Carolina AE6
PM	95799	Forest Fire-Smoldering-North Carolina AE6
PM	95804	Forest Fire-Flaming-Montana AE6
PM	95805	Forest Fire-Smoldering-Montana AE6
PM	95807	Forest Fire Understory-Flaming-Minnesota AE6
PM	95808	Forest Fire Understory-Smoldering-Minnesota AE6
PM	95809	Grass Fire-Field-Kansas AE6

3.2.2.1 Mobile source related $PM_{2.5}$ speciation profiles

For the onroad sector, for all processes except brake and tire wear, PM speciation occurs within MOVES itself, not within SMOKE (similar to the VOC speciation described above). The advantage of using MOVES to speciate PM is that during the internal calculation of MOVES, the model has complete information on the characteristics of the fleet and fuels (e.g., model year, sulfur content, process, etc.) to accurately match to specific profiles. This means that MOVES produces EF tables that include total PM (e.g., PM_{10} 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.[23] 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

[22] 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.
[23] 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/.

Emissions from On-road Vehicles in MOVES2014" (EPA, 2015c). No changes to the mobile source PM speciation profiles were made in the 2018v2 platform.

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). These formulas are based on brake wear profile 95462 and tire wear profile 95460 and are as follows:

```
POC = 0.6395 * PM25TIRE + 0.0503 * PM25BRAKE
PEC = 0.0036 * PM25TIRE + 0.0128 * PM25BRAKE
PNO3 = 0.000 * PM25TIRE + 0.000 * PM25BRAKE
PSO4 = 0.0 * PM25TIRE + 0.0 * PM25BRAKE
PNH4 = 0.000 * PM25TIRE + 0.0000 * PM25BRAKE
PNCOM = 0.2558 * PM25TIRE + 0.0201 * PM25BRAKE
```

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 factors applied to $PM_{2.5}$ 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 $PM_{2.5}$, 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 $PM_{2.5}$ split by speciation profile. Similar to how VOC and NONHAPTOG are speciated, $PM_{2.5}$ is now also speciated this way starting with MOVES2014b. For California and Texas, $PM_{2.5}$ emissions split by speciation profile are estimated from total $PM_{2.5}$ based on MOVES data in California and Texas, so that PM is speciated consistently across the country. The $PM_{2.5}$ profiles assigned to nonroad sources are listed in Table 3-15.

Table 3-15. Nonroad $PM_{2.5}$ 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

3.2.3 NO_X speciation

NOx emission factors and therefore NOx inventories are developed on a NO_2 weight basis. For air quality modeling, NO_X is speciated into NO, NO_2, and/or HONO. For the non-mobile sources, the EPA used a single profile "NHONO" to split NO_X into NO and NO_2.

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 NOx speciation for mobile sources. Based on tunnel studies, a HONO to NOx ratio of 0.008 was chosen (Sarwar, 2008). For the mobile sources except for onroad (e.g., nonroad, cmv, rail, othon sectors), and for specific SCCs in othar and ptnonipm, the profile “HONO” is used. Table 3-16 gives the split factor for these two profiles. The onroad sector does not use the “HONO” profile to speciate NO_X. MOVES2014 produces speciated NO, NO_2, and HONO by source, including emission factors for these species in the emission factor tables used by SMOKE-MOVES. Within MOVES, the HONO fraction is a constant 0.008 of NO_X. The NO fraction varies by heavy duty versus light duty, fuel type, and model year. The NO_2 fraction = 1 – NO – HONO. For more details on the NO_X fractions within MOVES, see 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/Exe/ZyPDF.cgi?Dockey=P100F1A5.pdf.

Table 3-16. NO_X speciation profiles

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

3.2.4 Creation of Sulfuric Acid Vapor (SULF)

Since 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 SO_2 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 SO_2 and relates the sulfate as a function of SO2.

Sulfate is computed from SO_2 assuming that gaseous sulfate, which is comprised of many components, is primarily H_2SO_4. The equation for calculating H_2SO_4 is given below.

$$Emissions\ of\ SULF\ (as\ \mathrm{H_2SO_4}) = SO_2\ emissions \times \frac{fraction\ of\ S\ emitted\ as\ sulfate}{fraction\ of\ S\ emitted\ as\ SO_2} \times \frac{MW\ H_2SO_4}{MW\ SO_2} \quad \text{Equation 3-1}$$

In the above, *MW* is the molecular weight of the compound. The molecular weights of H_2SO_4 and SO_2 are 98 g/mol and 64 g/mol, respectively.

This method does not reduce SO_2 emissions; it solely adds gaseous sulfate emissions as a function of SO2 emissions. The derivation of the profiles is provided in Table 3-17; a summary of the profiles is provided in Table 3-18.

Table 3-17. Sulfate split factor computation

Fuel	SCCs	Profile Code	Fraction as SO2	Fraction as sulfate	Split factor (mass fraction)
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

Fuel	SCCs	Profile Code	Fraction as SO2	Fraction as sulfate	Split factor (mass fraction)
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 3-18. SO_2 speciation profiles

Profile	pollutant	species	split factor
95014	SO2	SULF	0.0226
95014	SO2	SO2	1
87514	SO2	SULF	0.0245
87514	SO2	SO2	1
75014	SO2	SULF	0.0286
75014	SO2	SO2	1
99010	SO2	SULF	0.0155
99010	SO2	SO2	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. For 2018v2, temporal profile assignments to SCCs were updated for solvents and for some point and nonpoint SCCs. The new profiles for solvents only impacted the diurnal profiles and are based on Gkatzelis et al. (2021).

The temporal factors applied to the inventory are selected using some combination of country, state, county, SCC, and pollutant. Table 3-19 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 3-19. Temporal settings used for the platform sectors in SMOKE

Platform sector short name	Inventory resolution(s)	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process holidays as separate days
afdust_adj	Annual	Yes	week	All	Yes
afdust_ak_adj	Annual	Yes	week	All	Yes
airports	Annual	Yes	week	week	Yes
beis	Hourly	No	n/a	All	No
canada_ag	Monthly	No	mwdss	mwdss	No
canada_og2D	Annual	Yes	mwdss	mwdss	No
cmv_c1c2	Annual	Yes	aveday	aveday	No
cmv_c3	Annual	Yes	aveday	aveday	No
fertilizer	Monthly	No	All	all	No
livestock	Annual	Yes	All	all	No
nonpt	Annual	Yes	week	week	Yes
nonroad	Monthly	No	mwdss	mwdss	Yes
np_oilgas	Annual	Yes	aveday	aveday	No
np_solvents	Annual	Yes	aveday	aveday	No
onroad	Annual & monthly[1]	No	All	all	Yes
onroad_ca_adj	Annual & monthly[1]	No	All	all	Yes
onroad_nonconus	Annual & monthly[1]	No	All	all	Yes
othafdust_adj	Annual	Yes	week	all	No
othar	Annual & monthly	Yes	week	week	No
onroad_can	Monthly	No	week	week	No
onroad_mex	Monthly	No	week	week	No
othpt	Annual & monthly	Yes	mwdss	mwdss	No
othptdust_adj	Monthly	No	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	No	All	all	No
ptfire-rx	Daily	No	All	all	No
ptfire-wild	Daily	No	All	all	No
ptfire_othna	Daily	No	All	all	No
rail	Annual	Yes	aveday	aveday	No
rwc	Annual	No[3]	met-based[3]	All	No[3]

[1]Note 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.
[2]Only units that do not have matching hourly CEMS data use monthly temporal profiles.
[3]Except for 2 SCCs that do not use met-based temporal allocation.

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, 2018, which is intended to mitigate the effects of initial condition concentrations. The ramp-up period was 10 days (December 22-31, 2017). For most sectors, emissions from December 2018 (representative days) were used to fill in emissions for the end of December 2017. For biogenic emissions, December 2017 emissions were processed using 2017 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 livestock, nonroad, onroad, onroad_can, onroad_mex, othar, and othpt.

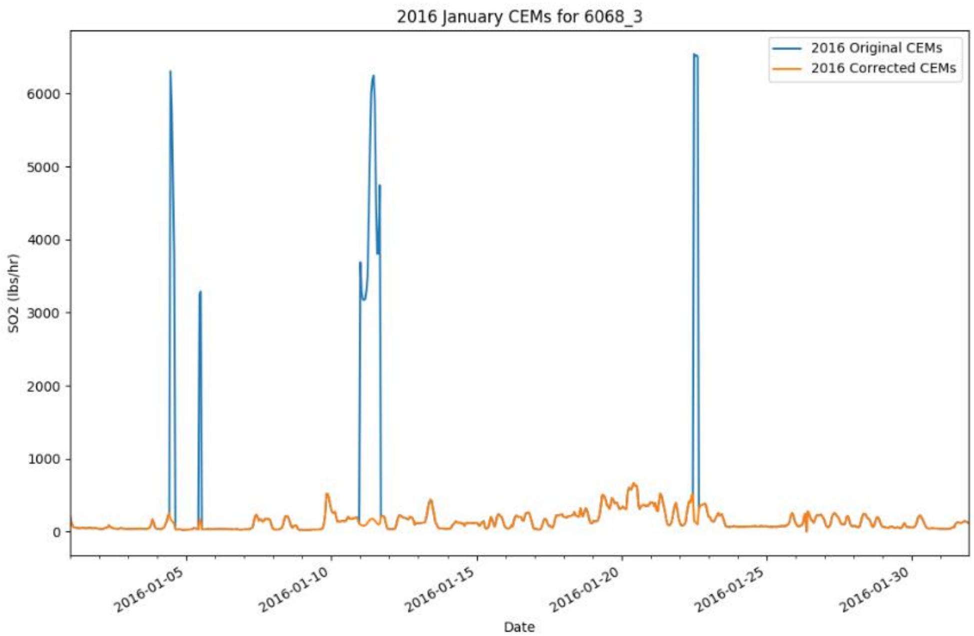
For livestock, meteorological-based temporalization (described in section 3.3.5) is used for month-to-day and day-to-hour temporalization. Monthly profiles for livestock are based on the daily data underlying the EPA estimates from 2014NEIv2.

3.3.2 Electric Generating Utility temporal allocation (ptegu)

3.3.2.1 Base year temporal allocation of EGUs

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 annual values in the 2018 annual inventory because the CEMS data replaces the NO_x and SO_2 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 3-3 for an example).

Figure 3-3. Eliminating unmeasured spikes in CEMS data



In modeling platforms prior to 2016 beta, unmatched EGUs were temporally allocated using daily and diurnal profiles weighted by CEMS values within an IPM region, season, and by fuel type (coal, gas, and other). All unit types (peaking and non-peaking) were given the same profile within a region, season and fuel bin. Units identified as municipal waste combustors (MWCs) or cogeneration units (cogens) were given flat daily and diurnal profiles. Beginning with the 2016 beta platform and continuing for the 2018 platforms, the small EGU temporalization process considers peaking units.

The region, fuel, and type (peaking or non-peaking) were identified for each input EGU with CEMS data that are used for generating profiles. The identification of peaking units was based on hourly heat input data from the 2018 base year and the two previous years (2016 and 2017). The heat input was summed for each year. Equation 3-2 shows how the annual heat input value is converted from heat units (BTU/year) to power units (MW) using the unit-level heat rate (BTU/kWh) derived from the NEEDS v6 database. In Equation 3-3 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 (2016, 2017, and 2018) and a 3-year average capacity factor of less than 0.1.

Annual Unit Power Output

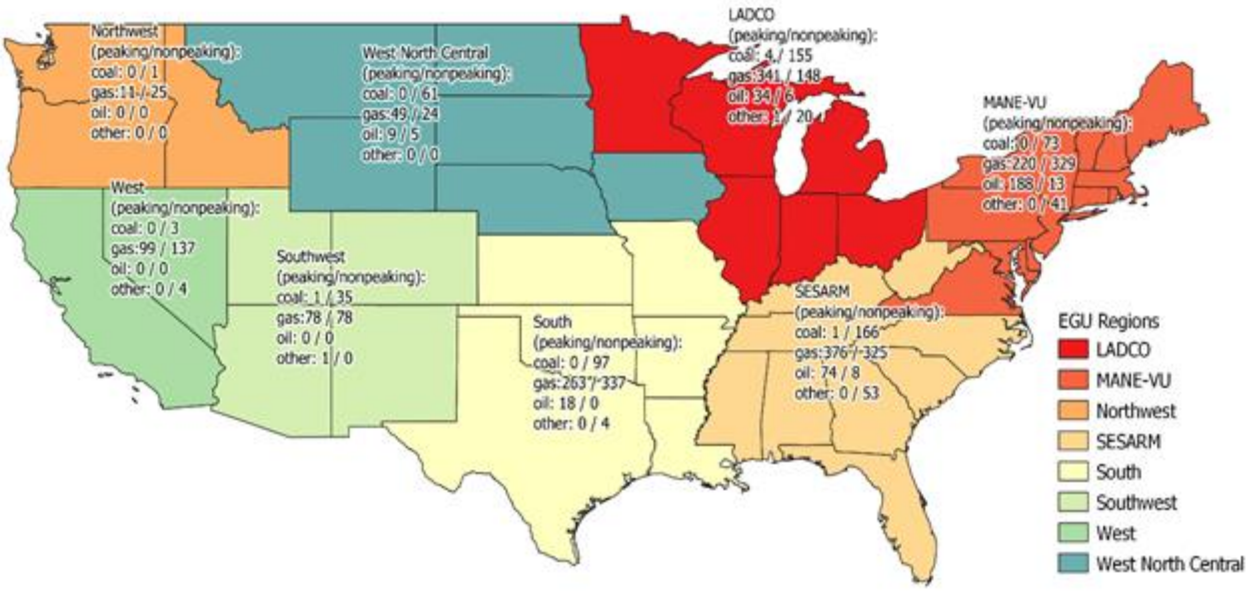
$$nnual\ Unit\ Output\ (MW) = \frac{\sum_{i=0}^{8760} \frac{Hourly\ HI}{(BTU)} * 1000\ \left(\frac{MW}{kW}\right)}{NEEDS\ Heat\ Rate\ \left(\frac{BTU}{kWh}\right)}$$ Equation 3-2

Unit Capacity Factor

$$nnual\ Unit\ Output\ (MW) = \frac{\sum_{i=0}^{8760} \frac{Hourly\ HI}{(BTU)} * 1000\ \left(\frac{MW}{kW}\right)}{NEEDS\ Heat\ Rate\ \left(\frac{BTU}{kWh}\right)}$$ Equation 3-3

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 in the 2016 platform are shown in Figure 3-4 by region, fuel, and for peaking/non-peaking. The counts should be similar for this platform. There are 64 unique profiles available based on 8 regions, 4 fuels, and 2 for peaking unit status (peaking and non-peaking).

Figure 3-4. Temporal Profile Input Unit Counts by Fuel and Peaking Unit Classification



The daily and diurnal profiles were calculated for each region, fuel, and peaking type group from the year 2018 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 3-5 shows peaking and non-peaking daily temporal profiles for the gas fuel type in the LADCO region. Figure 3-6 shows the diurnal profiles for the coal fuel type in the Mid-Atlantic Northeast Visibility Union (MANE-VU) region.

Figure 3-5. Example Daily Temporal Profiles for the LADCO Region and the Gas Fuel Type

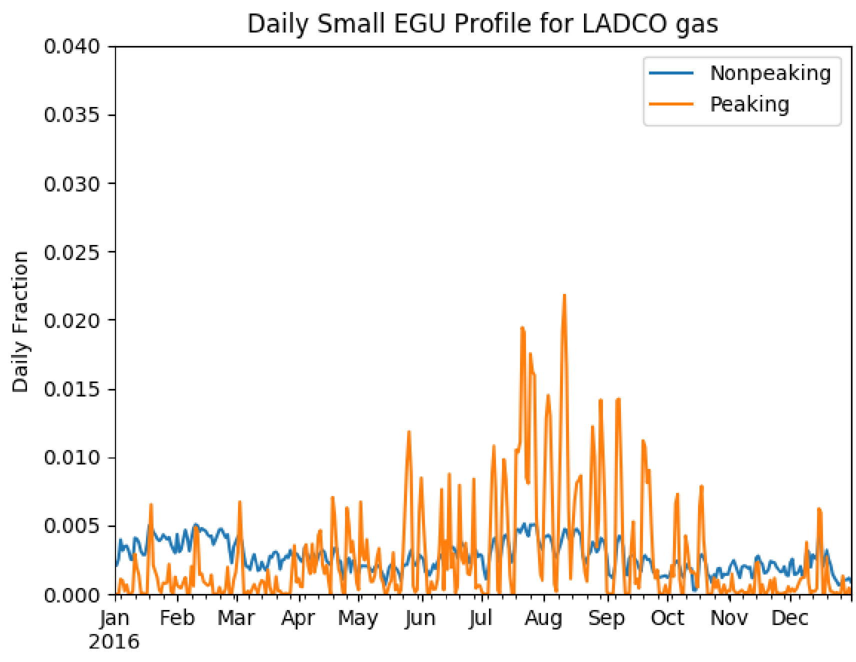
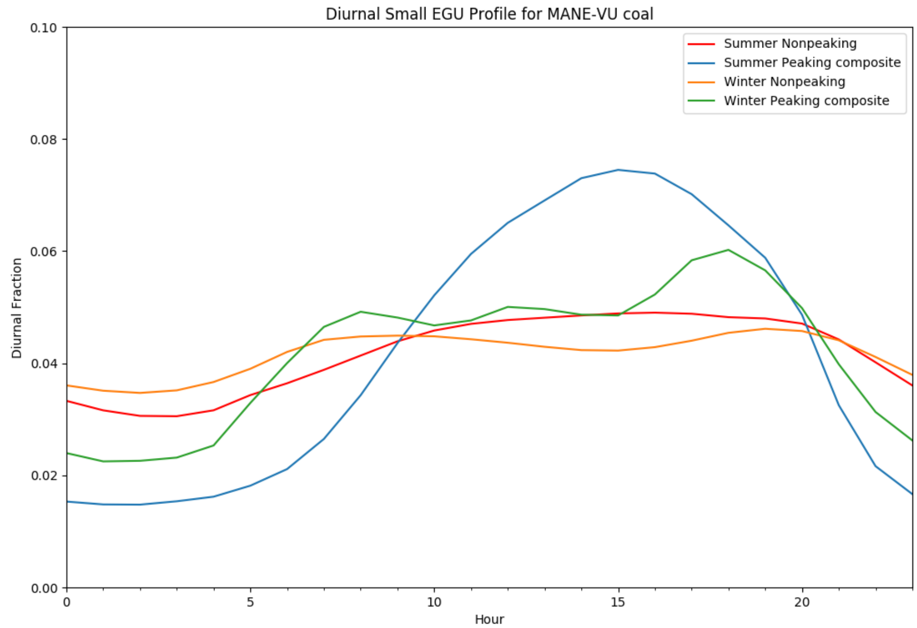
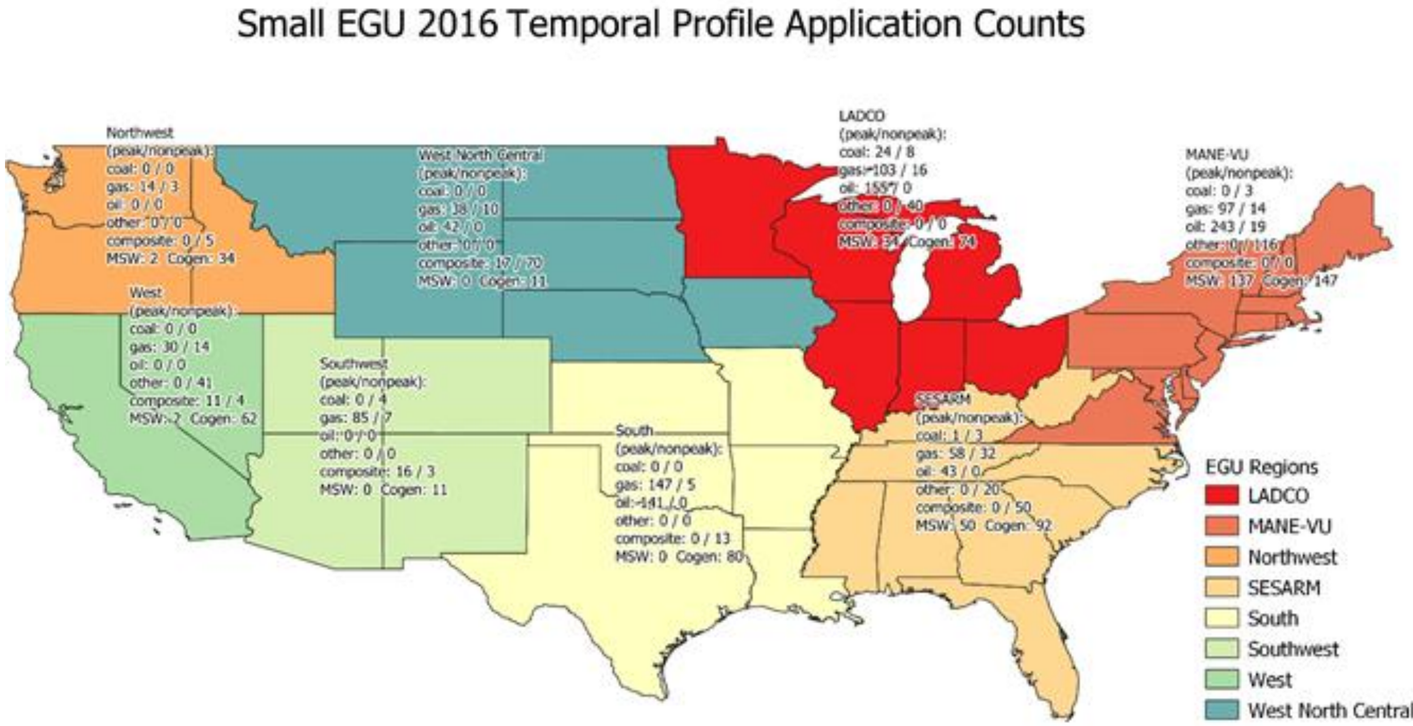


Figure 3-6. Example Diurnal Temporal Profiles for the MANE-VU Region and the Coal Fuel Type



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, $PM_{2.5}$, 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 221112. 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 regions used to aggregate each profile group are shown in Figure 3-7. The counts shown in this figure are from the 2016 platform. The numbers for this platform should be similar, although not exactly the same.

Figure 3-7. Non-CEMS EGU Temporal Profile Aggregation Regions



3.3.2.2 Analytic year temporal allocation of EGUs

For analytic year temporal allocation of unit-level EGU emissions, estimates of average winter (representing December through February), average winter shoulder (October through November and March through April), and average summer (May through September) values were provided by the IPM for all units. The winter shoulder was separated from the winter months starting with the 2016v3 platform and the approach has been retained for this platform. The seasonal emissions for the analytic year cases were produced by post processing of the IPM outputs. The unit-level data were converted into hourly values through the temporal allocation process using a 3-step methodology: annualized summer/winter value to month, month to day, and day to hour. CEMS data from the air quality analysis year (e.g., 2018) is used as much as possible to temporally allocate the EGU emissions.

The goal of the temporal allocation process is to reflect the variability in the unit-level emissions that can impact air quality over seasonal, daily, or hourly time scales, in a manner compatible with incorporating analytic-year emission projections into analytic-year air quality modeling. The temporal allocation process is applied to the seasonal emission projections for the three IPM seasons: summer (May through September), winter shoulder (October through November and March through April), and winter (December through February). The Flat File used as the input to the temporal allocation process contains unit-level emissions and stack parameters (i.e., stack location and other characteristics consistent with information found in the NEI). When the Flat File is produced from post-processed IPM outputs, a cross reference is used to map the units in version 6 of the NEEDS database to the stack parameter and facility, unit, release point, and process identifiers used in the NEI. This cross reference also maps sources to the hourly CEMS data used to temporally allocate the emissions in the base year air quality modeling.

All units have seasonal information provided in the analytic year Flat File, the monthly values in the Flat File input to the temporal allocation process are computed by multiplying the average summer day, average winter shield day, and average winter day emissions by the number of days in the respective month. When generating seasonal emissions totals from the Flat File winter shield emissions are summed with the winter emissions to create a total winter season. In summary, the monthly emission values shown in the Flat File are not intended to represent an actual month-to-month emission pattern. Instead, they are interim values that have translated IPM's seasonal projections into month-level data that serve as a starting point for the temporal allocation process.

The monthly emissions within the Flat File undergo a multi-step temporal allocation process to yield the hourly emission values at each unit, as is needed for air quality modeling: summer or winter value to month, month to day, and day to hour. For sources not matched to unit-specific CEMS data, the first two steps are done outside of SMOKE and the third step to get to hourly values is done by SMOKE using the daily emissions files created from the first two steps. For each of these three temporal allocation steps, NO_x and SO_2 CEMS data are used to allocate NO_x and SO_2 emissions, while CEMS heat input data are used to allocate all other pollutants. The approach defined here gives priority to temporalization based on the base year CEMS data to the maximum extent possible for both base and analytic year modeling. Prior to using the 2018 CEMS data to develop monthly, daily, and hourly profiles, the CEMS data were processed through the CEMCorrect tool to make adjustments for hours for which data quality flags indicated the data were not measured and that the reported values were much larger than the annual mean emissions for the unit. These adjusted CEMS data were used to compute the monthly, daily, and hourly profiles described below.

For units that have CEMS data available and that have CEMS units matched to the NEI sources, the emissions are temporalized according to the base year (i.e., 2018) CEMS data for that unit and pollutant. For units that are not matched to the NEI or for which CEMS data are not available, the allocation of the seasonal emissions to months is done using average fuel-specific season-to-month factors for both peaking and non-peaking units generated for each of the eight regions shown in Figure 3-7. These factors are based on a single year of CEMS data for the modeling base year associated with the air quality modeling analysis being performed, such as 2018. The fuels used for creating the profiles for a region were coal, natural gas, oil, and "other." The "other "fuels category is a broad catchall that includes fuels such as wood and waste. Separate profiles are computed for NO_x, SO_2, and heat input, where heat input is used to temporally allocate emissions for pollutants other than NO_x and SO_2. An overall composite profile across all fuels is also computed and can be used in the event that a region has too few units of a fuel type to make a reasonable average profile, or in the case when a unit changes fuels between the base and analytic year and there were previously no units with that fuel in the region containing the unit. A complete description of the generation and application of these regional fuel profiles is available in the base year temporalization section.

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

For units without or not matched to CEMS data, or for which the CEMS data are found to be unsuitable for use in the analytic year, emissions were allocated from month to day using IPM-region and fuel-specific average month-to-day factors based on CEMS data from the base year of the air quality modeling analysis. These instances include units that did not operate in the base year or for which it may not have been possible to match the unit to a specific unit in the NEI. Regional average profiles may be used for some units with CEMS data in the base year when one of the following cases is true: (1) units are projected to have substantially increased emissions in the analytic year compared to its emissions in the base (historic) year; (2) CEMS data were only available for a limited number of hours in that base year; (3) the unit is new in the analytic year; (4) when there were no CEMS data for one season in the base year but IPM runs the unit during both seasons; or (5) units experienced atypical conditions during the base year, such as lengthy downtimes for maintenance or installation of controls.

The temporal profiles that map emissions from days to hours were computed based on the region and fuel-specific seasonal (i.e., winter and summer) average day-to-hour factors derived from the CEMS data for heat input for those fuels and regions and for that season. Heat input was used because it is the variable that is the most complete in the CEMS data and should be present for all of the hours in which the unit was operating. SMOKE uses these diurnal temporal profiles to allocate the daily emissions data to hours of each day. Note that this approach results in each unit having the same hourly temporal allocation for all the days of a season.

The emissions from units for which unit-specific profiles were not used were temporally allocated to hours reflecting patterns typical of the region in which the unit is located. Analysis of year 2016 CEMS data for units in each of the 8 regions shown in Figure 3-4 revealed that there were differences in the temporal patterns of historic emission data that correlate with fuel type (e.g., coal, gas, oil, and other), time of year, pollutant, season (i.e., winter versus summer) and region of the country. The correlation of the temporal pattern with fuel type is explained by the relationship of units' operating practices with the fuel burned. For example, coal units take longer to ramp up and ramp down than natural gas units, and some oil units are used only when electricity demand cannot otherwise be met. Geographically, the patterns were less dependent on state location than they were on regional location. Figure 3-5 provides an example of daily profiles for gas fuel in the LADCO region for 2016. The EPA developed year-specific seasonal average emission profiles, each derived from base year CEMS data for each season across all units sharing both IPM region and fuel type. Figure 3-6 provides an example of seasonal profiles that allocate daily emissions to hours in the MANE-VU region. These average day-to-hour temporal profiles were also used for sources during seasons of the year for which there were no CEMS data available, but for which IPM predicted emissions in that season. This situation can occur for multiple reasons, including how the CEMS was run at each source in the base year.

For units that do have CEMS data in the base year and were matched to units in the IPM output, the base year CEMS data were scaled so that their seasonal emissions match the IPM-projected totals. The scaling process used the fraction of the unit's seasonal emissions in the base year as computed for each hour of the season, and then applied those fractions to the seasonal emissions from the analytic year Flat File. Any pollutants other than NO_x and SO_2 were temporally allocated using heat input. Through the temporal allocation process, the analytic year emissions will have the same temporal pattern as the base year CEMS data, where available, while the analytic-year seasonal total emissions for each unit match the analytic-year unit-specific projection for each season (see example in Figure 3-8). The year IPM output for 2030 maps to the year 2032 and was therefore used for the 2032 modeling case.

In cases when the emissions for a particular unit are projected to be substantially higher in the analytic year than in the base year, the proportional scaling method to match the emission patterns in the base year described above can yield emissions for a unit that are much higher than the historic maximum emissions for that unit. To help address this issue in the analytic case, the maximum measured emissions of NO_x and SO_2 in the period of 2015-2019 were computed. The temporally allocated emissions were then evaluated at each hour to determine whether they were above this maximum. The amount of "excess emissions" over the maximum were then computed. For units for which the "excess emissions" could be reallocated to other hours, those emissions were distributed evenly to hours that were below the maximum. Those hourly emissions were then reevaluated against the maximum, and the procedure of reallocating the excess emissions to other hours was repeated until all of the hours had emissions below the maximum, whenever possible (see example in Figure 3-9).

Figure 3-8. Analytic Year Emissions Follow the Pattern of Base Year Emissions

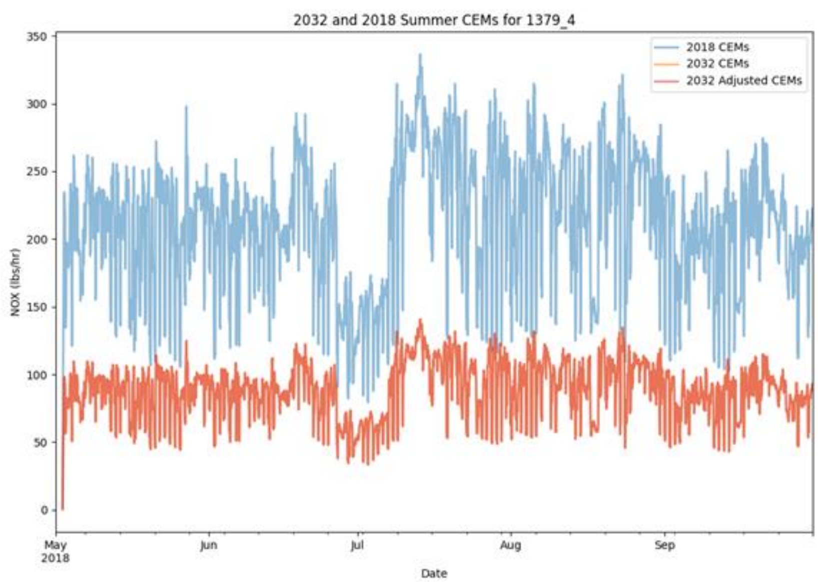
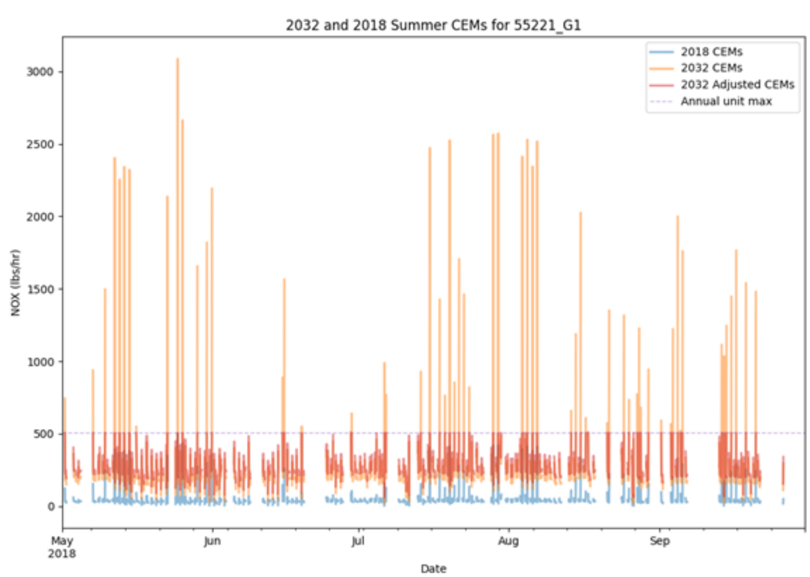


Figure 3-9. Excess Emissions Apportioned to Hours Less than the Historic Maximum



Using the above approach, it was not always possible to reallocate excess emissions to hours below the historic maximum, such as when the total seasonal emissions of NO_x or SO_2 for a unit divided by the number of hours of operation are greater than the 2015-2019 maximum emissions level. For these units, the regional fuel-specific average profiles were applied to all pollutants, including heat input, for the respective season (see example in Figure 3-10). It was not possible for SMOKE to use regional profiles for some pollutants and adjusted CEMS data for other pollutants for the same unit and season, therefore, all pollutants in the unit and season are assigned to regional profiles when regional profiles are needed. For some units, hourly emissions values still exceed the 2015-2019 annual maximum for the unit even after regional profiles were applied (see example in Figure 3-11).

Figure 3-10. Regional Profile Applied due to not being able to Adjust below Historic Maximum

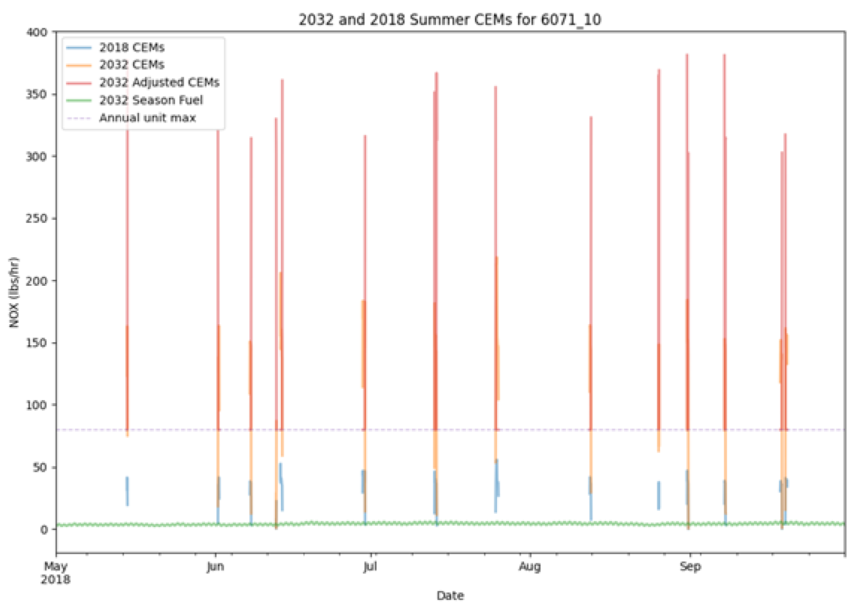
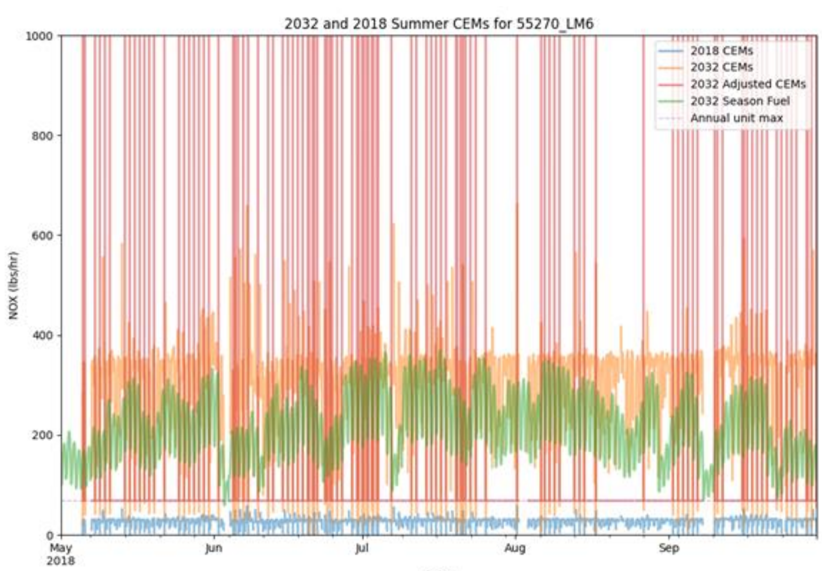


Figure 3-11. Regional Profile Applied, but Exceeds Historic Maximum in Some Hours



3.3.3 Airport Temporal allocation (airports)

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. 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 3-12 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). An overview of the Operations Network data system is here: http://aspmhelp.faa.gov/index.php/Operations_Network_%28OPSNET%29. 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 3-12, Figure 3-13, and Figure 3-14. The weekly and monthly profiles from 2014 are used in this platform. Note that Alaska seaplanes use the monthly profile shown in Figure 3-15. These were assigned based on the facility ID.

Figure 3-12. Diurnal Profile for all Airport SCCs

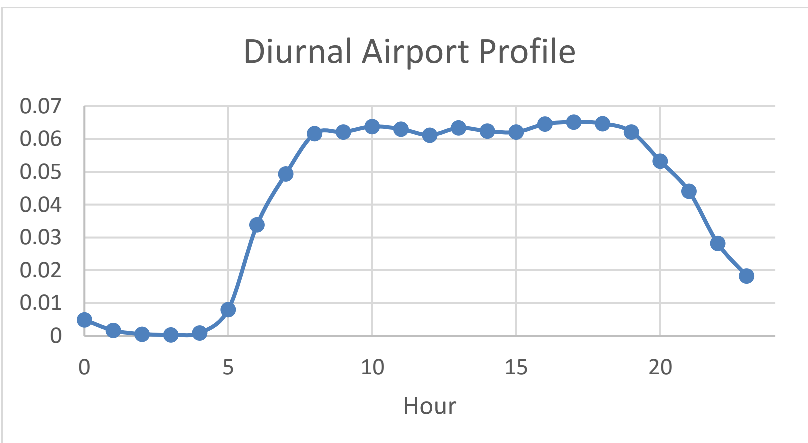


Figure 3-13. Weekly profile for all Airport SCCs

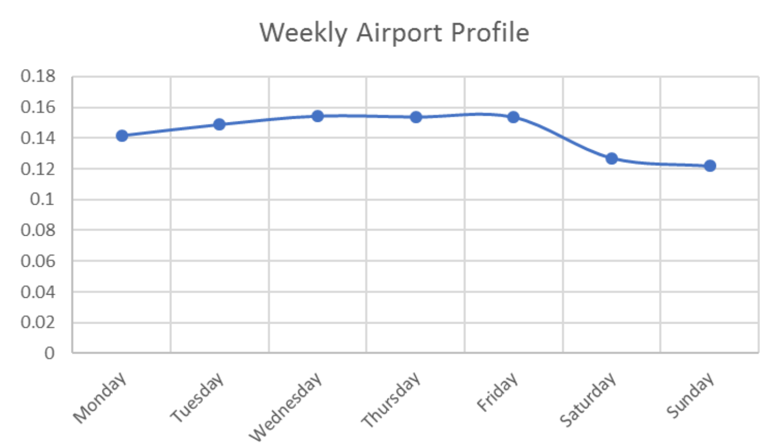


Figure 3-14. Monthly Profile for all Airport SCCs

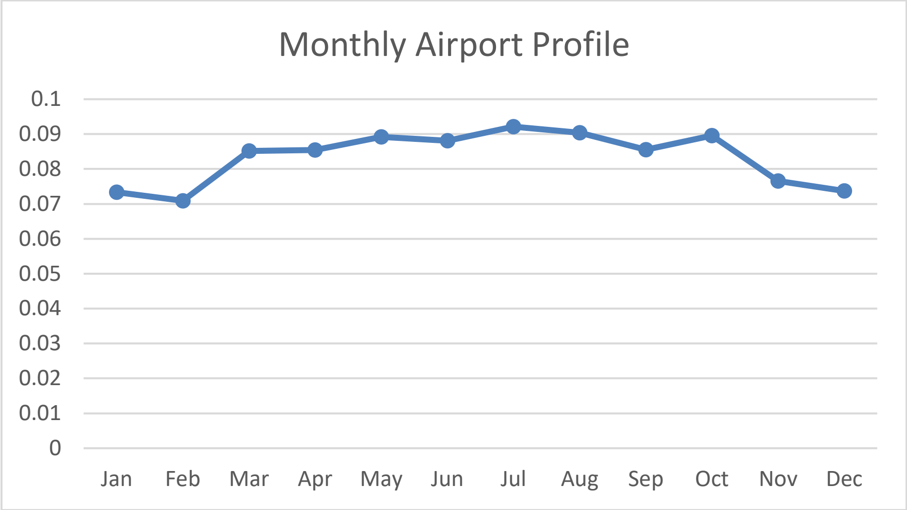
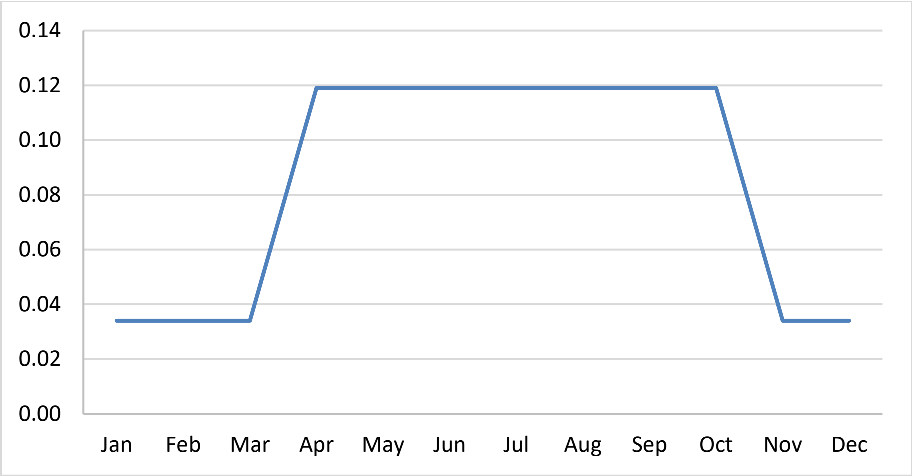


Figure 3-15. Alaska Seaplane Profile



3.3.4 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 NH_3; and a generic meteorology-based algorithm for other situations. Meteorological-based temporal allocation was used for portions of the rwc sector and for agricultural livestock and fertilizer emissions.

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.

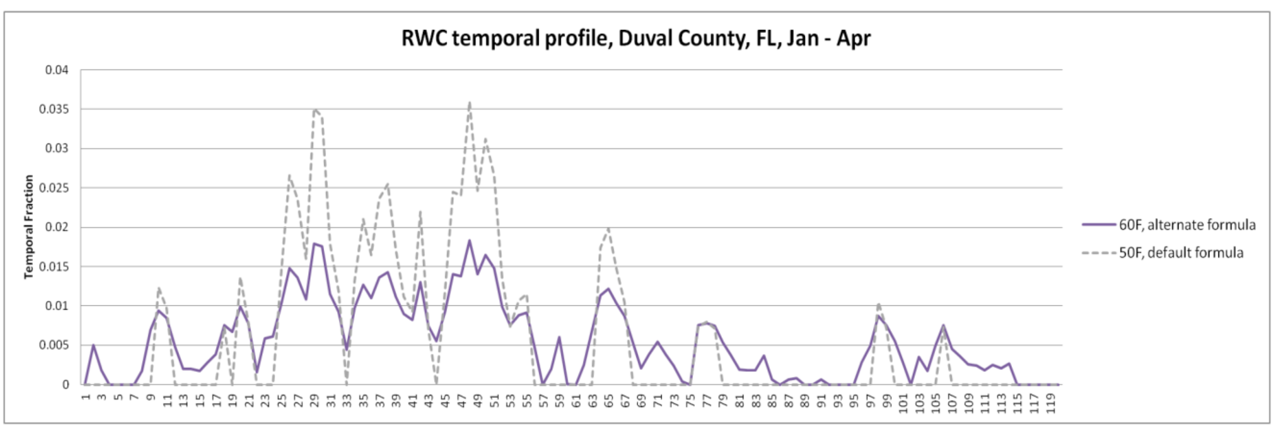
For the RWC algorithm, Gentpro uses the daily minimum temperature to determine the temporal allocation of emissions to days of the year. Gentpro was used to create an annual-to-day temporal profile for the RWC sources. These generated profiles distribute annual RWC emissions to the coldest days of the 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 Td >= Tt: no emissions that day
> If Td < Tt: daily factor = 0.79*(Tt -Td)
>
> where (Td = minimum daily temperature; Tt = 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.

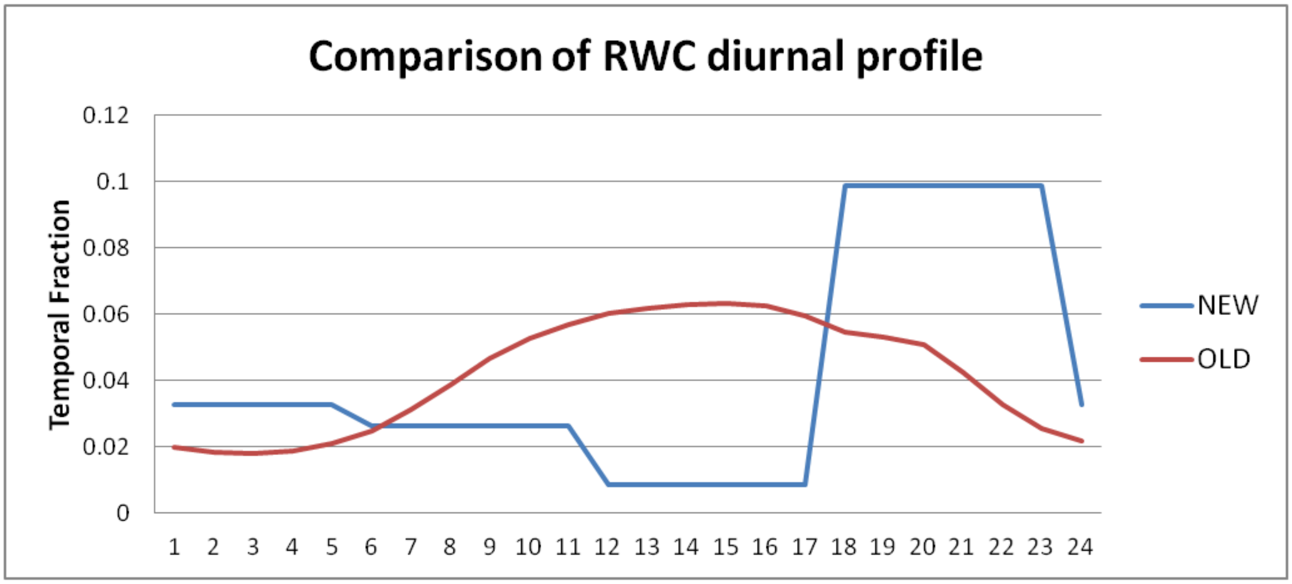
Figure 3-16 illustrates the impact of changing the temperature threshold for a warm climate county. The plot shows the temporal fraction by day for Duval County, Florida, for the first four months of 2007. The default 50 ˚F threshold creates large spikes on a few days, while the 60 ˚F threshold dampens these spikes and distributes a small amount of emissions to the days that have a minimum temperature between 50 and 60 ˚F.

Figure 3-16. Example of RWC temporal allocation using a 50 versus 60 ˚F threshold



The diurnal profile used for most RWC sources (see Figure 3-17) 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.[24] 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 3-17. RWC diurnal temporal profile



The temporal allocation for "Outdoor Hydronic Heaters" (i.e., "OHH," SCC=2104008610) and "Outdoor wood burning device, NEC (fire-pits, chimineas, etc.)" (i.e., "recreational RWC," SCC=21040087000) is 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 OHH, the annual-to-month, day-of-week and diurnal profiles were modified based on information in the New York State Energy Research and Development Authority's (NYSERDA) "Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater Technologies, Final Report" (NYSERDA, 2012), as well as a Northeast States for Coordinated Air Use Management (NESCAUM) report "Assessment of Outdoor Wood-fired Boilers" (NESCAUM, 2006). A Minnesota 2008 Residential Fuelwood Assessment Survey of individual household responses (MDNR, 2008) provided additional annual-to-month, day-of-week, and diurnal activity information for OHH as well as recreational RWC usage.

Data used to create the diurnal profile for OHH, shown in Figure 3-18, are based on a conventional single-stage heat load unit burning red oak in Syracuse, New York. As shown in Figure 3-19, 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.

[24] https://s3.amazonaws.com/marama.org/wp-content/uploads/2019/11/13093804/Open_Burning_Residential_Areas_Emissions_Report-2004.pdf.

Annual-to-month temporal allocation for OHH as well as recreational RWC were computed from the MDNR 2008 survey and are illustrated in Figure 3-20. The OHH emissions still exhibit strong seasonal variability, but do not drop to zero because many units operate year-round for water and pool heating. In contrast to all other RWC appliances, recreational RWC emissions are used far more frequently during the warm season.

Figure 3-18. Data used to produce a diurnal profile for OHH, based on heat load (BTU/hr)

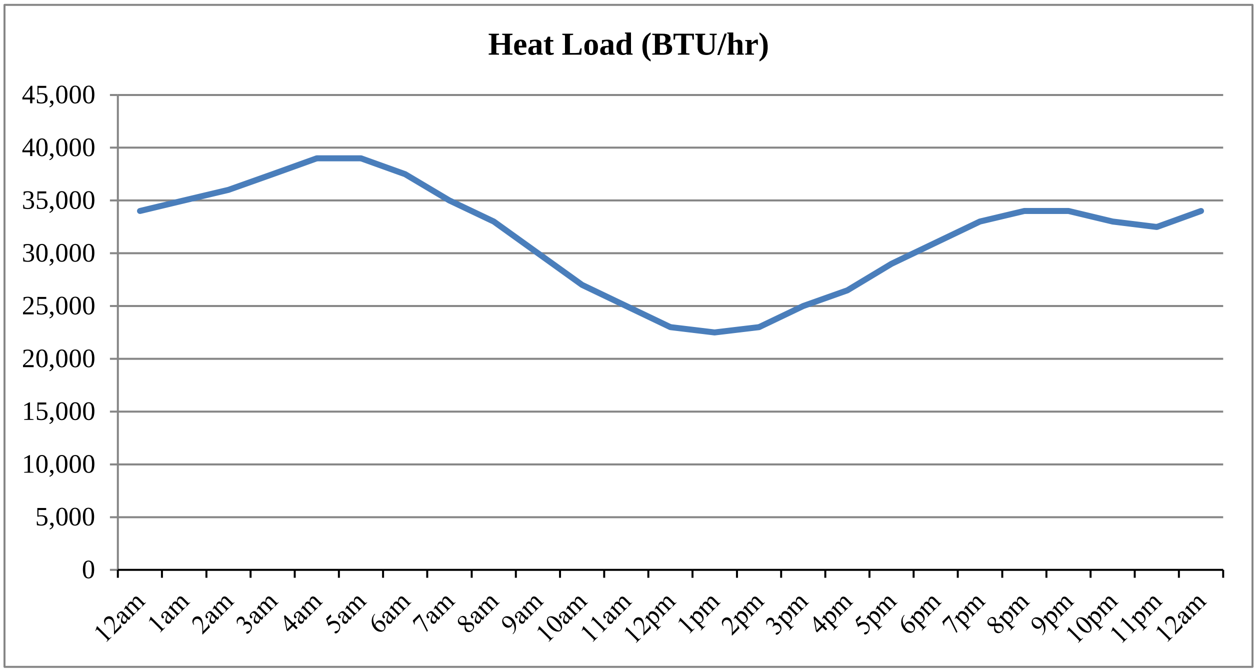


Figure 3-19. Day-of-week temporal profiles for OHH and Recreational RWC

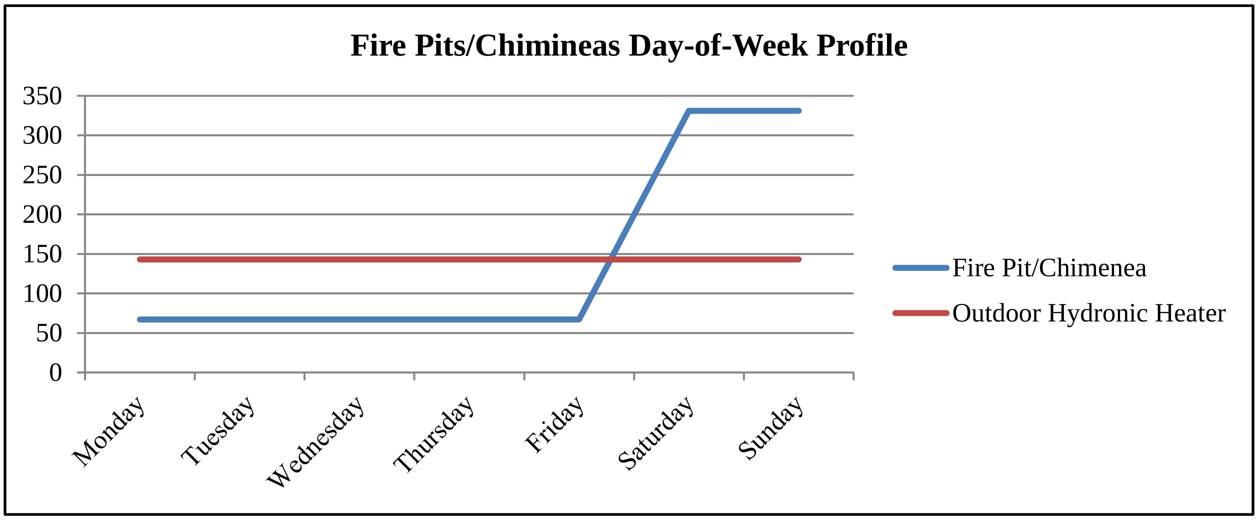
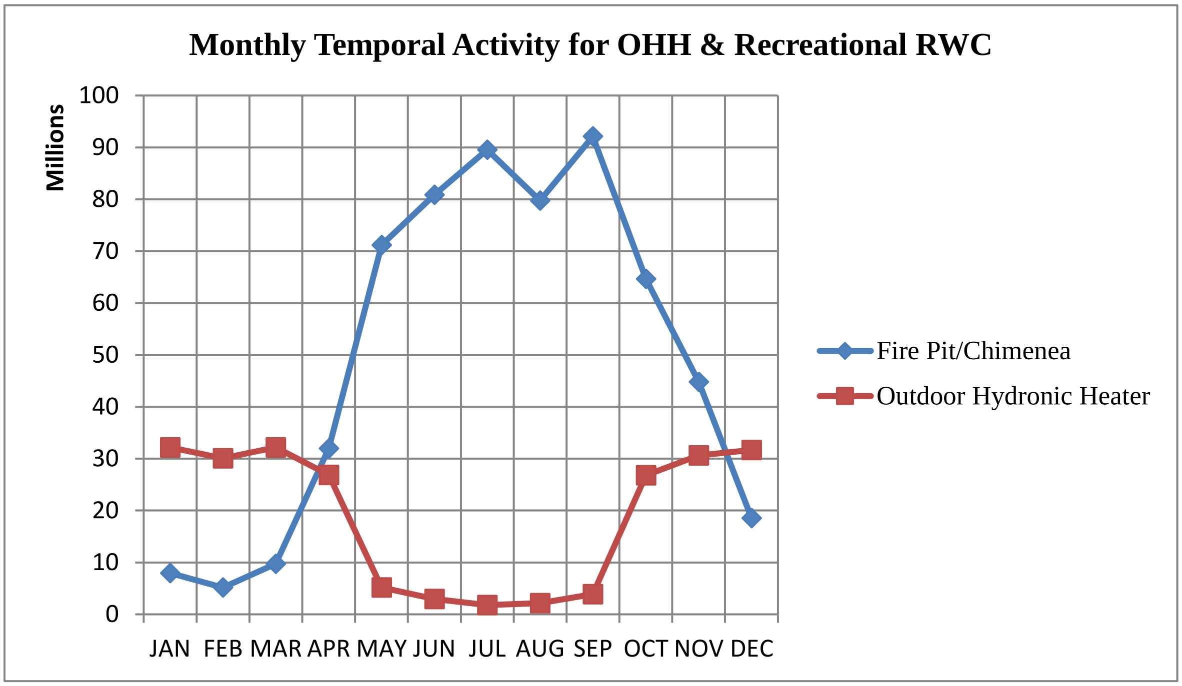


Figure 3-20. Annual-to-month temporal profiles for OHH and recreational RWC



3.3.5 Agricultural Ammonia Temporal Profiles (livestock)

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

$$E_{i,h} = [161500/T_{i,h} \text{ x } e^{(-1380/T_{i,h})}] \text{ x } AR_{i,h} \qquad \text{Equation 3-4}$$

$$PE_{i,h} = E_{i,h} / \text{Sum}(E_{i,h}) \qquad \text{Equation 3-5}$$

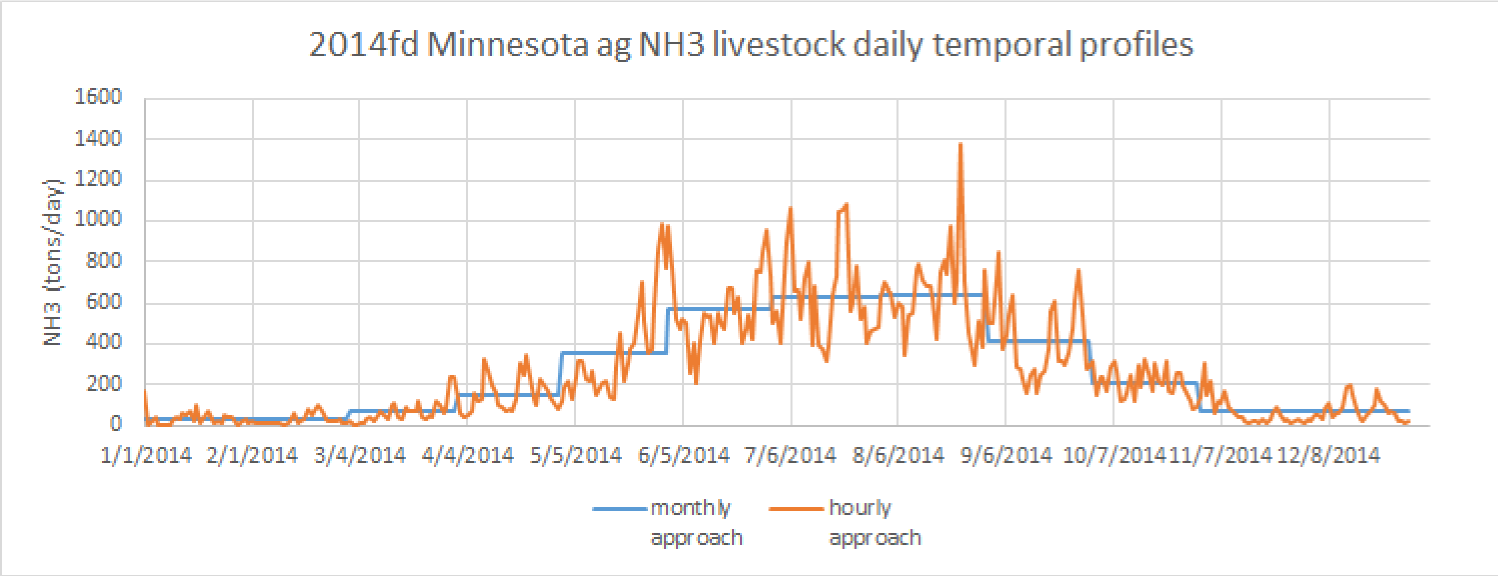
where

- $PE_{i,h}$ = 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 3-21 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 3-21. Example of animal NH_3 emissions temporal allocation approach (daily total emissions)



For the 2018 platform, the GenTPRO approach is applied to all sources in the livestock and fertilizer sectors, NH_3 and non- NH_3. Monthly profiles are based on the daily-based EPA livestock emissions from the 2014 NEI. Profiles are by state/SCC_category, where SCC_category is one of the following: beef, broilers, layers, dairy, swine.

3.3.6 Oil and gas temporal allocation (np_oilgas)

Monthly oil and gas temporal profiles by county and SCC were updated to use 2018 activity information for the 2018 platform. Weekly and diurnal profiles are flat and are based on comments received on a version of the 2011 platform.

3.3.7 Onroad mobile temporal allocation (onroad)

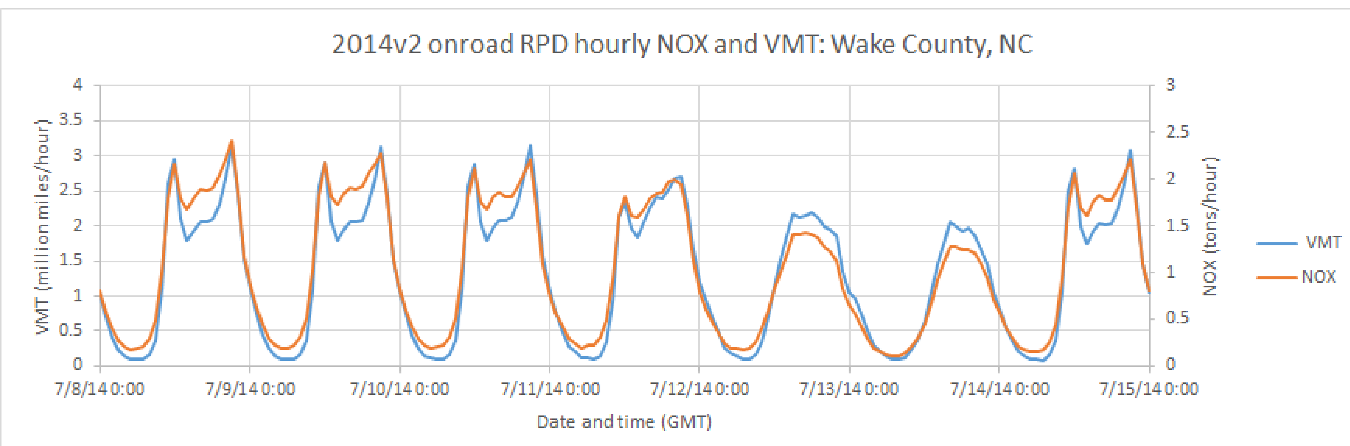
For the onroad sector, the temporal distribution of emissions is a combination of traditional temporal profiles and the influence of meteorology. This section will discuss both the meteorological influences and the development of the temporal profiles for this platform.

The "inventories" referred to in Table 3-19 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 require a speed profile (SPDPRO) that consists of vehicle speed by hour for a typical weekday and weekend day. For onroad, the temporal profiles and SPDPRO will impact not only the distribution of emissions through time but also the total emissions. Because SMOKE-MOVES (for RPD) calculates emissions 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 3-22 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 vehicle (RPV, RPH, RPHO, RPS, and RPP) processes use the gridded meteorology (MCIP) either directly or indirectly. For RPD, RPV, RPS, RPH, and RPHO, 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 3-22. 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 3-23. 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 3-24 shows which counties have temporal profiles specific to that county, and which counties use MSA or regional average profiles. Figure 3-25 shows the regions used to compute regional average profiles.

Figure 3-23. Sample onroad diurnal profiles for Fulton County, GA

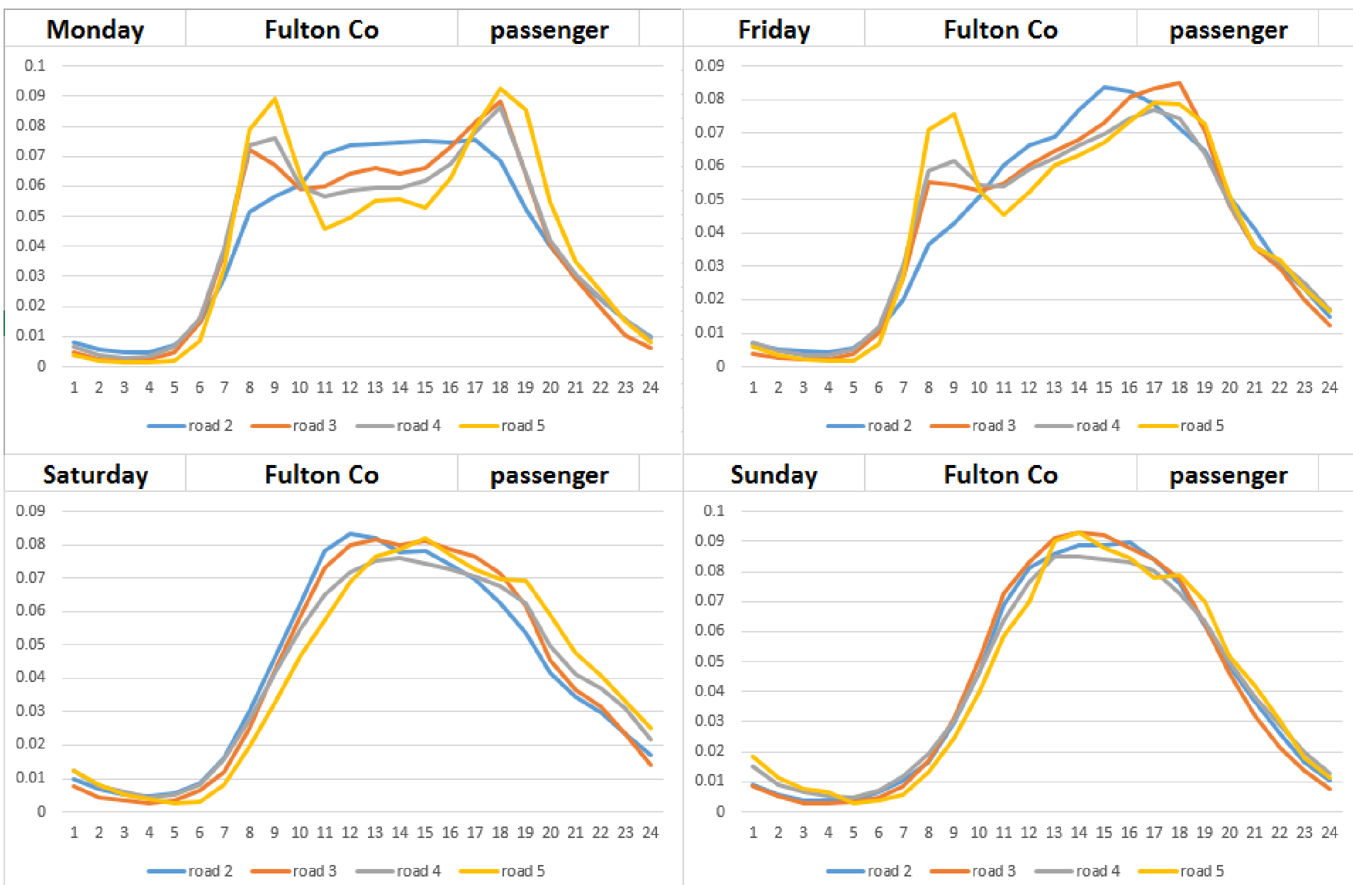
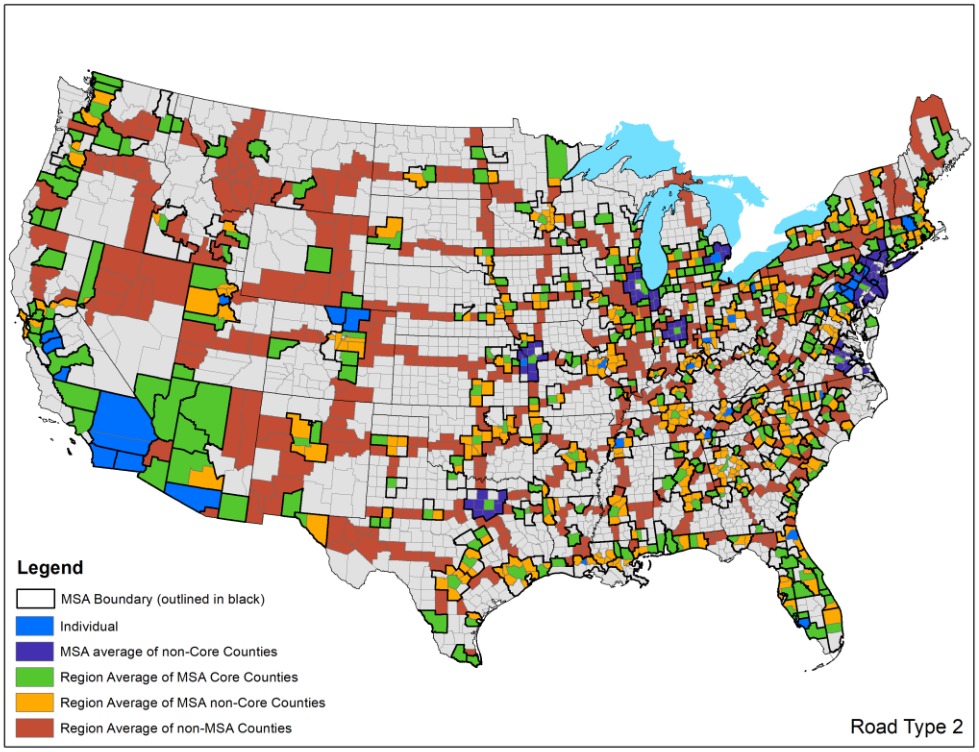


Figure 3-24. Methods to Populate Onroad Speeds and Temporal Profiles by Road Type



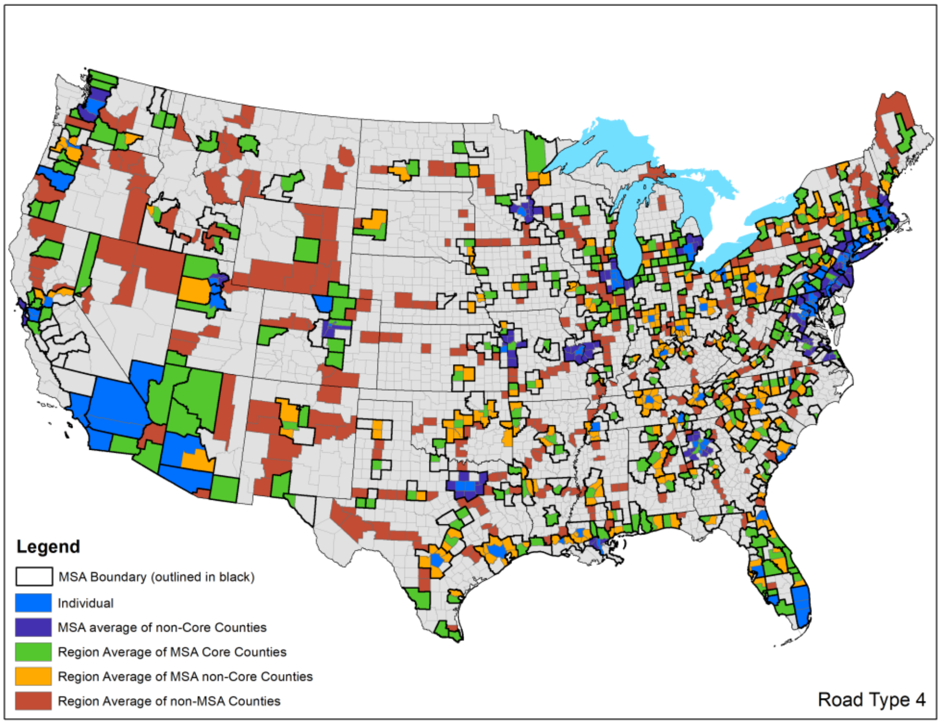
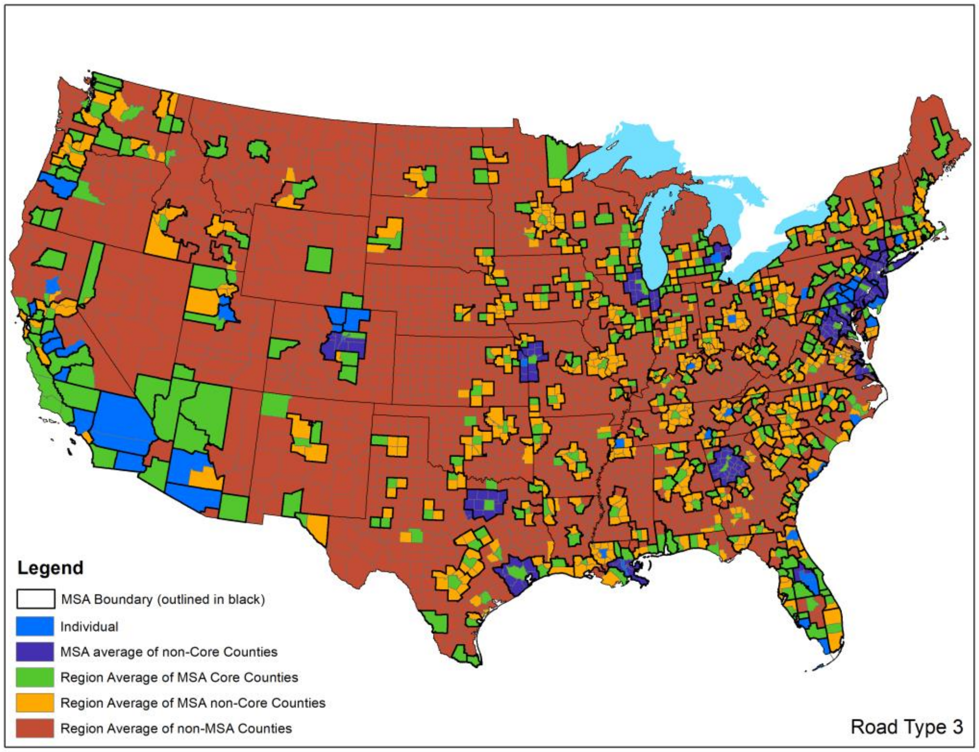


Figure 3-24 Methods to Populate Onroad Speeds and Temporal Profiles by Road Type (ctd).



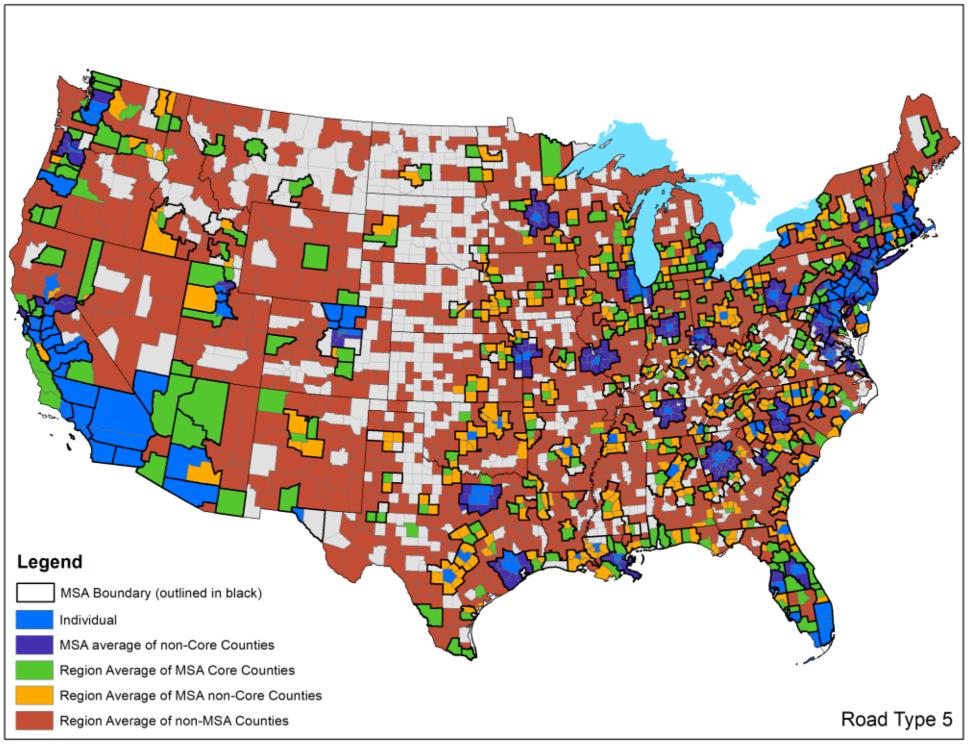
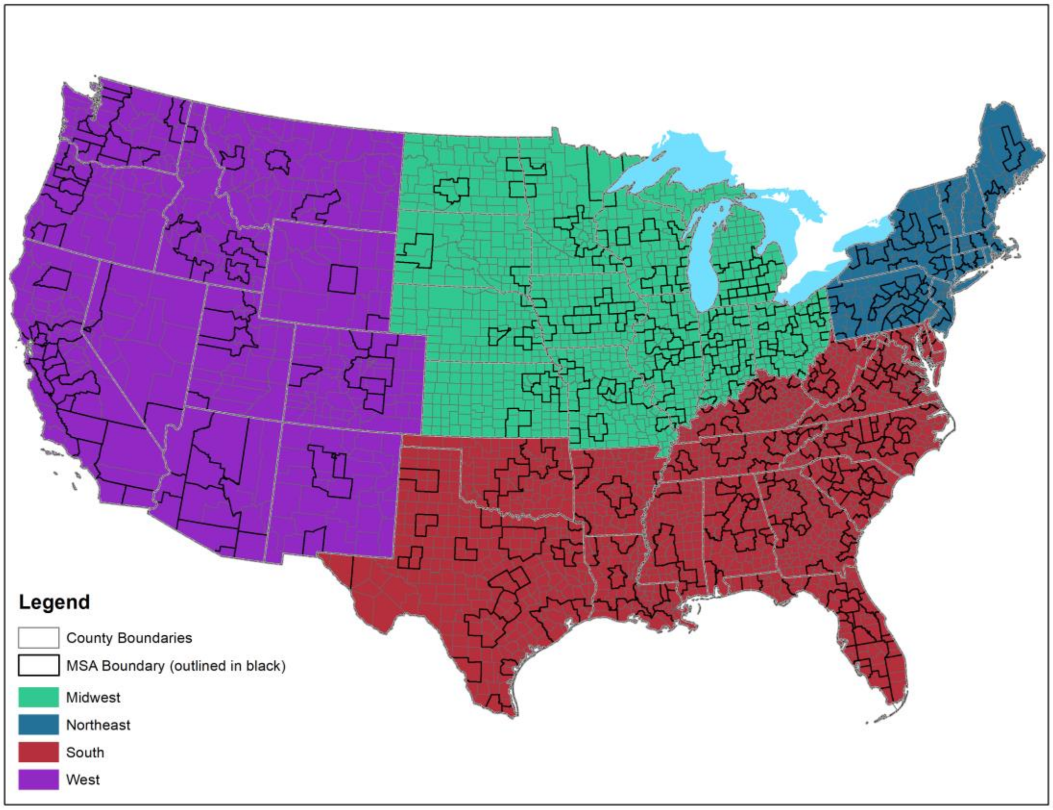


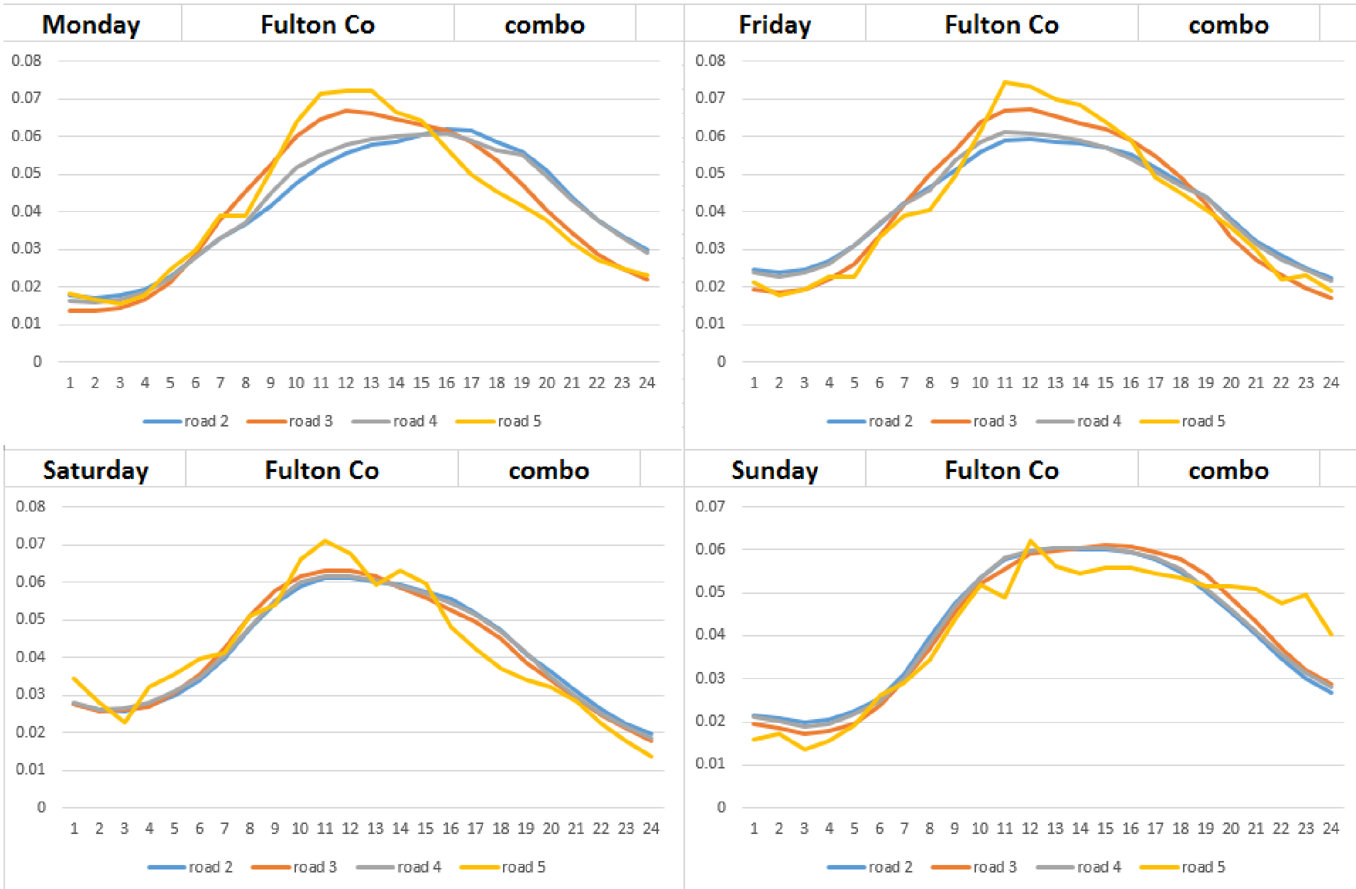
Figure 3-25. Regions for computing Region Average Speeds and Temporal Profiles



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 3-26.

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 temporal profiles for starts are applied nationally and are based on the default starts-per-day-per-vehicle and starts-hour-fraction tables from MOVES.

Figure 3-26. Example of Temporal Profiles for Combination Trucks



3.3.8 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 into this platform, some 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 3-27 shows two previously use temporal profiles (9 and 18) and the updated temporal profile (19) that has lower emissions on weekends. In this platform, construction and commercial lawn and garden sources use profile 19. Residental lawn and garden sources use profile 9 and agricultural sources use profile 19.

Figure 3-27. Example Nonroad Day-of-week Temporal Profiles

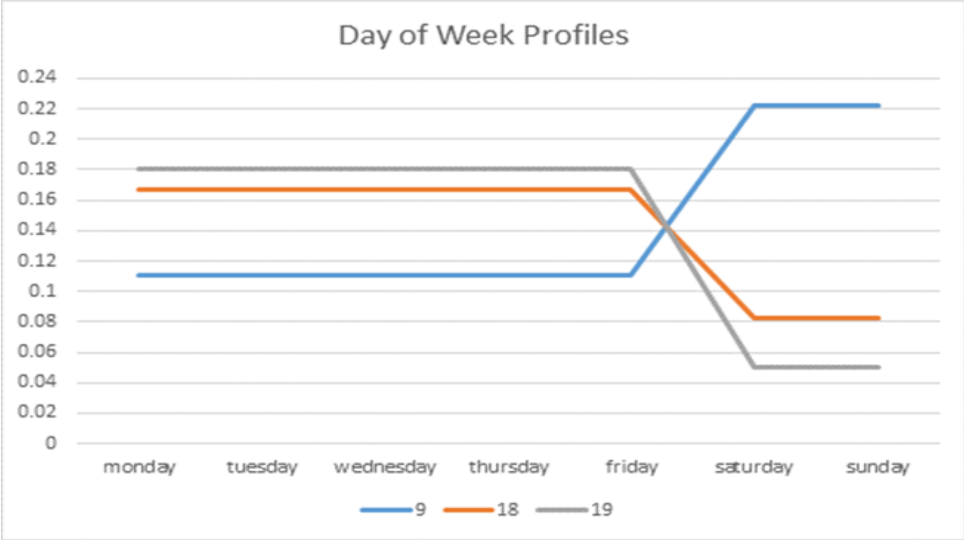
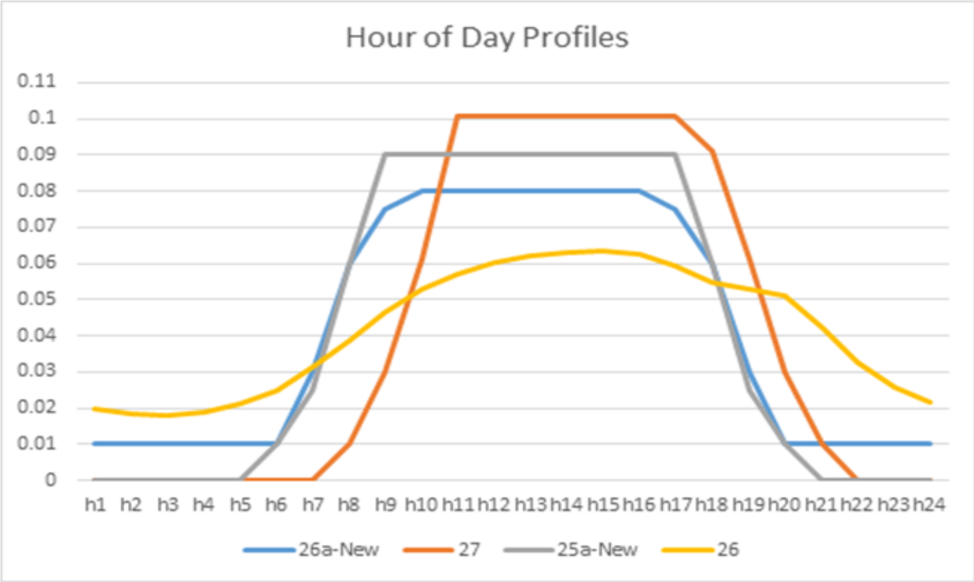


Figure 3-28 shows the previously existing temporal profiles 26 and 27 along with the temporal profiles (25a and 26a) that have lower emissions overnight. In this platform, construction sources use profile 26a. Commercial lawn and garden and agriculture sources use the profiles 26a and 25a, respectively. Residental lawn and garden sources use profile 27.

Figure 3-28. Example Nonroad Diurnal Temporal Profiles



3.3.9 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. For this reason, to ensure consistency between grid resolutions, afdust emissions for the 36US3 grid are aggregated from the 12US1 emissions. Application of the transport fraction and meteorological adjustments prevents the overestimation of fugitive dust impacts in the grid modeling as compared to ambient samples.

Biogenic emissions in the beis sector vary by every hour 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.

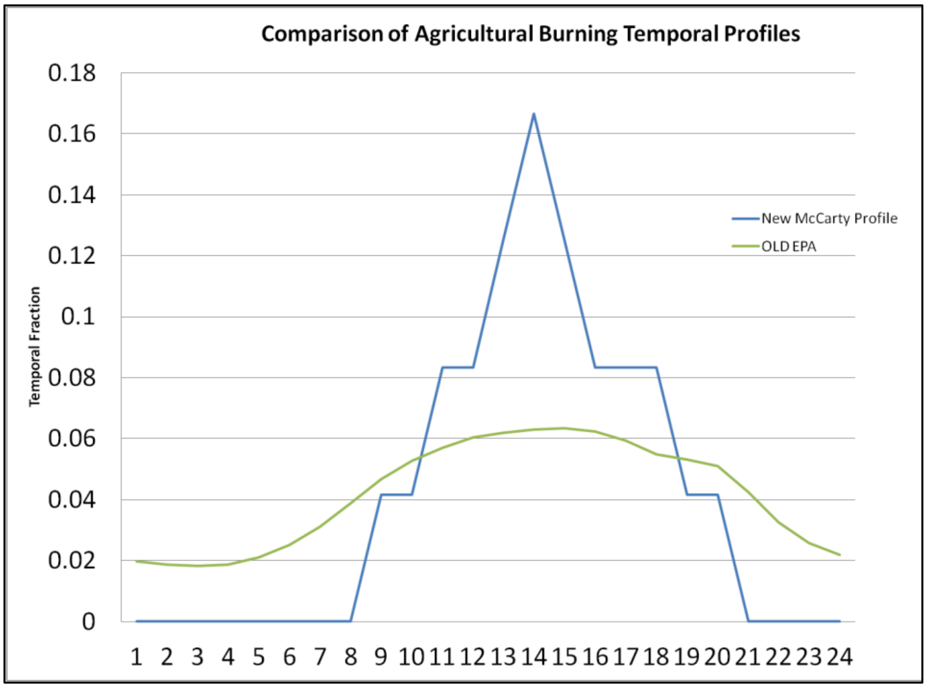
For the nonroad sector, while the NEI only stores the annual totals, the modeling platform uses monthly inventories from output from MOVES. For California, CARB's annual inventory was temporalized to monthly using monthly temporal profiles applied in SMOKE by SCC.

For the cmv sectors, most areas use hourly emission inventories derived from the 5-minute AIS data. In some areas where AIS data are not available, such as in Canada between the St. Lawrence Seaway and the Great Lakes and in the southern Caribbean, the flat temporal profiles are used for hourly and day-of-week values. Most regions without AIS data also use a flat monthly profile, with some offshore areas using an average monthly profile derived from the 2008 ECA inventory monthly values. These areas without AIS data also use flat day of week and hour of day profiles.

For the rail sector, new monthly profiles were developed for the 2016 platform and continue to be used in this 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 used 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 3-29 (McCarty et al., 2009). This puts most of the emissions during the workday and suppresses the emissions during the middle of the night.

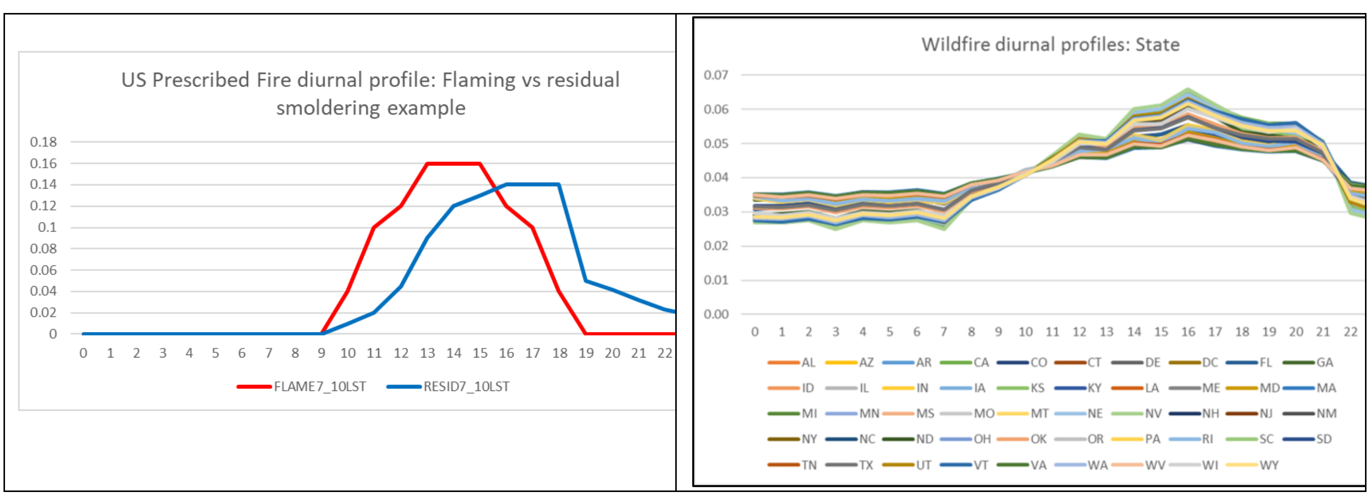
Figure 3-29. Agricultural burning diurnal temporal profile



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. Separate hourly profiles for prescribed and wildfires were used. Figure 3-30 shows the profiles used for each state for the 2018gc and 2018v2 modeling platforms. The wildfire diurnal profiles are similar but vary according to the average meteorological conditions in each state. The 2018gc and 2018v2 platforms used diurnal profiles for prescribed profile that better reflect flaming and residual smoldering phases and average burn practices. These flaming and residual smoldering diurnal profiles vary slightly by region.

Figure 3-30. Prescribed and Wildfire diurnal temporal profiles



3.4 Spatial Allocation

The methods used to perform spatial allocation are summarized in this section. The spatial factors are typically applied by SCC to allocate emissions from a county or province-based emissions inventory to specific grid cells. They are not used for point source data since those usually have specific locations assigned. If a particular spatial dataset used to develop a spatial surrogate does not have data for all counties (or provinces) for which there could be emissions assigned to use that surrogate, data are added to the surrogate from other more comprehensive surrogates to ensure that emissions data are not lost when the spatial surrogate is applied. Through gap-filling, data for entire counties or provinces are pulled from a secondary or tertiary surrogate into the primary surrogate so that the gap-filled surrogate has entries for all counties that may have a particular type of emissions.

As described in Section 3.1, spatial allocation was performed for national 36-km and 12-km domains. To accomplish this, SMOKE used national 36-km and 12-km spatial surrogates and a SMOKE area-to-point data file. For the U.S., the spatial surrogates are based on circa 2017 to 2018 data wherever possible. For Mexico, the spatial surrogates used as described below. For Canada, surrogates were provided by ECCC for the 2016v7.2 (beta) platform and those continue to be used in this platform. The U.S., Mexican, and Canadian 36-km and 12-km surrogates cover the entire CONUS domain 12US1 shown in Figure 3-1. The 36US3 domain includes a portion of Alaska, thus special considerations are taken to include Alaska emissions in 36-km modeling.

2018v2 platform uses the same surrogates and surrogate assignments as the 2016v3 platform, which were essentially the same as those used for the 2016v2 platform. Documentation of the origin of the spatial surrogates for the platform is provided in the 2018v2 surrogate specifications workbook. The remainder of this subsection summarizes the data used for the spatial surrogates and the area-to-point data which is used for airport refueling.

3.4.1 Spatial Surrogates for U.S. emissions

There are more than 80 spatial surrogates available for spatially allocating U.S. county-level emissions to the 36-km and 12-km grid cells used by the air quality model. Spatial surrogates are typically developed based on nationally available data sources (e.g., census data, national land cover database). An exception is when a regional inventory is used (e.g., the WRAP oil and gas inventory) and regional surrogates are used in association with that inventory. As described in Section 3.4.2, an area-to-point approach overrides the use of surrogates for airport refueling sources. Table 3-20 lists the codes and descriptions of the spatial surrogates. In this table, surrogate names and codes listed in *italics* are not directly assigned to any sources for this platform, but they may be used to gapfill other surrogates. The WRAP oil and gas surrogates used in this platform are not listed in Table 3-20 but are instead listed in Table 3-22.

Many surrogates were updated or newly developed for use in the 2014v7.0 platform (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 NLCD-based surrogates largely replaced the FEMA category (500 series) surrogates that were used in the 2011 platform. Additionally, onroad surrogates were developed using average annual daily traffic counts from the highway monitoring performance system (HPMS). Previously, the "activity" for the onroad surrogates was length of road miles. These and other surrogates are described in a reference (Adelman, 2016).

Issues were identified in the rail surrogates 261 and 271 that caused emissions to be allocated to cells far from the county. Comparisons were made in which county-cell mappings from all surrogates, were compared with the land area surrogate, and looked for county-cells that were two or more 36km cells away from the nearest cell for each county in the land area surrogate. Several problem cells were identified in 261 and 271. Therefore surrogates 261 and 271 were edited by removing the problem county-cells, and renormalizing the remaining factors so they sum to one.

Some surrogates were updated or newly developed for this platform or for the 2016 platforms:

- oil and gas surrogates represent activity during the year 2018;
- onroad spatial allocation uses surrogates that do not distinguish between urban and rural road types, correcting the issue arising in some counties due to the inconsistent urban and rural definitions between MOVES, the activity data, and the surrogate data, and were further updated for the 2016 platform;
- spatial surrogates for on-roadway sources use annual average daily traffic (AADT) for 2017;
- the surrogate used for truck stops was updated in 2019;
- a public schools surrogate (#508) was added in the 2016v2 platform;
- surrogate 508: “Public Schools” from 2018-2019 NCES public school was developed and is assigned to school buses;
- surrogate 259, used for transit bus off-network (onroad), was re-gapfilled using 306 (NLCD Med+High) first and population second – this addressed the overallocation to rural areas noted with the prior gapfilling approach;
- surrogate 306 (NLCD Med+High) now used in place of 259 since intercity bus is now other bus;
- the use of 500 series surrogates (except for the new #508) were phased out;
- rail surrogates 261 and 271 were updated to fix some misallocated emissions;
- surrogate 535 was reassigned to 307 (NLCD All Development); and
- surrogate 505 was reassigned to 306 (NLCD Med+High).

The surrogates for the U.S. were mostly generated using the Surrogate Tools DB tool, although a few were developed using the Spatial Allocator. The tool and documentation for the Surrogate Tools DB is available at https://www.cmascenter.org/surrogate_tools_db/.

Table 3-20. U.S. Surrogates available for this modeling platforms

Code	Surrogate Description	Code	Surrogate Description
N/A	Area-to-point approach (see 3.6.2)	*318*	*NLCD Pasture Land*
100	Population	319	NLCD Crop Land
110	*Housing*	320	NLCD Forest Land
131	*urban Housing*	321	NLCD Recreational Land
132	*Suburban Housing*	*340*	*NLCD Land*
134	*Rural Housing*	350	NLCD Water
137	*Housing Change*	508	Public Schools
140	*Housing Change and Population*	650	Refineries and Tank Farms
150	Residential Heating – Natural Gas	670	Spud Count – CBM Wells
160	*Residential Heating – Wood*	671	Spud Count – Gas Wells

Code	Surrogate Description	Code	Surrogate Description
170	Residential Heating – Distillate Oil	*672*	*Gas Production at Oil Wells*
180	Residential Heating – Coal	*673*	*Oil Production at CBM Wells*
190	Residential Heating – LP Gas	674	Unconventional Well Completion Counts
201	*Urban Restricted Road Miles*	676	Well Count – All Producing
202	Urban Restricted AADT	*677*	*Well Count – All Exploratory*
205	Extended Idle Locations	678	Completions at Gas Wells
211	*Rural Restricted Road Miles*	679	Completions at CBM Wells
212	*Rural Restricted AADT*	681	Spud Count – Oil Wells
221	*Urban Unrestricted Road Miles*	683	Produced Water at All Wells
222	*Urban Unrestricted AADT*	6831	Produced water at CBM wells
231	*Rural Unrestricted Road Miles*	6832	Produced water at gas wells
232	*Rural Unrestricted AADT*	6833	Produced water at oil wells
239	Total Road AADT	685	Completions at Oil Wells
240	Total Road Miles	*686*	*Completions at All Wells*
241	*Total Restricted Road Miles*	687	Feet Drilled at All Wells
242	All Restricted AADT	689	Gas Produced – Total
243	*Total Unrestricted Road Miles*	691	Well Counts - CBM Wells
244	All Unrestricted AADT	*692*	*Spud Count – All Wells*
258	Intercity Bus Terminals	693	Well Count – All Wells
259	Transit Bus Terminals	694	Oil Production at Oil Wells
260	*Total Railroad Miles*	695	Well Count – Oil Wells
261	NTAD Total Railroad Density	696	Gas Production at Gas Wells
271	NTAD Class 1 2 3 Railroad Density	*697*	*Oil Production at Gas Wells*
272	*NTAD Amtrak Railroad Density*	698	Well Count – Gas Wells
273	*NTAD Commuter Railroad Density*	699	Gas Production at CBM Wells
275	*ERTAC Rail Yards*	*710*	*Airport Points*
280	*Class 2 and 3 Railroad Miles*	711	Airport Areas
300	NLCD Low Intensity Development	801	Port Areas
301	*NLCD Med Intensity Development*	*802*	*Shipping Lanes*
302	*NLCD High Intensity Development*	*805*	*Offshore Shipping Area*
303	*NLCD Open Space*	*806*	*Offshore Shipping NEI2014 Activity*
304	NLCD Open + Low	*807*	*Navigable Waterway Miles*
305	NLCD Low + Med	*808*	*2013 Shipping Density*
306	NLCD Med + High	*820*	*Ports NEI2014 Activity*
307	NLCD All Development	850	Golf Courses
308	NLCD Low + Med + High	860	Mines
309	NLCD Open + Low + Med	*890*	*Commercial Timber*
310	NLCD Total Agriculture		

For the onroad sector, the on-network (RPD) emissions were spatially allocated differently from other off-network processes (e.g., 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 3-21. 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 those updates were carried into this platform.

Table 3-21. 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 3-22 using 2018 data consistent with what was used to develop the 2018gc nonpoint oil and gas emissions. The exception was the use of WRAP spatial surrogates from 2016v2 platform for production in New Mexico and North Dakota. 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 2018. In total, over 1 million unique wells were compiled from the above data sources (ERG, 2021). The wells cover 34 states and over 1,100 counties.

Table 3-22. 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

Surrogate Code	Surrogate Description
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
2688	WRAP Gas production at oil wells
2689	WRAP Gas production at all wells
2691	WRAP Well count - CBM wells
2693	WRAP Well count - all wells
2694	WRAP Oil production at oil wells
2695	WRAP Well count - oil wells
2696	WRAP Gas production at gas wells
2697	WRAP Oil production at gas wells
2698	WRAP Well count - gas wells
2699	WRAP Gas production at CBM wells
6831	Produced water at CBM wells
6832	Produced water at gas wells
6833	Produced water at oil wells

Not all of the available surrogates are used to spatially allocate sources in the modeling platform; that is, some surrogates shown in Table 3-20 were not assigned to any SCCs, although many of the “unused” surrogates are actually used to “gap fill” primary surrogates, as discussed above. Table 3-23 shows the CAP emissions (i.e., NH_3, NOx, $PM_{2.5}$, SO_2, and VOC) by sector assigned to each spatial surrogate.

For 36US3 modeling in this platform, most U.S. emissions sectors were processed using 36-km spatial surrogates, and if applicable, 36-km meteorology. Exceptions include:

- For the onroad and onroad_ca_adj sectors, instead of running SMOKE-MOVES with 36km meteorological data, 36US3 emissions were aggregated from 12US1 by summing emissions from a 3x3 group of 12-km cells into a single 36-km cell. Differences in the 12-km and 36-km meteorology can introduce differences in onroad emissions, so this approach ensures that the 36-km and 12-km onroad emissions are consistent. However, this approach means that 36US3 onroad does not include emissions in Southeast Alaska; therefore, Alaska onroad emissions are included in a separate sector called onroad_nonconus that is processed for only the 36US3 domain. The 36US3 onroad_nonconus emissions are spatially allocated using 36-km surrogates and processed with 36-km meteorology.

- Similarly to onroad, because afdust emissions incorporate meteorologically-based adjustments, afdust_adj emissions for 36US3 were aggregated from 12US1 to ensure consistency in emissions between modeling domains. Again, similarly to onroad, this means 36US3 afdust does not include emissions in Southeast Alaska; therefore, Alaska afdust emissions are processed in a separate sector called afdust_ak_adj. The 36US3 afdust_ak_adj emissions are spatially allocated using 36-km surrogates and adjusted with 36-km meteorology.
- The ag and rwc sectors are processed using 36-km spatial surrogates, but using temporal profiles based on 12-km meteorology.

Table 3-23. Selected 2018 CAP emissions by sector for U.S. Surrogates (short tons in 12US1)

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
Afdust	240	Total Road Miles	0	0	312,090	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
fertilizer	310	NLCD Total Agriculture	1,636,229	0	0	0	0
livestock	310	NLCD Total Agriculture	2,582,189	0	0	0	226,398
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	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	1,914	198	1	376
nonroad	304	NLCD Open + Low	4	1,690	144	4	2,488
nonroad	305	NLCD Low + Med	95	14,943	3,859	104	106,139

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
nonroad	306	NLCD Med + High	326	166,683	10,459	297	89,752
nonroad	307	NLCD All Development	101	29,905	15,389	97	170,454
nonroad	308	NLCD Low + Med + High	551	286,527	23,894	234	47,904
nonroad	309	NLCD Open + Low + Med	121	21,137	1,246	135	45,692
nonroad	310	NLCD Total Agriculture	420	329,678	23,876	187	34,856
nonroad	320	NLCD Forest Land	15	3,954	558	8	3,731
nonroad	321	NLCD Recreational Land	83	12,636	5,805	76	215,471
nonroad	350	NLCD Water	191	114,414	4,918	212	293,014
nonroad	850	Golf Courses	13	2,066	118	14	5,685
nonroad	860	Mines	2	2,523	251	1	476
np_oilgas	670	Spud Count - CBM Wells	0	0	0	0	183
np_oilgas	671	Spud Count - Gas Wells	0	0	0	0	6,021
np_oilgas	674	Unconventional Well Completion Counts	31	25,368	618	30	1,110
np_oilgas	678	Completions at Gas Wells	0	9,892	254	3,674	37,861
np_oilgas	679	Completions at CBM Wells	0	5	0	237	700
np_oilgas	681	Spud Count - Oil Wells	0	0	0	0	46,149
np_oilgas	683	Produced Water at All Wells	0	22	0	0	868
np_oilgas	685	Completions at Oil Wells	0	438	0	2,026	57,876
np_oilgas	687	Feet Drilled at All Wells	0	84,073	2,261	115	3,834
np_oilgas	689	Gas Produced - Total	0	569	28	2	32,663
np_oilgas	691	Well Counts - CBM Wells	0	12,025	222	5	16,035
np_oilgas	692	Spud Count – All Wells	0	365	12	42	34
np_oilgas	693	Well Count – All Wells	0	0	0	0	2
np_oilgas	694	Oil Production at Oil Wells	0	2,607	0	1,651	477,995
np_oilgas	695	Well Count - Oil Wells	0	137,335	3,239	19,295	435,954
np_oilgas	696	Gas Production at Gas Wells	0	40,240	0	4,249	235,302
np_oilgas	697	Oil Production at Gas Wells	0	858	0	0	80,817
np_oilgas	698	Well Count - Gas Wells	7	277,705	3,918	141	444,273
np_oilgas	699	Gas Production at CBM Wells	0	29	5	0	3,531
np_oilgas	2688	WRAP Gas production at oil wells	0	7,188	0	5,435	206,000
np_oilgas	2689	WRAP Gas production at all wells	0	25,667	772	1,108	19,346
np_oilgas	2691	WRAP Well count - CBM wells	0	190	15	0	1,269
np_oilgas	2693	WRAP Well count - all wells	0	84	3	0	5
np_oilgas	2694	WRAP Oil production at oil wells	0	31,299	446	17,337	70,025
np_oilgas	2695	WRAP Well count - oil wells	0	1,233	124	4	55,343
np_oilgas	2696	WRAP Gas production at gas wells	0	1,424	19	1	22,763
np_oilgas	2697	WRAP Oil production at gas wells	0	29	0	0	10,273
np_oilgas	2698	WRAP Well count - gas wells	0	728	56	0	49,283
np_oilgas	2699	WRAP Gas production at CBM wells	0	9,026	268	8	6,984
np_oilgas	6831	Produced water at CBM wells	0	0	0	0	740
np_oilgas	6832	Produced water at gas wells	0	0	0	0	16,231
np_oilgas	6833	Produced water at oil wells	0	0	0	0	74,707

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
np_solvents	100	Population	0	0	0	0	1,354,437
np_solvents	240	Total Road Miles	0	0	0	0	50,500
np_solvents	306	NLCD Med + High	33	27	300	1	395,102
np_solvents	307	NLCD All Development	24	6	19	5	365,628
np_solvents	308	NLCD Low + Med + High	0	0	129	0	8,324
np_solvents	310	NLCD Total Agriculture	0	0	0	0	162,850
onroad	205	Extended Idle Locations	333	31,740	616	17	3,337
onroad	242	All Restricted AADT	34,519	922,998	23,496	6,667	137,657
onroad	244	All Unrestricted AADT	63,741	1,538,528	53,194	14,424	387,798
onroad	259	Transit Bus Terminals	15	2,725	63	2	510
onroad	304	NLCD Open + Low	0	872	27	0	6,880
onroad	306	NLCD Med + High	927	94,894	3,461	86	19,921
Onroad	307	NLCD All Development	3,494	211,798	6,822	1,352	584,337
Onroad	308	NLCD Low + Med + High	206	21,756	549	78	31,605
Onroad	508	Public Schools	15	2,140	85	1	562
Rail	261	NTAD Total Railroad Density	15	35,364	988	32	1,704
Rail	271	NTAD Class 1 2 3 Railroad Density	350	535,605	14,016	695	23,244
Rwc	300	NLCD Low Intensity Development	16,143	34,093	299,278	7,988	323,969

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: https://www.epa.gov/sites/default/files/2020-10/documents/emissions_tsd_vol1_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

Spatial surrogates for allocating Mexico municipio level emissions were updated in the 2014v7.1 platform and carried forward into this platform. For the 2016 beta (v7.2) platform, a set of Canada shapefiles were provided by ECCC along with cross references to spatially allocate the year 2015 Canadian emissions. Gridded surrogates were generated using the Surrogate Tool (previously referenced); Table 3-24 provides a list. For computational reasons, total roads (1263) were used instead of the unpaved rural road surrogate provided. The population surrogate for Mexico; surrogate code 11, uses 2015 population data at 1 km resolution and replaced 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 3-25.

Table 3-24. Canadian Spatial Surrogates

Code	Canadian Surrogate Description	Code	Description
100	Population	923	TOTAL INSTITUTIONAL AND GOVERNEMNT
101	total dwelling	924	Primary Industry
104	capped total dwelling	925	Manufacturing and Assembly
106	ALL_INDUST	926	Distribution and Retail (no petroleum)
113	Forestry and logging	927	Commercial Services
200	Urban Primary Road Miles	932	CANRAIL
210	Rural Primary Road Miles	940	PAVED ROADS NEW
211	Oil and Gas Extraction	945	Commercial Marine Vessels
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
904	General Aviation LTO	1265	OFFR_CANRAIL
921	Commercial Fuel Combustion	9450	Commercial Marine Vessel Ports

Table 3-25. CAPs Allocated to Mexican and Canadian Spatial Surrogates (short tons in 36US3)

Sector	Code	Mexican / Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
othafdust	106	CAN ALL_INDUST	0	0	609	0	0
othafdust	212	CAN Mining except oil and gas	0	0	3,142	0	0
othafdust	221	CAN Total Mining	0	0	17,315	0	0
othafdust	222	CAN Utilities	0	0	2,792	0	0
othafdust	940	CAN Paved Roads New	0	0	29,862	0	0

Sector	Code	Mexican / Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
othafdust	955	CAN UNPAVED_ROADS_AND_TRAILS	0	0	426,511	0	0
othar	11	MEX 2015 Population	0	0	0	0	628,869
othar	14	MEX Residential Heating - Wood	251	44,151	121,868	3,765	327,369
othar	16	MEX Residential Heating – Distillate Oil	4	121	0	0	5
othar	22	MEX Total Road Miles	1	236	5,247	1	5,900
othar	24	MEX Total Railroad Miles	0	53,191	1,141	492	2,003
othar	26	MEX Total Agriculture	573,834	74,104	47,068	1,866	16,648
othar	32	MEX Commercial Land	0	387	8,290	0	100,237
othar	34	MEX Industrial Land	176	4,104	4,022	13	100,682
othar	36	MEX Commercial plus Industrial Land	7	22,388	1,365	15	229,263
othar	40	MEX Residential (RES1-4)+Comercial+Industrial+Institutional+Government	4	87	373	14	102,973
othar	42	MEX Personal Repair (COM3)	0	0	0	0	25,438
othar	44	MEX Airports Area	0	14,556	186	1,111	5,970
othar	48	MEX Brick Kilns	0	2,752	54,113	4,952	1,322
othar	50	MEX Mobile sources - Border Crossing	3	63	2	0	50
othar	100	CAN Population	795	52	622	15	225
othar	101	CAN total dwelling	0	0	0	0	151,094
othar	104	CAN Capped Total Dwelling	361	31,746	2,335	2,671	1,650
othar	113	CAN Forestry and logging	152	1,818	9,778	37	5,140
othar	211	CAN Oil and Gas Extraction	1	43	433	74	2,122
othar	212	CAN Mining except oil and gas	0	0	11	0	0
othar	221	CAN Total Mining	0	0	293	0	0
othar	222	CAN Utilities	57	3,439	166	464	65
othar	308	CAN Food manufacturing	0	0	19,253	0	17,468
othar	321	CAN Wood product manufacturing	873	4,822	1,646	383	16,605
othar	323	CAN Printing and related support activities	0	0	0	0	11,778
othar	324	CAN Petroleum and coal products manufacturing	0	1,201	1,632	467	9,368
othar	326	CAN Plastics and rubber products manufacturing	0	0	0	0	24,270
othar	327	CAN Non-metallic mineral product manufacturing	0	0	6,541	0	0
othar	331	CAN Primary Metal Manufacturing	0	158	5,598	30	72
othar	412	CAN Petroleum product wholesaler-distributors	0	0	0	0	45,634
othar	448	CAN clothing and clothing accessories stores	0	0	0	0	143
othar	482	CAN Rail Transportation	1	4,106	89	1	258
othar	562	CAN Waste management and remediation services	247	1,981	2,747	2,508	9,654
othar	901	CAN Airport	0	108	10	0	11
othar	921	CAN Commercial Fuel Combustion	206	24,819	2,435	1,669	1,254
othar	923	CAN TOTAL INSTITUTIONAL AND GOVERNEMNT	0	0	0	0	14,847
othar	924	CAN Primary Industry	0	0	0	0	40,409
othar	925	CAN Manufacturing and Assembly	0	0	0	0	70,468
othar	926	CAN Distribution and Retail (no petroleum)	0	0	0	0	7,475
othar	927	CAN Commercial Services	0	0	0	0	32,096
othar	932	CAN CANRAIL	52	91,908	1,822	48	3,901

Sector	Code	Mexican / Canadian Surrogate Description	NH_3	NO_X	PM_{2_5}	SO_2	VOC
othar	946	CAN Construction and Mining	0	0	0	0	10,211
othar	951	CAN Wood Consumption Percentage	1,010	11,223	113,852	1,603	161,174
othar	990	CAN TOTFERT	49	4,185	276	6,834	160
othar	996	CAN urban_area	0	0	3,182	0	0
othar	1251	CAN OFFR_TOTFERT	77	57,573	3,951	52	5,312
othar	1252	CAN OFFR_MINES	1	849	60	1	122
othar	1253	CAN OFFR Other Construction not Urban	70	33,981	4,176	44	11,227
othar	1254	CAN OFFR Commercial Services	43	15,106	2,335	33	36,291
othar	1255	CAN OFFR Oil Sands Mines	23	12,478	410	12	1,330
othar	1256	CAN OFFR Wood industries CANVEC	8	2,680	260	5	1,018
othar	1257	CAN OFFR Unpaved Roads Rural	26	11,193	656	20	28,180
othar	1258	CAN OFFR_Utilities	9	4,169	200	6	873
othar	1259	CAN OFFR total dwelling	17	6,127	619	13	12,817
othar	1260	CAN OFFR_water	23	6,736	373	31	27,471
othar	1261	CAN OFFR_ALL_INDUST	4	5,287	157	2	1,081
othar	1262	CAN OFFR Oil and Gas Extraction	1	1,267	78	1	229
othar	1263	CAN OFFR_ALLROADS	3	1,548	150	2	474
othar	1265	CAN OFFR_CANRAIL	0	541	17	0	42
onroad_can	200	CAN Urban Primary Road Miles	1,617	69,363	2,232	324	7,452
onroad_can	210	CAN Rural Primary Road Miles	667	41,473	1,255	137	3,276
onroad_can	220	CAN Urban Secondary Road Miles	3,036	110,302	4,484	681	19,873
onroad_can	230	CAN Rural Secondary Road Miles	1,764	78,435	2,467	369	9,127
onroad_can	240	CAN Total Road Miles	349	48,945	1,384	76	99,474
onroad_mex	11	MEX 2015 Population	0	299,194	1,737	567	298,729
onroad_mex	22	MEX Total Road Miles	10,795	1,204,621	59,899	27,420	245,504
onroad_mex	36	MEX Commercial plus Industrial Land	0	8,520	153	31	9,594

4 Analytic Year Emissions Inventories and Approaches

The emission inventories for the analytic year of 2032 have been developed using projection methods that are specific to the type of emissions source. Analytic year emissions are projected from the base year either by running models to estimate analytic year emissions from specific types of emission sources (e.g., EGUs, and onroad and nonroad mobile sources), or for other types of sources by adjusting the base year emissions according to the best estimate of changes expected to occur in the intervening years (e.g., non-EGU point and nonpoint sources). For some sectors, the same emissions are used in the base and analytic years, such as biogenic, all fire sectors, and fertilizer. Emissions for these sectors are held constant in future years because the base year meteorological data are also used for the future year air quality model runs, and emissions for these sectors are highly correlated with meteorological conditions. For the remaining sectors, rules and specific legal obligations that go into effect in the intervening years, along with changes in activity for the sector, are considered when possible. For sectors that were projected, the methods used to project those sectors to 2032 are summarized in Table 4-1.

Table 4-1. Overview of projection methods for the analytic year cases

Platform Sector: ***abbreviation***	**Description of Projection Methods for Analytic Year Inventories**
EGU units: ***ptegu***	The Integrated Planning Model (IPM) outputs from the EPA's Post-IRA 2022 Reference Case were used. For 2032, the 2030 IPM output year was used. Emission inventory Flat Files for input to SMOKE were generated using post-processed IPM output data. **A list of included rules is provided in Section 4.1**.
Point source oil and gas: ***pt_oilgas***	First, known closures were applied to the 2018 pt_oilgas sources. Production-related sources were then grown from 2018 to 2032 using historic production data. The production-related sources were then grown to 2032 based on growth factors derived from the Annual Energy Outlook (AEO) 2022 data for oil, natural gas, or a combination thereof. The grown emissions were then controlled to account for the impacts of New Source Performance Standards (NSPS) for oil and gas sources, process heaters, natural gas turbines, reciprocating internal combustion engines (RICE), and the Good Neighbor Plan for the 2015 Ozone NAAQS. These projection factors were applied to 2018 emissions in the entire US, including the WRAP region.
Airports: ***airports***	Point source airport emissions were grown from 2016 to 2032 using factors derived from the 2021 Terminal Area Forecast (TAF) released in June 2022 (see https://www.faa.gov/data_research/aviation/taf/). The 2016 emissions included corrections to emissions for ATL from the state of Georgia, as well as some corrections for specific airports in the state of Texas that were part of the 2016v3 platform.
Remaining non-EGU point: ***ptnonipm***	2026gf from the 2016v3 platform was used as a starting point to project emissions to 2032 using factors derived from AEO2022 to reflect growth from 2026 to 2032 (including railyards). 2026gf included controls to account for relevant NSPS for RICE, gas turbines, refineries (subpart Ja), and process heaters. The Boiler MACT is assumed to be fully implemented in 2018. Controls are reflected for the regional haze program in Arizona and Good neighbor plan for the 2015 Ozone NAAQS. In 2026gf known closures as of that time those inventories were developed are reflected and new sources were added based on 2019 NEI. Growth in MARAMA states was derived from MARAMA spreadsheets after incorporating AEO 2022 data. Railyards in California were updated with CARB data for 2032. Point source solvents are based on 2019 NEI and projected to 2032.

Platform Sector: ***abbreviation***	**Description of Projection Methods for Analytic Year Inventories**
Category 1, 2 CMV: ***cmv_c1c2***	Category 1 and category 2 (C1C2) CMV emissions sources outside of California were projected to 2030 (2030 emissions were used to represent 2032) based on factors from the Regulatory Impact Analysis (RIA) Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder. California emissions were calculated using new 2018->2030 factors based on interpolations of the same CARB data used to calculate factors in 2016 platforms (2030 was used for 2032). Projection factors for Canada emissions were calculated using 2018->2028 factors based on interpolations of the ECCC data provided for the 2016 platforms, then multiplied by the 2028-2030 US-based factors (same as in 2032fj in the 2016v2 platform).
Category 3 CMV: ***cmv_c3***	Category 3 (C3) CMV emissions were projected to 2030 using an EPA report on projected bunker fuel demand that projects fuel consumption by region out to the year 2030 (2030 was used for 2032). Bunker fuel usage was used as a surrogate for marine vessel activity. Factors based on the report were used for all pollutants except NOx. The NOx growth rates from the EPA C3 Regulatory Impact Assessment (RIA) were refactored to use the new bunker fuel usage growth rates. Assumptions of changes in fleet composition and emissions rates from the C3 RIA were preserved and applied to bunker fuel demand growth rates for 2030 to arrive at the final growth rates. Projection factors for Canada emissions were calculated using 2018->2028 factors based on interpolations of the ECCC data provided for the 2016 platforms, then multiplied by the 2028-2030 US-based factors (same as in 2032fj in the 2016v2 platform).
Locomotives: ***rail***	Rail was projected from 2026fj to 2032 using AEO2022-based growth factors, plus ERTAC-based pollutant-specific factors for Class I. California rail used new CARB 2032 inventory.
Area fugitive dust: ***afdust***	Paved road dust was grown to 2032 levels based on the growth in VMT from 2018 to 2032. Emissions for the remainder of the sector including building construction, road construction, agricultural dust, and unpaved road dust were held constant at 2018 levels.
Livestock: ***livestock***	Livestock were projected using factors developed for 2016v3 platform. Emissions were projected from 2018 to 2032 based on factors created from USDA National livestock inventory projections published in 2022 (https://www.ers.usda.gov/publications/pub-details/?pubid=103309).
Nonpoint source oil and gas: ***np_oilgas***	Exploration-related sources were based on an average of 2017 through 2019 exploration data with NSPS controls applied, where applicable. Production-related emissions were initially projected to 2021 using historical data and then grown to 2032 based on factors generated from AEO2022 reference case. Based on the SCC, factors related to oil, gas, or combined growth were used. Coalbed methane SCCs were projected independently. These projection factors were applied to 2018 production emissions in the entire US, including the WRAP region. Controls were then applied to account for NSPS for oil and gas and RICE.
Residential Wood Combustion: ***rwc***	2018 RWC emissions are the same as 2017 NEI. RWC emissions were projected from 2018 to 2032 based on growth and control assumptions compatible with EPA's 2011v6.3 platform, which accounts for growth, retirements, and NSPS, although implemented in the Mid-Atlantic Regional Air Management Association (MARAMA)'s growth tool. Factors provided by North Carolina were used for that state. RWC emissions in California, Oregon, and Washington were held constant at 2017 levels.

Platform Sector: *abbreviation*	Description of Projection Methods for Analytic Year Inventories
Solvents: ***solvents***	The same projection and control factors to 2032 were applied to solvent emissions as if these SCCs were in nonpt. Additional SCCs in the new inventory that correlate with human population were also projected. Applied the same OTC Rules controls as 2016v3, but only included controls that took effect after 1/1/2018.
Remaining nonpoint: ***nonpt***	Projected base year to 2032 using 2016v3-consistent projection and control packets. For the purposes of the projection packets, 2016 was used as the base year, because the base year nonpt inventory was from only one year later (2017NEI) and so that projection packets from 2016 platform could be reused. Industrial emissions were grown according to factors derived from AEO2022 to reflect growth from 2021 onward. Data from earlier AEOs were used to derive factors through 2021. Portions of the nonpt sector were grown using factors based on expected growth in human population. The MARAMA projection tool was used to project emissions to 2032 after the AEO-based factors were updated to AEO2022. Projection factors provided by North Carolina and New Jersey were used through 2026, with MARAMA-based projections used from 2026 to 2032. Controls were applied to reflect relevant NSPS rules (i.e., reciprocating internal combustion engines (RICE), natural gas turbines, and process heaters). Emissions were also reduced in 2016v2 and v3 to account for fuel sulfur rules in the mid-Atlantic and northeast not fully implemented by 2017. OTC controls for PFCs are included.
Nonroad: ***nonroad***	Outside California and Texas and Texas, the MOVES3.0.3 model was newly run for this case to create nonroad emissions for 2032. Fuels used in MOVES3 are specific to 2032. Updated data from CARB were used for 2032. Texas nonroad emissions were provided by TCEQ for 2023 and 2028, and interpolated to 2026; they were then projected to 2032 using factors derived from MOVES.
Onroad: ***onroad, onroad_nonconus***	Activity data for 2018 were projected from the 2017 NEI. Activity data were then projected to 2032 using factors derived from AEO2022. To create the emission factors, MOVES3 was run for the year 2032 using 2018 meteorological data and fuels, but with age distributions projected to represent 2032 and the remaining inputs consistent with those used in 2017NEI. The 2032-specific activity data and emission factors were then combined using SMOKE-MOVES to produce the 2032 emissions. Inspection and maintenance updates were included for NC and TN (this changed the representative county groupings for 2032). Adjustments were applied to reflect the Control of Air Pollution from New Motor Vehicles: Heavy-Duty Engine and Vehicle Standards (2022) and the Final Rule to Revise Existing National GHG Emissions Standards for Passenger Cars and Light Trucks Through Model Year 2026 (2021). **Section 4.3.2 describes the applicable rules that were considered when projecting onroad emissions**.
Onroad California: ***onroad_ca_adj***	CARB-provided emissions were used for 2032 in California.
Other Area Fugitive dust sources not from the NEI: ***othafdust***	Area fugitive dust emissions were provided by ECCC prior to 2016v1. Projection factors were derived from those inventories and applied to the 2016v2 inventory to estimate the 2028 emissions and those emissions were used to represent 2032 in this platform. Mexico emissions are not included in this sector.
Other Point Fugitive dust sources not from the NEI: ***othptdust***	Base year inventories from ECCC were held flat from 2018 for the analytic year 2032, including the same transport fraction as the base year and the meteorology-based (precipitation and snow/ice cover) zero-out.

Platform Sector: *abbreviation*	Description of Projection Methods for Analytic Year Inventories
Other point sources not from the NEI: ***othpt***	Canada emissions for analytic years were provided by ECCC for use in 2016v1. Projection factors were derived from those inventories to estimate 2028 emissions, and those emissions were used to represent 2032. Canada projections were applied by province-subclass where possible (i.e., where subclasses did not change between platforms). For inventories where that was not possible, including airports and most stationary point sources except for oil and gas, projections were applied by province. For Mexico sources, Mexico's 2016 inventory was grown to 2028 (that inventory was used to represent 2032) using state and pollutant-specific factors based on the 2016v1 platform inventories.
Canada ag not from the NEI: ***canada_ag***	Base year low-level agricultural sources were projected to 2028 (which was used to represent 2032) using projection factors based on data provided by ECCC and applied by province, pollutant, and ECCC sub-class code.
Canada oil and gas 2D not from the NEI: ***canada_og2D***	Low-level point oil and gas sources from the ECCC 2016 emission inventory were projected to the analytic years based on province-subclass changes in the ECCC-provided data used for 2016v1. 2028 projections were used to represent 2032.
Other non-NEI nonpoint and nonroad: ***othar***	Analytic year Canada nonpoint inventories were provided by ECCC for 2016v1. For Canadian nonpoint sources, factors were provided from which the analytic year inventories could be derived. Projection factors for 2028 were derived from those inventories and applied to the 2016v2 Canada nonpoint inventory to represent 2032. For Canada nonroad, the previously generated 2026 data from 2016v2 platform was projected to 2032 using trends calculated from MOVES in the US. For Mexico nonpoint and nonroad sources, state-pollutant projection factors for 2028 were calculated from the 2016v1 inventories, and then applied to the 2016v2 base year inventories, with 2028 representing 2032.
Other non-NEI onroad sources: ***onroad_can***	For Canadian mobile onroad sources, analytic year inventories were projected from 2016 to 2026 using ECCC-provided projection data from v1 platform at the province and subclass (which is similar to SCC but not exactly) level. The previously generated 2026 data from 2016v2 platform was projected to 2032 using trends calculated from MOVES in the US.
Other non-NEI onroad sources: ***onroad_mex***	Monthly onroad mobile inventories were developed at municipio resolution based on an interpolation of runs of MOVES-Mexico for 2028 and 2035.

4.1 EGU Point Source Projections (ptegu)

The 2032 EGU emissions inventories relied on the EPA's Post-IRA 2022 Reference Case of the Integrated Planning Model (IPM), with additional update of Final Good Neighbor Plan (GNP). IPM is a linear programming model that accounts for variables and information such as energy demand, planned unit retirements, and planned rules to forecast unit-level energy production and configurations. The following specific rules and regulations are included in the IPM run (see the Final PM NAAQS web page for more details, documentation of inputs and outputs to the modeling projections for this analysis):

- Final Good Neighbor Plan for 2015 Ozone NAAQS.
- Inflation Reduction Act of 2021 (reflecting Tax Credits).
- The Revised Cross-State Air Pollution Rule (CSAPR) Update, a federal regulatory measure affecting EGU emissions from 12 states to address transport under the 2008 National Ambient Air Quality Standards (NAAQS) for ozone.
- The Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units through rate limits.
- The Mercury and Air Toxics Rule (MATS) finalized in 2011. MATS establishes National Emissions Standards for Hazardous Air Pollutants (NESHAP) for the "electric utility steam generating unit" source category.
- Current and existing state regulations, including current and existing Renewable Portfolio Standards and Clean Energy Standards as of the summer of 2021.
- The latest actions EPA has taken to implement the Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations Final Rule. The BART limits approved in these plans (as of summer 2020) that will be in place for EGUs are represented in the Updated Summer 2021 Reference Case.
- California AB 32 CO2 allowance price projections and the Regional Greenhouse Gas Initiative (RGGI) rule.
- Three non-air federal rules affecting EGUs: National Pollutant Discharge Elimination System-Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, Hazardous, and Solid Waste Management System; Disposal of Coal Combustion Residuals from Electric Utilities; and the Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category.

IPM is run for a set of years, including 2030 and 2035. 2030 outputs were used in this analysis. All inputs, outputs and full documentation of EPA's Post-IRA 2022 Reference Case and the associated EGU fleet information (NEEDS for EPA Post-IRA 2022 Reference Case rev: 10-14-22) are available on the Final PM NAAQS modeling. Some of the key parameters used in the IPM run are:

- Demand: AEO 2021+ on-the-books OTAQ GHG Rules
- Gas and Coal Market assumptions: updated as of December 2021
- Cost and performance of fossil generation technologies: AEO 2021
- Cost and performance of renewable energy generation technologies: NREL ATB 2021 (mid-case)

- Environmental rules and regulations (on-the-books): Final GNP, Revised CSAPR, MATS, BART, CA AB 32, RGGI, various RPS and CES, non-air rules (Cooling Water Intake, ELC, CCR), State Rules and mandates
- Financial assumptions: 2016-2020 data, reflects tax credit extensions from Consolidated Appropriations Act of 2021
- Transmission: updated data with build options
- Retrofits: carbon capture and sequestration option for CCs
- Operating reserves (in select runs): Greater detail in representing interaction of load, wind, and solar, ensuring availability of quick response of resources at higher levels of RE penetration
- Fleet: NEEDS for EPA Post-IRA 2022 Reference Case rev: 10-14-22

The 2030 outputs of the IPM projections were used for the 2032 inventory. Units that are identified to have a primary fuel of landfill gas, fossil waste, non-fossil waste, residual fuel oil, or distillate fuel oil may be missing emissions values for certain pollutants in the generated inventory flat file. Units with missing emissions values are gapfilled using projected base year values. The projections are calculated using the ratio of the analytic year seasonal generation in the IPM parsed file and the base year seasonal generation at each unit for each fuel type in the unit as derived from EIA-923 tables and the 2018 NEI. New controls identified at a unit in the IPM parsed file are accounted for with appropriate emissions reductions in the gapfill projection values. When base year unit-level generation data cannot be obtained no gapfill value is calculated for that unit.

Once IPM has been run, a process is performed to first parse the results to unit level and then to generate a flat file in a format that SMOKE can read. To accomplish this, a cross reference file is needed to map the NEEDS IDs to NEI IDs for facility and unit and for stack parameters. The cross reference file used for the IPM outputs was "*NEEDS_NEI_xref_2016_2019stk_13apr22.xlsx*" and incorporates information about unit and stack configurations from the 2019 NEI Point source inventory. The flat file that results from this process includes emissions for five summer months (May to September), four "shoulder" months (March, April, October, November) and three winter months (January, February, and December). The emissions from each of these "seasons" were placed into separate flat files so that SMOKE can preserve the total emissions within each season to the extent possible within rounding errors. Large EGUs in the IPM-derived flat file inventory are associated with hourly CEMS data for NOX and SO2 emissions values in the base year. To maintain a temporal pattern consistent with the base year, the NOX and SO2 values in the base year hourly CEMS inventories are projected to match the total seasonal emissions values in the analytic years as described in Section 3.3.2.2.

Combined cycle units produce some of their energy from process steam that turns a steam turbine. The IPM model assigns a fraction of the total combined cycle production to the steam turbine. When the emissions are calculated these steam units are assigned emissions values that come from the combustion portion of the process. In the base year NEI steam turbines are usually implicit to the total combined cycle unit. To achieve the proper plume rise for the total combined cycle emissions, the stack parameters for the steam turbine units were updated with the parameters from the combustion release point. Additionally, some units, such as landfill gas, may not be assigned a valid SCC in the initial flat file. The SCCs for these units were updated based on the base year SCC for the unit-fuel type.

The EGU sector NO_x emissions by state are listed in Table 4-2 for the cases that comprise this platform. The state total emissions in this table may not exactly match the sum of the emissions for each state in the flat files for each season due to the process of apportioning seasonal total emissions to hours for input to SMOKE followed by summing the daily emissions back up to annual. However, any difference should be well within one percent of the state total emissions.

Table 4-2. EGU sector NOx emissions by State for the 2018v2 cases

State	2018gg	2032gg2
Alabama	27,026	10,596
Arizona	20,658	5,700
Arkansas	23,203	3,344
California	7,326	6,988
Colorado	20,016	2,146
Connecticut	3,818	2,415
Delaware	1,093	634
District of Columbia	NA	11
Florida	52,308	23,390
Georgia	29,172	7,530
Idaho	1,238	767
Illinois	34,258	7,023
Indiana	65,695	21,206
Iowa	25,880	20,056
Kansas	14,164	929
Kentucky	47,728	10,302
Louisiana	37,962	9,037
Maine	4,824	3,094
Maryland	8,691	2,478
Massachusetts	6,608	5,575
Michigan	47,391	16,734
Minnesota	21,469	3,090
Mississippi	16,380	4,672
Missouri	51,292	24,481
Montana	14,940	8,860
Nebraska	22,751	17,669
Nevada	4,788	2,558
New Hampshire	2,371	545
New Jersey	6,706	4,344
New Mexico	11,378	1,131
New York	15,512	10,653
North Carolina	36,939	5,064
North Dakota	34,009	19,602
Ohio	50,958	15,096
Oklahoma	22,084	2,689

State	2018gg	2032gg2
Oregon	4,198	518
Pennsylvania	38,097	18,268
Rhode Island	577	567
South Carolina	15,132	4,628
South Dakota	1,193	1,205
Tennessee	9,132	1,489
Texas	110,843	22,197
Tribal Areas	23,755	2,762
Utah	25,601	6,111
Vermont	231	27
Virginia	23,233	8,070
Washington	10,096	2,398
West Virginia	41,410	16,532
Wisconsin	15,667	4,565
Wyoming	33,380	13,428

4.2 Sectors with Projections Computed using CoST

To project U.S. emissions for sectors other than EGUs, facility/unit closures information, growth (projection) factors and/or controls were applied to certain categories within those sectors. Some facility or sub-facility-level closure information was applied to the point sources. There are also a handful of situations where new inventories were generated for sources that did not exist in the NEI (e.g., biodiesel and cellulosic plants, yet-to-be constructed cement kilns). This subsection provides details on the data and projection methods used to develop analytic year emissions for sectors other than EGUs that were developed using the Control Strategy Tool.

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

The impacts of the projection and control factors on the emissions for each sector are shown in tables in this section. In addition, the actual projection and control factors used to develop the analytic year emissions are shown when they are general enough to fit into a table of reasonable length, although in some cases, there are hundreds or thousands of factors used and the tables would be too large. To see these factors, visit the spreadsheets: *2032gg2_CoST_projection_packets_11may2023.xlsx* and *2032gg2_CoST_projection_packets_11may2023.xlsx* on the FTP site for this platform.

4.2.1 Background on the Control Strategy Tool (CoST)

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

CoST allows the user to apply projection (growth) factors, controls and closures at various geographic and inventory key field resolutions. Using these CoST datasets, also called "packets" or "programs," supports the process of developing and quality assuring control assessments as well as creating SMOKE-ready analytic year (i.e., projected) inventories. Analytic year inventories are created for each emissions modeling sector by applying a CoST control strategy type called "Project future year inventory" and each strategy includes all base year inventories and applicable CoST packets. For reasons to be discussed later, some emissions modeling sectors may require multiple CoST strategies to account for the compounding of control programs that impact the same type of sources. There are also available linkages to existing and user-defined control measure databases and it is up to the user to determine how control strategies are developed and applied. The EPA typically creates individual CoST packets that represent specific intended purposes (e.g., aircraft projections for airports are in a separate PROJECTION packet from residential wood combustion sales/appliance turnover-based projections). CoST uses three packet types:

- CLOSURE: Closure packets are applied first in CoST. This packet can be used to zero-out (close) point source emissions at resolutions as broad as a facility to as specific as a release point. The EPA uses these types of packets for known post-base year controls as well as information on closures provided by states on specific facilities, units or release points. This packet type is only used for the ptnonipm and pt_oilgas sectors.
- PROJECTION: Projection packets support the increase or decrease in emissions for virtually any geographic and/or inventory source level. Projection factors are applied as multiplicative factors to the base year emissions inventories prior to the application of any possible subsequent CONTROLs. A PROJECTION packet is necessary whenever emissions increase from the base year and is also desirable when information is based more on activity assumptions rather than on known control measures. The EPA uses PROJECTION packet(s) for many modeling sectors.
- CONTROL: Control packets are applied after any/all CLOSURE and PROJECTION packet entries. They support of similar level of specificity of geographic and/or inventory source level application as PROJECTION packets. Control factors are expressed as a percent reduction (0 – meaning no reduction, to 100 – meaning full reduction) and can be applied in addition to any pre-existing inventory control, or as a replacement control. For replacement controls, any controls specified in the inventory are first backed out prior to the application of a more-stringent replacement control).

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

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

Ultimately, CoST concatenates all PROJECTION packets into one PROJECTION dataset and uses a hierarchal matching approach to assign PROJECTION factors to the inventory. For example, a packet entry with Ranking=1 will supersede all other potential inventory matches from other packets. CoST then computes the projected emissions from all PROJECTION packet matches and then performs a similar routine for all CONTROL packets. Therefore, when summarizing “emissions reduced” from CONTROL packets, it is important to note that these reductions are not relative to the base year inventory, but rather to the intermediate inventory ***after*** application of any/all PROJECTION packet matches (and CLOSURES). A subset of the more than 70 hierarchy options is shown in Table 4-3, where the fields in the table are similar to those used in the SMOKE FF10 inventories. For example, “REGION_CD” is the county-state-county FIPS code (e.g., Harris county Texas is 48201) and “STATE” would be the 2-digit state FIPS code with three trailing zeroes (e.g., Texas is 48000).

Table 4-3. Subset of CoST Packet Matching Hierarchy

Rank	Matching Hierarchy	Inventory Type
1	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, SCC, POLL	point
2	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, POLL	point
3	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, POLL	point
4	REGION_CD, FACILITY_ID, UNIT_ID, POLL	point
5	REGION_CD, FACILITY_ID, SCC, POLL	point
6	REGION_CD, FACILITY_ID, POLL	point
7	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID, SCC	point
8	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID, PROCESS_ID	point
9	REGION_CD, FACILITY_ID, UNIT_ID, REL_POINT_ID	point
10	REGION_CD, FACILITY_ID, UNIT_ID	point
11	REGION_CD, FACILITY_ID, SCC	point
12	REGION_CD, FACILITY_ID	point
13	REGION_CD, NAICS, SCC, POLL	point, nonpoint

Rank	Matching Hierarchy	Inventory Type
14	REGION_CD, NAICS, POLL	point, nonpoint
15	STATE, NAICS, SCC, POLL	point, nonpoint
16	STATE, NAICS, POLL	point, nonpoint
17	NAICS, SCC, POLL	point, nonpoint
18	NAICS, POLL	point, nonpoint
19	REGION_CD, NAICS, SCC	point, nonpoint
20	REGION_CD, NAICS	point, nonpoint
21	STATE, NAICS, SCC	point, nonpoint
22	STATE, NAICS	point, nonpoint
23	NAICS, SCC	point, nonpoint
24	NAICS	point, nonpoint
25	REGION_CD, SCC, POLL	point, nonpoint
26	STATE, SCC, POLL	point, nonpoint
27	SCC, POLL	point, nonpoint
28	REGION_CD, SCC	point, nonpoint
29	STATE, SCC	point, nonpoint
30	SCC	point, nonpoint
31	REGION_CD, POLL	point, nonpoint
32	REGION_CD	point, nonpoint
33	STATE, POLL	point, nonpoint
34	STATE	point, nonpoint
35	POLL	point, nonpoint

The contents of the controls, local adjustments and closures for the analytic year cases are described in the following subsections. Year-specific projection factors (PROJECTION packets) for each analytic year were used to create the analytic year cases, unless noted otherwise in the specific subsections. The contents of a few of these projection packets (and control reductions) are provided in the following subsections where feasible. However, most sectors used growth or control factors that varied geographically, and their contents could not be provided in the following sections (e.g., facilities and units subject to the Boiler MACT reconsideration has thousands of records). The remainder of Section 4.2 is divided into subsections that are summarized in Table 4-4. Note that independent analytic year inventories were used rather than projection or control packets for some sources.

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

Subsection	Title	Sector(s)	Brief Description
4.2.2	CoST Plant CLOSURE packet	ptnonipm, pt_oilgas	All facility/unit/stack closures information, primarily from Emissions Inventory System (EIS), but also includes information from states and other organizations.
4.2.3	CoST PROJECTION packets	All	Introduces and summarizes national impacts of all CoST PROJECTION packets to the analytic year.
4.2.3.1	Fugitive dust growth	Afdust	PROJECTION packet: county-level resolution, primarily based on VMT growth.
4.2.3.2	Livestock population growth	Livestock	PROJECTION packet: national, by-animal type resolution, based on animal population projections.

Subsection	Title	Sector(s)	Brief Description
4.2.3.3	Category 1 and 2 commercial marine vessels	cmv_c1c2	PROJECTION packet: Category 1 & 2: CMV uses SCC/poll for all states except Calif.
4.2.3.4	Category 3 commercial marine vessels	cmv_c3	PROJECTION packet: Category 3: region-level by-pollutant, based on cumulative growth and control impacts from rulemaking.
4.2.3.5	Oil and gas and industrial source growth	nonpt, np_oilgas, ptnonipm, pt_oilgas	Several PROJECTION packets: varying geographic resolutions from state, county, and by-process/fuel-type applications. Data derived from AEO2022 were used for nonpt, ptnonipm, np_oilgas, and pt_oilgas sectors.
4.2.3.6	Non-IPM Point Sources	Ptnonipm	Several PROJECTION packets: specific projections from MARAMA region and states, AEO-based projection factors for industrial sources for non-MARAMA states.
4.2.3.7	Airport Sources	Ptnonipm	PROJECTION packet: by-airport for all direct matches to FAA Terminal Area Forecast data, with state-level factors for non-matching NEI airports.
4.2.3.8	Nonpoint sources	nonpt	Several PROJECTION packets: MARAMA states projection for Portable Fuel Containers and for all other nonpt sources. Non-MARAMA states projected with AEO-based factors for industrial sources. Evaporative Emissions from Finished Fuels projected using AEO-based factors. Human population used as growth for applicable sources.
4.2.3.9	Solvents	np_solvents	Several PROJECTION packets including population-based, and MARAMA state factors.
4.2.3.10	Residential wood combustion	rwc	PROJECTION packet: national with exceptions, based on appliance type sales growth estimates and retirement assumptions and impacts of recent NSPS.
4.2.4	CoST CONTROL packets	ptnonipm, nonpt, np_oilgas, pt_oilgas, np_solvents	Introduces and summarizes national impacts of all CoST CONTROL packets to the analytic year.
4.2.4.1	Oil and Gas NSPS	np_oilgas, pt_oilgas	CONTROL packets: reflect the impacts of the NSPS for oil and gas sources.
4.2.4.2	RICE NSPS	ptnonipm, nonpt, np_oilgas, pt_oilgas	CONTROL packets apply reductions for lean burn, rich burn, and combined engines for identified SCCs.
4.2.4.3	Fuel Sulfur Rules	ptnonipm, nonpt	CONTROL packet: updated by MARAMA, applies reductions to specific units in ten states.
4.2.4.4	Natural Gas Turbines NOx NSPS	ptnonipm	CONTROL packets apply NOx emission reductions established by the NSPS for turbines.

Subsection	Title	Sector(s)	Brief Description
4.2.4.5	Process Heaters NOx NSPS	ptnonipm	CONTROL packet: applies NOx emission limits established by the NSPS for process heaters.
4.2.4.6	Ozone Transport Commission Rules	nonpt, np_solvents	CONTROL packets reflecting rules for solvents and portable fuel containers.

4.2.2 CoST CLOSURE Packet (ptnonipm, pt_oilgas)

Packets:

CLOSURES_2016v3_platform_ptnonipm_09jan2023_v1

The CLOSURES packet contains facility, unit and stack-level closure information derived from an Emissions Inventory System (EIS) unit-level report from June 9, 2021, with closure status equal to "PS" (permanent shutdown; i.e., post-2018 permanent facility/unit shutdowns known in EIS as of the date of the report). The starting point for the closures packet was the version from the 2016v3 platform. For 2018v2, additional closures were added and those are cumulative with the closures in 2018gc. Any data provided by commenters for closures were updated to match the SMOKE FF10 inventory key fields, with all duplicates removed, and a single CoST packet was generated. These changes impact sources in the ptnonipm and pt_oilgas sectors. Additional closures provided in comments on the 2018gc inventories were incorporated in the 2018v2 platform for multiple states including Ohio, Wisconsin, North Carolina, and North Dakota. The spreadsheet in the reports folder on the 2016v3 FTP site called *point_controls_packet_2016v3.xlsx* lists all closures, while the spreadsheet called *ptnonipm_19_2023gf_new_closures.xlsx* available lists the closures there were new in 2016v3 and their impacts. The cumulative reduction in emissions for ptnonipm and pt_oilgas are shown in Table 4-5. The amount of emission reductions are from 2019 emissions levels, not 2016 emissions, because the closures were applied to the 2019 inventory that was used as the starting point for the projection to 2032.

Table 4-5. Reductions from all facility/unit/stack-level closures in 2032 from 2018 emissions levels

Pollutant	pt_oilgas
CO	985
NH3	0
NOX	2,154
PM10	30
PM2.5	30
SO2	1
VOC	193

4.2.3 CoST PROJECTION Packets (afdust, airports, cmv, livestock, nonpt, np_oilgas, np_solvents, ptnonipm, pt_oilgas, rail, rwc)

For point inventories, after the application of any/all CLOSURE packet information, the next step CoST performs when running a control strategy is to apply all of the PROJECTION packets. Regardless of inventory type (point or nonpoint), the PROJECTION packets are applied prior to the CONTROL packets. For several emissions modeling sectors (e.g., airports, np_oilgas, pt_oilgas), there is only one

PROJECTION packet applied for each analytic year. For other sectors, there may be several different sources of projection data and as a result there are multiple PROJECTION packets that are concatenated by CoST during a control strategy run. The outputs are then quality-assured regarding duplicates and applicability to the inventories in the CoST strategy. Similarly, CONTROL packets are kept in distinct datasets for different control programs. Having the PROJECTION (and CONTROL) packets separated into "key" projection and control programs allows for quick summaries of the impacts of these distinct control programs on emissions.

Throughout the process of developing the 2016 platforms, MARAMA provided projection factors for states including: Connecticut, Delaware, Maryland, Massachusetts, New Hampshire, New York, New Jersey, North Carolina, Pennsylvania, Rhode Island, Vermont, Virginia, West Virginia, Maine, and the District of Columbia. Some other states also provided projection factors. Many of these were based on data from the AEO available at the time the factors were generated. For the 2016v2 platform, MARAMA provided new spreadsheets of projection factors to facilitate the incorporation of newer AEO data available at that time, along with and other surrogate data used for projection factors. The new spreadsheets also reflected sources affected by the Pennsylvania Reasonably Available Control Technology (RACT) II. The data in these spreadsheets were further updated for the 2016v3 platform to use factors based on AEO 2022. For some sectors, the 2016v3 inventories for the year 2026 were used as the starting point for projection emissions to 2032 in this study. This facilitated the retention of some state-provided data from the 2016 platforms in this platform. For states not covered by the MARAMA or other state-provided packets, projection factors were developed using nationally available data and methods.

Quantitative impacts of the projections on the emissions by sector nationally and by state are available in the reports folder on the FTP site in the file *2032gg2_projections_by_sector_packet.xlsx*. Some excerpts from this workbook are included in the subsections that follow.

4.2.3.1 Fugitive dust growth (afdust)

Packets:

Projection_2018_2032_afdust_paved_roads_for2032gg_14sep2022_v0

For paved roads (SCC 2294000000), the 2018 afdust emissions were projected to analytic year 2032 based on differences in county total VMT:

Analytic year afdust paved roads = 2018 afdust paved roads * (Analytic year county total VMT) / (2018 county total VMT)

The VMT projections are described in the onroad section. Paved road dust emissions were projected this way in all states, including MARAMA states. All emissions other than paved roads are held constant in the analytic year projections. Unlike in 2016v3 platform, separate projection packets for the MARAMA region were not use for this study for this sector. The impacts of the projections are shown in Table 4-6.

Table 4-6. Increase in $PM_{2.5}$ emissions from projections in 2018v2

Sector	2018 Emissions	2032 Emissions	Percent Increase in 2032
Paved Roads	1,580,736	1,888,454	19.47%
All afdust	2,283,902	2,357,271	3.11%

4.2.3.2 Airport sources (airports)

Packets:

airport_projections_itn_taf2021_2016_2032_25apr2022_v0

Airport emissions for 2016v3 were projected from the 2016 airport emissions to 2032 based on TAF 2021 based on the corrected 2017 NEI airport emissions (released in June 2022), and starting from the base year 2016 instead of 2017. Year 2016 emissions were the starting point because they included corrections to some airports in Georgia and Texas that were not in the 2017 NEI. The Terminal Area Forecast (TAF) data available from the Federal Aviation Administration (see https://www.faa.gov/data_research/aviation/taf/).

Projection factors were computed using the ratio of the itinerant (ITN) data from the Airport Operations table between the base and projection year. Where possible, airport-specific projection factors were used. For airports that could not be matched to a unit in the TAF data, state default growth factors by itinerant class (i.e., commercial, air taxi, and general) were created from the set of unmatched airports. Emission growth factors for facilities from 2016 to 2032 were limited to a range of 0.2 (80% reduction) to 5.0 (400% growth), and the state default projection factors were limited to a range of 0.5 (50% reduction) to 2.0 (100% growth). Military state default projection values were kept flat (i.e., equal to 1.0) to reflect uncertainly in the data regarding these sources. The projection factors for 25 major airports in the Continental US are shown in Table 4-7. Separate projection factors are applied to commercial aviation, general aviation, and air taxi SCCs. For airports without a projection factor specific to the air taxi category, a state average projection factor is used. The national impact of the projections on airport emissions from 2016 to 2032 is shown in Table 4-8.

Table 4-7. TAF 2021 growth factors for major airports, 2016 to 2032

Facility ID	State	Airport	Commercial Aviation	General Aviation	Air Taxi
10583311	Arizona	Phoenix (PHX)	1.5718	1.0276	0.5803
2255111	California	Los Angeles (LAX)	1.4171	0.7881	0.4868
9997011	California	San Francisco (SFO)	1.5497	0.9495	0.3167
9816811	Colorado	Denver (DEN)	1.6638	1.2331	0.3694
9762111	Florida	Orlando (MCO)	1.5906	1.0984	1.0474
9791511	Florida	Fort Lauderdale (FLL)	1.6579	1.0083	1.4303
9806211	Florida	Miami (MIA)	1.3662	0.9082	0.6174
9748811	Georgia	Atlanta (ATL)	1.4741	1.0626	n/a
2681611	Illinois	Chicago O'Hare (ORD)	1.8234	0.7652	n/a
9562811	Massachusetts	Boston (BOS)	1.5039	1.3743	0.9986
9535411	Michigan	Detroit (DTW)	1.5078	1.1021	n/a
6151711	Minnesota	Minneapolis (MSP)	1.4789	0.8776	0.2454
9392311	Nevada	Las Vegas (LAS)	1.3173	1.0173	1.0626
9376211	New Jersey	Newark (EWR)	1.5739	1.1233	n/a
9333211	New York	La Guardia (LGA)	1.2305	0.8187	n/a
9333311	New York	John F Kennedy (JFK)	1.4134	1.5807	0.2286
9279611	North Carolina	Charlotte (CLT)	1.7513	1.0288	n/a

Facility ID	State	Airport	Commercial Aviation	General Aviation	Air Taxi
9246511	Oregon	Portland (PDX)	1.4561	0.9561	0.9602
9185011	Pennsylvania	Philadelphia (PHL)	1.5738	1.0464	n/a
9171111	Tennessee	Memphis (MEM)	1.4163	0.9277	0.5331
9076711	Texas	Dallas/Fort Worth (DFW)	1.6638	0.9549	n/a
9128911	Texas	Houston Intercontinental (IAH)	1.5991	0.9606	n/a
9076611	Utah	Salt Lake City (SLC)	1.6959	1.2681	0.5587
9063811	Virginia	Washington Dulles (IAD)	1.6017	0.957	0.4119
9093911	Washington	Seattle (SEA)	1.4455	0.7548	0.5497

Table 4-8. Impact of 2016 to 2032 factors on airport emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	494,548	589,941	95,393	19.3%
NOX	128,306	170,662	42,356	33.0%
PM10-PRI	10,267	11,051	785	7.6%
PM25-PRI	8,969	9,711	742	8.3%
SO2	15,472	20,874	5,402	34.9%
VOC	55,234	65,524	10,290	18.6%
CO	494,548	589,941	95,393	19.3%

4.2.3.3 Category 1, Category 2 Commercial Marine Vessels (cmv_c1c2)

Packets:

Projection_2018_2030_cmv_c1c2_for_2032gg_15sep2022_v0
Projection_2018_2030_cmv_Canada_for_2032gg_15sep2022_v0

Category 1 and category 2 (C1C2) CMV emissions sources outside of California were projected to 2030 (with 2030 used for 2032) based on factors derived from the Regulatory Impact Analysis (RIA) Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters per Cylinder (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-locomotive). The 2030 cmv_c1c2 emissions for 2018v2 are based on the same base year data as the 2018gc emissions. California cmv_c1c2 emissions were projected based on factors provided by the state. Table 4-9 lists the pollutant-specific projection factors to 2030 that were used for cmv_c1c2 sources outside of California. California sources were projected to 2030 using the factors in Table 4-10, which are based on data provided by CARB.

Projection factors for Canada for 2030 were based on ECCC-provided 2023 and 2028 data projected to 2030.

Table 4-9. National projection factors for cmv_c1c2

Pollutant	U.S. 2018-to-2030 (%)	Canada 2028 to 2030 (%)
CO	+2.4%	+1.0%
NOX	-44.2%	-8.4%
PM10	-42.5%	-8.8%
PM2.5	-42.5%	-8.8%
SO2	-46.7%	-0.6%
VOC	-46.0%	-7.8%

Table 4-10. California projection factors for cmv_c1c2

Pollutant	2018-to-2030 (%)
CO	+19.6%
NOX	-15.8%
PM10	-29.8%
PM2.5	-29.8%
SO2	+50.5%
VOC	+0.1%

4.2.3.4 Category 3 Commercial Marine Vessels (cmv_c3)

Packets:

Projection_2018_2030_cmv_c3_for_2032gg_15sep2022_v0
Projection_2018_2030_cmv_Canada_for_2032gg_15sep2022_v0

Growth rates for cmv_c3 emissions from 2018 to 2030 (with 2030 emissions used to represent 2032) were projected using an EPA report on projected bunker fuel demand that included values through 2030. Bunker fuel usage was used as a surrogate for marine vessel activity. Bunker fuel usage was used as a surrogate for marine vessel activity. Factors based on the report were used for all pollutants except NOx.

Growth factors for NOx emissions were handled separately to account for the phase in of Tier 3 vessel engines. To estimate these emissions, the NOx growth rates from the EPA C3 Regulatory Impact Assessment (RIA)[25] were refactored to use the new bunker fuel usage growth rates. The assumptions of changes in fleet composition and emissions rates from the C3 RIA were preserved and applied to the new bunker fuel demand growth rates for 2030 to arrive at the final growth rates. The Category 3 marine diesel engines Clean Air Act and International Maritime Organization standards from April, 2010 (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-new-marine-compression-0) were also considered when computing the emissions.

The 2030 cmv_c3 emissions for 2018v2 are based on the same base year data as the 2018gc emissions for this sector. Projection factors for Canada for 2030 were based on ECCC-provided 2023 and 2028 data projected to 2030.

[25] https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1005ZGH.TXT.

The 2030 projection factors are shown in Table 4-11. Some regions for which 2018 projection factors were available did not have 2030 projection factors specific to that region, so factors from another region were used as follows:

- Alaska was projected using North Pacific factors.
- Hawaii was projected using South Pacific factors.
- Puerto Rico and Virgin Islands were projected using Gulf Coast factors.
- Emissions outside Federal Waters (FIPS 98) were projected using the factors given in Table 4-11 for the region "Other."
- California was projected using a separate set of state-wide projection factors based on CMV emissions data provided by the California Air Resources Board (CARB). These factors are shown in Table 4-12

Table 4-11. 2018-to-2030 CMV C3 projection factors outside of California

Region	US 2018-to-2030 NOX	US 2018-to-2030 other pollutants	Canada 2028-to-2030 NOX	Canada 2028-to-2030 other pollutants
US East Coast	-5.7%	+48.3%	-0.6%	+5.8%
US South Pacific (excl. California)	-31.0%	+50.8%	n/a	n/a
US North Pacific	-2.9%	+41.0%	-0.3%	+4.6%
US Gulf	-13.1%	+35.7%	n/a	n/a
US Great Lakes	+23.0%	+29.3%	+3.7%	+4.3%
Other	+42.7%	+42.7%	n/a	n/a

Non-Federal Waters	2018-to-2030
SO2	-73.6%
PM (main engines)	-25.9%
PM (aux. engines)	-30.1%
Other pollutants	+42.7%

Table 4-12. 2018-to-2030 CMV C3 projection factors for California

Pollutant	2018-to-2030
CO	+33.2%
NOx	+27.9%
PM_{10} / $PM_{2.5}$	+36.7%
SO_2	+32.3%
VOC	+44.3%

4.2.3.5 Livestock population growth (livestock)

Packets:

Projection_2018gg_2032gg_ag_livestock_12sep2022_v0

The 2018v2 livestock emissions were projected to year 2032 using projection factors created from USDA National livestock inventory projections published in February 2022 (https://www.ers.usda.gov/publications/pub-details/?pubid=103309) and are shown in Table 4-13, along with the overall impacts on the livestock NH_3 and VOC emissions. For emission projections to 2032, a ratio was created between animal inventory counts for 2032 and 2018 to create a projection factor. This process was completed for the animal categories of beef, dairy, broilers, layers, turkeys, and swine. The projection factor was then applied to the base year emissions for the specific animal type to estimate 2032 NH_3 and VOC emissions.

Table 4-13. National projection factors for livestock: 2018 to 2032

Animal	2018-to-2032
Beef	+0.57%
Swine	+10.54%
Broilers	+17.47%
Turkeys	+3.26%
Layers	+17.24%
Dairy	+0.09%
Overall NH_3	+6.39%
Overall VOC	+6.12%

4.2.3.6 Nonpoint Sources (nonpt)

Packets:

Projection_2016_2026_all_nonpoint_version2_platform_NC_30aug2022_nf_v2
Projection_2016_2026_finished_fuels_volpe_16jul2021_v0
Projection_2016_2026_industrial_bySCC_version3_platform_09nov2022_v1
Projection_2016_2026_nonpt_PFC_version2_platform_MARAMA_noNC_16jul2021_v1
Projection_2016_2026_nonpt_other_version3_platform_MARAMA_22aug2022_v0
Projection_2016_2026_nonpt_population_version2_platform_noMARAMA_16jul2021_v0
Projection_2016_2026_nonpt_version2_platform_NJ_16jul2021_v0
Projection_2026_2028_finished_fuels_volpe_13aug2021_v0
Projection_2026_2032_industrial_bySCC_version3_platform_12sep2022_nf_v1
Projection_2026_2032_nonpt_other_ver3_platform_MARAMA_for2032gg_12sep2022_v0
Projection_2026_2032_nonpt_PFC_version2_platform_MARAMA_13aug2021_v0
Projection_2026_2030_nonpt_population_version2_platform_noMARAMA_05aug2021_v0

In 2018v2, emissions sources in the nonpt sectors are based on 2017 NEI, and are projected to 2032 in two parts. First, base year 2017NEI emissions were projected to 2026 using projection packets developed for the 2016v3 platform. These projection packets reference 2016 as the base year because they are from 2016v3 platform, but for the nonpt sector in particular, these packets are applicable to the 2017NEI emissions used in 2018v2 platform. Then, the newly projected 2026 emissions were projected to 2032 emissions using a second set of projection packets in which 2026 is the base year.

Inside MARAMA region

2016-to-2026 and 2026-to-2032 projection packets for all nonpoint sources were provided by MARAMA for the following states and updated with data from AEO2022: CT, DE, DC, ME, MD, MA, NH, NJ, NY, NC, PA, RI, VT, VA, and WV. MARAMA provided one projection packet for portable fuel containers

(PFCs), and a second projection packet per year for all other nonpt sources. The impacts of these factors on nonpt emissions other than PFCs are shown in Table 4-14. The impacts of the factors on PFC sources are shown in Table 4-15.

The MARAMA projection packets were used throughout the MARAMA region, except for 2016-to-2026 projections in North Carolina and New Jersey. Both NC and NJ provided separate projection packets for the nonpt sector for 2016v1 and those projection packets were used instead of the MARAMA packets in those two states. New Jersey did not provide projection factors for PFCs, and so NJ PFCs were projected using the MARAMA PFC growth packet. NC- and NJ-provided projection packets were not available for 2032, so MARAMA projection factors were used in those two states beyond 2026. The impacts of the North Carolina and New Jersey factors from 2016-2026 are shown in Table 4-16 and Table 4-17, respectively.

Table 4-14. Impact of 2016-2026 factors on nonpt emissions in MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	405,690	410,106	4,416	1.1%
NH3	10,721	10,959	238	2.2%
NOX	183,170	186,704	3,534	1.9%
PM10-PRI	119,049	119,373	324	0.3%
PM25-PRI	106,750	107,056	306	0.3%
SO2	22,668	22,028	-640	-2.8%
VOC	107,154	112,662	5,508	5.1%

Table 4-15. Impact of factors on nonpt PFC emissions in MARAMA states

Factor Years	Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
2016-2026	VOC	25,987	26,620	633	2.4%
2026-2032	VOC	20,879	21,112	233	1.1%

Table 4-16. Impact of 2016-2026 factors on nonpt emissions in North Carolina

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	25,506	26,730	1,224	4.8%
NH3	1,196	1,339	143	11.9%
NOX	9,463	10,423	960	10.1%
PM10-PRI	9,326	9,961	635	6.8%
PM25-PRI	8,506	9,087	581	6.8%
SO2	418	434	16	3.8%
VOC	16,811	16,214	-597	-3.6%

Table 4-17. Impact of 2016-2026 factors on nonpt emissions in New Jersey

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	19,492	19,924	432	2.2%
NH3	404	395	-9	-2.2%
NOX	22,302	22,544	242	1.1%
PM10-PRI	6,320	6,502	182	2.9%
PM25-PRI	5,759	5,924	165	2.9%
SO2	367	367	0	0.0%
VOC	16,934	16,082	-852	-5.0%

Industrial Sources outside MARAMA region

Because each AEO only includes data for one or two years prior to its publication year, projection factors were developed from by industrial sector using a series of AEOs to cover the period from 2016 through 2032: AEO2018 was used to go from 2016 to 2017; AEO2019 to go from 2017 to 2020; AEO2021 to go from 2020 to 2021; and AEO2022 to go from 2021 to 2032. SCCs were mapped to AEO categories and projection factors were created using a ratio between the base year and projection year estimates from each specific AEO category. For the nonpt sector, only AEO Table 2 was used to map SCCs to AEO categories for the projections of industrial sources. Depending on the category, a projection factor may be national or regional. The maximum projection factor was capped at a factor of 2.25 for 2016 to 2026, and 1.75 for 2026 to 2032. Sources within the MARAMA region were *not* projected with these factors, but with the MARAMA-provided growth factors. The impacts of these factors on emissions from 2016-2026 and 2025-2032 on nonpt emissions are shown in Table 4-18 and Table 4-19. The impacts of the factors not associated with SCCs are shown in Table 4-20.

In response to comments, distillate emissions for SCCs 2103004000, 2103004001, and 2103004002 were held flat with a 1.0 projection factor instead of showing increasing emissions in 2032.

Table 4-18. Impact of 2016-2026 industrial factors by SCC on nonpt emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	291,269	307,431	16,163	5.5%
NH3	5,122	5,653	530	10.4%
NOX	300,170	319,970	19,800	6.6%
PM10-PRI	146,635	136,472	-10,163	-6.9%
PM25-PRI	97,608	98,086	478	0.5%
SO2	128,668	93,840	-34,829	-27.1%
VOC	17,254	18,968	1,714	9.9%

Table 4-19. Impact of 2026-2032 industrial factors by SCC on nonpt emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	282,178	288,504	6,326	2.2%
NH3	5,653	5,780	128	2.3%
NOX	281,164	286,474	5,310	1.9%
PM10-PRI	136,472	140,194	3,722	2.7%
PM25-PRI	98,086	101,296	3,210	3.3%
SO2	93,840	95,261	1,421	1.5%
VOC	18,968	19,298	330	1.7%

Table 4-20. Impact of 2026-2032 factors other than by SCC on nonpt emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	456,758	457,537	779	0.2%
NH3	12,693	12,624	-70	-0.5%
NOX	218,267	215,622	-2,645	-1.2%
PM10-PRI	135,834	136,607	773	0.6%
PM25-PRI	122,067	122,762	695	0.6%
SO2	14,089	13,886	-203	-1.4%
VOC	142,476	139,851	-2,625	-1.8%

Evaporative Emissions from Transport of Finished Fuels outside MARAMA region

Estimates on growth of evaporative emissions from transporting finished fuels are partially covered in the nonpoint and point oil and gas projection packets. However, there are some processes with evaporative emissions from storing and transporting finished fuels which are not included in the nonpoint and point oil and gas projection packets, e.g., withdrawing fuel from tanks at bulk plants, filling tanks at service stations, etc., and those processes are included in nonpoint other. AEO2018 was used as a starting point for projecting volumes of finished fuel that would be transported in analytic years. Then these volumes were used to calculate inventories associated with evaporative emissions in 2016, 2023, and 2028 using upstream modules in the Emissions Modeling Framework. Those emission inventories were mapped to the appropriate SCCs and projection packets were generated from 2016 to 2028 using the upstream modules. For these sources, projection factors for 2028 were applied and the resulting emissions were used to represent 2032. Sources within the MARAMA region were not projected with these factors, but with the MARAMA-provided growth factors. The impact of the factors from 2016-2026 and 2026-2028 are shown in Table 4-21.

Table 4-21. Impact of factors on nonpt finished fuel emissions

Factor years	Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
2016-2026	VOC	405,952	336,366	-69,586	-17.1%
2026-2028	VOC	336,366	317,038	-19,327	-5.7%

Human Population Growth outside MARAMA region

For SCCs that were projected based on human population growth, population projection data were available from the Benefits Mapping and Analysis Program (BenMAP) model by county for several years, including 2017, 2025, and 2030. These human population data were used to create modified county-specific projection factors. The impacted SCCs are shown in Table 4-22. Note that 2017 is being used as the base year since 2016 human population is not available in this dataset. A newer human population dataset was assessed but it did not have realistic population projections through the 2020s, and was therefore not used. For example, rural areas of NC were projected to have more growth than urban areas, which is the opposite of what has happened in recent years. Growth factors were limited to 5% cumulative annual growth (e.g. 35% annual growth over 7 years), but none of the factors fell outside that range. For these population-based projection factors, 2030 population was used to represent 2032. Sources within the MARAMA region were *not* projected with these factors, but with the MARAMA-provided growth factors. The impact of the population growth-based factors on the nonpt emissions is shown in Table 4-23 and Table 4-24.

Table 4-22. SCCs in nonpt that use Human Population Growth for Projections

SCC	Description
2302002100	Industrial Processes;Food and Kindred Products: SIC 20;Commercial Cooking - Charbroiling;Conveyorized Charbroiling
2302002200	Industrial Processes;Food and Kindred Products: SIC 20;Commercial Cooking - Charbroiling;Under-fired Charbroiling
2302003000	Industrial Processes;Food and Kindred Products: SIC 20;Commercial Cooking - Frying;Deep Fat Frying
2302003100	Industrial Processes;Food and Kindred Products: SIC 20;Commercial Cooking - Frying;Flat Griddle Frying
2302003200	Industrial Processes;Food and Kindred Products: SIC 20;Commercial Cooking - Frying;Clamshell Griddle Frying
2501011011	Storage and Transport;Petroleum and Petroleum Product Storage;Residential Portable Gas Cans;Permeation
2501011012	Storage and Transport;Petroleum and Petroleum Product Storage;Residential Portable Gas Cans;Evaporation (includes Diurnal losses)
2501011013	Storage and Transport;Petroleum and Petroleum Product Storage;Residential Portable Gas Cans;Spillage During Transport
2501011014	Storage and Transport;Petroleum and Petroleum Product Storage;Residential Portable Gas Cans;Refilling at the Pump - Vapor Displacement
2501011015	Storage and Transport;Petroleum and Petroleum Product Storage;Residential Portable Gas Cans;Refilling at the Pump – Spillage
2501012011	Storage and Transport;Petroleum and Petroleum Product Storage;Commercial Portable Gas Cans;Permeation
2501012012	Storage and Transport;Petroleum and Petroleum Product Storage;Commercial Portable Gas Cans;Evaporation (includes Diurnal losses)

SCC	Description
2501012013	Storage and Transport;Petroleum and Petroleum Product Storage;Commercial Portable Gas Cans;Spillage During Transport
2501012014	Storage and Transport;Petroleum and Petroleum Product Storage;Commercial Portable Gas Cans;Refilling at the Pump - Vapor Displacement
2501012015	Storage and Transport;Petroleum and Petroleum Product Storage;Commercial Portable Gas Cans;Refilling at the Pump – Spillage
2630020000	Waste Disposal, Treatment, and Recovery;Wastewater Treatment;Public Owned;Total Processed
2640000000	Waste Disposal, Treatment, and Recovery;TSDFs;All TSDF Types;Total: All Processes
2810025000	Miscellaneous Area Sources;Other Combustion;Residential Grilling (see 23-02-002-xxx for Commercial);Total
2810060100	Miscellaneous Area Sources;Other Combustion;Cremation;Humans

Table 4-23. Impact of 2016-2026 population-based factors on nonpt emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	105,731	117,336	11,605	11.0%
NH3	1,555	1,707	152	9.8%
NOX	1,747	1,942	195	11.2%
PM10-PRI	90,772	100,389	9,617	10.6%
PM25-PRI	83,068	91,860	8,792	10.6%
SO2	92	102	9	10.3%
VOC	64,056	70,658	6,603	10.3%

Table 4-24. Impact of 2026-2030 population-based factors on nonpt emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	117,336	121,978	4,641	4.0%
NH3	1,707	1,768	61	3.6%
NOX	1,942	2,020	78	4.0%
PM10-PRI	100,389	104,236	3,847	3.8%
PM25-PRI	91,860	95,377	3,517	3.8%
SO2	102	105	4	3.7%
VOC	70,658	73,299	2,641	3.7%

4.2.3.7 Solvents (np_solvents)

Packets:

Projection_2016_202X_solvents_v3platform_Idaho_asphalt_09aug2022_v0
Projection_2018_2032_np_solvents_for_2032gg_MARAMA_14sep2022_v0
Projection_2018_2030_np_solvents_for_2032gg_noMARAMA_13sep2022_v0

The projection methodology for np_solvents is similar to the method used in the 2016v3 platform. Projection factors from MARAMA were applied inside the MARAMA region, and projection factors based on human population trends are applied for most solvent categories elsewhere. All of these packets were checked to confirm they cover all SCCs in the solvents sector, and packets were supplemented with additional SCCs as needed, copied from factors for existing SCCs. The SCCs in np_solvents that are projected using human population growth are shown in Table 4-25.

The following updates were made starting in 2016v3 platform to supplement the SCCs included in the projection packets:

- all 2460- SCCs and 2402000000 use human population (copied from an existing 2460- SCC);
- most surface coating and graphic arts SCCs use either human population (MARAMA and non-MARAMA regions) or employment data (some SCCs in MARAMA region only);
- added new SCC 2460030999 (lighter fluid) to project based on human population in all regions.

For 2016v3, Idaho asphalt emissions (SCCs = 2461021000, 2461022000) were reduced by 14.2% based on a comment from the state. The impact of the population-based factors on the np_solvents sector emissions outside of MARAMA states are shown in Table 4-26. The impacts of the factors on np_solvents emissions in MARAMA states are shown in Table 4-27.

Table 4-25. SCCs in np_solvents that use Human Population Growth for Projections

SCC	SCC Descriptions
2401001000	Solvent Utilization;Surface Coating;Architectural Coatings;Total: All Solvent Types
2401005000	Solvent Utilization;Surface Coating;Auto Refinishing: SIC 7532;Total: All Solvent Types
2401005700	Solvent Utilization;Surface Coating;Auto Refinishing: SIC 7532;Top Coats
2401008000	Solvent Utilization;Surface Coating;Traffic Markings;Total: All Solvent Types
2401010000	Solvent Utilization;Surface Coating;Textile Products: SIC 22;Total: All Solvent Types
2401015000	Solvent Utilization;Surface Coating;Factory Finished Wood: SIC 2426 thru 242;Total: All Solvent Types
2401020000	Solvent Utilization;Surface Coating;Wood Furniture: SIC 25;Total: All Solvent Types
2401025000	Solvent Utilization;Surface Coating;Metal Furniture: SIC 25;Total: All Solvent Types
2401030000	Solvent Utilization;Surface Coating;Paper: SIC 26;Total: All Solvent Types
2401035000	Solvent Utilization;Surface Coating;Plastic Products: SIC 308;Total: All Solvent Types
2401040000	Solvent Utilization;Surface Coating;Metal Cans: SIC 341;Total: All Solvent Types
2401045000	Solvent Utilization;Surface Coating;Metal Coils: SIC 3498;Total: All Solvent Types
2401050000	Solvent Utilization;Surface Coating;Miscellaneous Finished Metals: SIC 34 - (341 + 3498);Total: All Solvent Types
2401055000	Solvent Utilization;Surface Coating;Machinery and Equipment: SIC 35;Total: All Solvent Types
2401060000	Solvent Utilization;Surface Coating;Large Appliances: SIC 363;Total: All Solvent Types
2401065000	Solvent Utilization;Surface Coating;Electronic and Other Electrical: SIC 36 - 363;Total: All Solvent Types

SCC	SCC Descriptions
2401070000	Solvent Utilization;Surface Coating;Motor Vehicles: SIC 371;Total: All Solvent Types
2401075000	Solvent Utilization;Surface Coating;Aircraft: SIC 372;Total: All Solvent Types
2401080000	Solvent Utilization;Surface Coating;Marine: SIC 373;Total: All Solvent Types
2401085000	Solvent Utilization;Surface Coating;Railroad: SIC 374;Total: All Solvent Types
2401090000	Solvent Utilization;Surface Coating;Miscellaneous Manufacturing;Total: All Solvent Types
2401100000	Solvent Utilization;Surface Coating;Industrial Maintenance Coatings;Total: All Solvent Types
2401200000	Solvent Utilization;Surface Coating;Other Special Purpose Coatings;Total: All Solvent Types
2425000000	Solvent Utilization;Graphic Arts;All Processes;Total: All Solvent Types
2425020000	Solvent Utilization;Graphic Arts;Letterpress;Total: All Solvent Types
2425030000	Solvent Utilization;Graphic Arts;Rotogravure;Total: All Solvent Types
2440000000	Solvent Utilization;Miscellaneous Industrial;All Processes;Total: All Solvent Types
2440020000	Solvent Utilization;Miscellaneous Industrial;Adhesive (Industrial) Application;Total: All Solvent Types
2460030999	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;Lighter Fluid, Fire Starter, Other Fuels;Total: All Volatile Chemical Product Types
2460100000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All Personal Care Products;Total: All Solvent Types
2460200000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All Household Products;Total: All Solvent Types
2460400000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All Automotive Aftermarket Products;Total: All Solvent Types
2460500000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All Coatings and Related Products;Total: All Solvent Types
2460600000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All Adhesives and Sealants;Total: All Solvent Types
2460800000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;All FIFRA Related Products;Total: All Solvent Types
2460900000	Solvent Utilization;Miscellaneous Non-industrial: Consumer and Commercial;Miscellaneous Products (Not Otherwise Covered);Total: All Solvent Types
2461800001	Solvent Utilization;Miscellaneous Non-industrial: Commercial;Pesticide Application: All Processes;Surface Application

Table 4-26. Impact of population-based factors on np_solvents emissions in non-MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	15	17	3	17.7%
NH3	58	65	7	12.6%
NOX	27	32	5	17.9%
PM10-PRI	450	508	58	12.9%
PM25-PRI	429	484	55	12.8%
SO2	1	1	0	18.2%
VOC	1,435,256	1,613,518	178,262	12.4%

Table 4-27. Impact of factors on np_solvents emissions in MARAMA states

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
VOC	565,443	595,664	30,221	5.3%

4.2.3.8 Oil and Gas Sources (np_oilgas, pt_oilgas)

Packets:

Projection_2018_2032_np_oilgas_for_2032gg_21sep2022_v0
Projection_2018_2032_pt_oilgas_for_2032gg_22sep2022_v0

Analytic year projections for the 2018v2 platform were generated for point oil and gas sources for the year 2032. This projection consisted of three components: (1) applying facility closures to the pt_oilgas sector using the CoST CLOSURE packet (see Section 4.2.4); (2) using historical and/or forecast activity data to generate analytic-year emissions before applicable control technologies are applied using the CoST PROJECTION packet; and (3) estimating impacts of applicable control technologies on analytic-year emissions using the CoST CONTROL packet. Applying the CLOSURE packet to the pt_oilgas sector resulted in small emissions changes to the national summary shown in Table 4-5.

For pt_oilgas growth to 2032, the oil and gas sources were separated into production-related and pipeline-related sources by NAICS and SCC. These sources were further subdivided by fuel-type and by NAICS and SCC into either OIL, natural gas (NGAS), or BOTH (where oil or natural gas fuels are possible). The next two subsections describe the growth component of the process.

For np_oilgas growth to 2032, oil and gas sources were separated into production-related and exploration-related sources. These sources were further separated into oil, natural gas or coal bed methane production related.

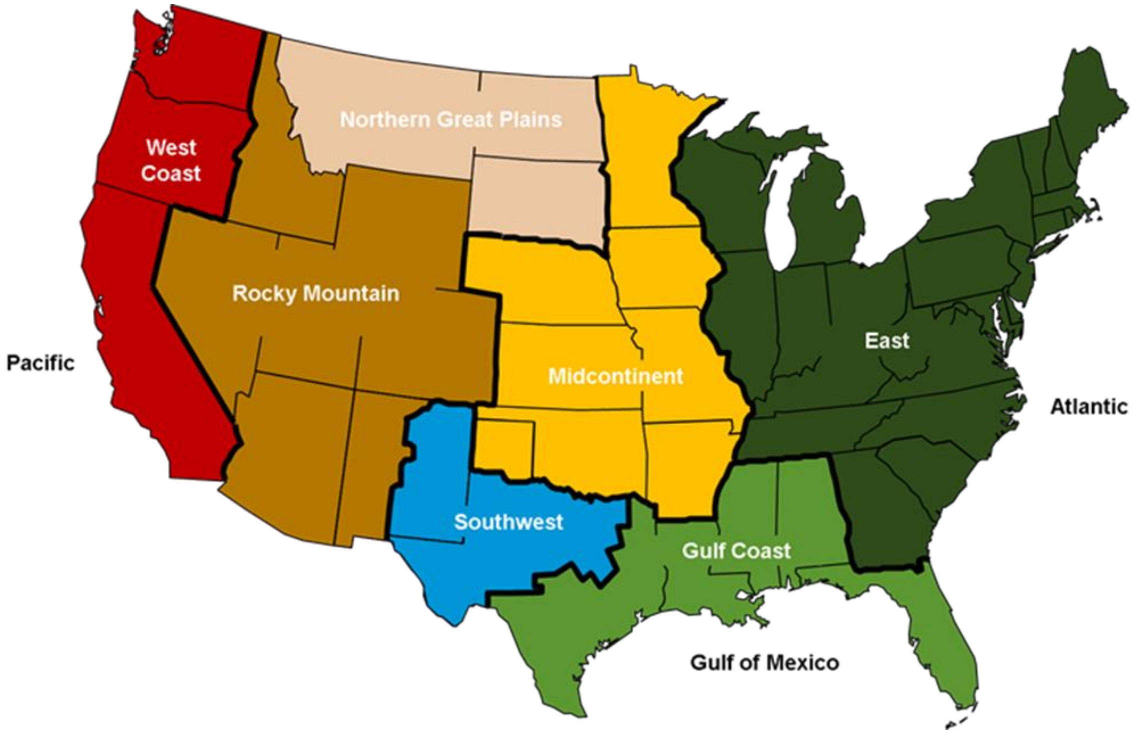
Production-related Sources (pt_oilgas, np_oilgas)

The growth factors for the production-related NAICS-SCC combinations were generated in a two-step process. The first step used historical production data at the state-level to get state-level short-term trends or factors from 2018 to year 2021. These historical data were acquired from EIA from the following links:

- Historical Natural Gas: http://www.eia.gov/dnav/ng/ng_sum_lsum_a_epg0_fgw_mmcf_a.htm
- Historical Crude Oil: http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbbl_a.htm
- Historical CBM: https://www.eia.gov/dnav/ng/ng_prod_coalbed_s1_a.htm

The second step involved using the Annual Energy Outlook (AEO) 2022 reference case for the Lower 48 forecast production tables to project from the year 2021 to the year of 2032. Specifically, *AEO 2022 Table 58 "Lower 48 Crude Oil Production and Wellhead Prices by Supply Region"* and *AEO 2022 Table 59 "Lower 48 Natural Gas Production and Supply Prices by Supply Region"* were used in this projection process. The AEO2022 forecast production is supplied for each EIA Oil and Gas Supply region shown in Figure 4-1.

Figure 4-1. EIA Oil and Gas Supply Regions as of AEO2022



The result of this second step is a growth factor for each Supply Region from 2021 to 2032. A Supply Region mapping to FIPS cross-walk was developed so the regional growth factors could be applied for each FIPS (for pt_oilgas) or to the county-level np_oilgas inventories. Note that portions of Texas are in three different Supply Regions and portions of New Mexico are in two different supply regions. The state-level historical factor (from 2018 to 2021) was then multiplied by the Supply Region factor (from 2021 to the analytic years) to produce a state-level or FIPS-level factor to grow from 2018 to 2032. This process was done using crude production forecast information to generate a factor to apply to oil-production related SCCs or NAICS-SCC combinations and it was also done using natural gas production forecast information to generate a factor to apply to natural gas-production related NAICS-SCC combinations. For the SCC and NAICS-SCC combinations that are designated "BOTH" the average of the oil-production and natural-gas production factors was calculated and applied to these specific combinations.

The state of Texas provided specific comments on the growth of production-related point sources. Texas provided updated basin specific production for 2018 and 2021 to allow for a better calculation of the estimated growth for this three-year period (http://webapps.rrc.texas.gov/PDQ/generalReportAction.do). The AEO2022 was used as described above for the three AEO Oil and Gas Supply Regions that include Texas counties to grow from 2021 to 2032. However, Texas only wanted these growth factors applied to sources in the Permian and Eagle Ford basins and the oil and gas production point sources in the other basins in Texas were not grown.

The state of New Mexico is broken up into two AEO Oil and Gas Supply Regions. County production data for New Mexico was obtained from their state website (https://wwwapps.emnrd.nm.gov/ocd/ocdpermitting/Reporting/Production/CountyProductionInjectionSummary.aspx) so that a better estimate of growth from 2018 to 2021 for the AEO Supply Regions in New Mexico could be calculated.

Transmission-related Sources (pt_oilgas)

Projection factors for transmissions-related sources were generated using the same AEO2022 tables used for production sources. These growth factors sources were developed solely using AEO 2022 data for the entire lower 48 states (one national factor for oil transmission and one national factor for natural gas transmission). The 2018-to-2032 growth for oil transmission was +21.2%, and the growth for natural gas was +28.0%. The impact of the projection factors on the pt_oilgas emissions is shown in Table 4-28.

Table 4-28. Impact of 2018-2032 projections on pt_oilgas emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	166,667	181,220	14,553	8.7%
NH3	365	283	-82	-22.5%
NOX	338,206	397,481	59,276	17.5%
PM10-PRI	11,400	12,705	1,305	11.4%
PM25-PRI	10,844	12,029	1,186	10.9%
SO2	32,881	42,055	9,174	27.9%
VOC	209,368	218,922	9,554	4.6%

Exploration-related Sources (np_oilgas)

Years 2017 through 2019 exploration emissions were generated using the 2017NEI version of the Oil and Gas Tool. Table 4-29 provides a high-level national summary of the emissions data for the three years. This three-year average (2017-2019) emissions data were used in 2018v2 because they reflected the most recent average of exploration activity and emissions. These averaged emissions were used for the 2032 analytic year. Note that CoST was not used to perform this projection step for exploration sources, but is used to apply controls to exploration sources for 2032. The change in emissions from 2018 to 2032 due to the impact of the projections is shown in Table 4-30.

Table 4-29. Year 2017-2019 high-level summary of national oil and gas exploration emissions

Pollutant	2017 emissions	2018 emissions	2019 emissions	Three Year avg (2017-2019) (tons)
NOX	73,992	123,908	108,957	102,285
VOC	118,004	136,916	106,505	120,474

Table 4-30. Impact of 2018-2032 projections on np_oilgas emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	518,419	561,343	42,924	8.3%
NH3	7	2	-5	-71.9%
NOX	382,846	417,535	34,690	9.1%
PM10-PRI	7,177	7,503	326	4.5%
PM25-PRI	7,114	7,440	326	4.6%
SO2	48,690	69,946	21,256	43.7%
VOC	1,920,896	2,209,159	288,264	15.0%

4.2.3.1 Non-EGU point sources (ptnonipm)

<u>Packets:</u>

Projection_2026_2028_finished_fuels_volpe_13aug2021_v0
Projection_2026_2032_industrial_byNAICS_SCC_version3_platform_22sep2022_v0
Projection_2026_2032_industrial_bySCC_version3_platform_12sep2022_nf_v1
Projection_2026_2032_ptnonipm_version2_platform_MARAMA_13aug2021_v0
projection_2026_2028_corn_ethanol_E0B0_Volpe_13aug2021_v0

Projections to 2032 ptnonipm start with the year 2026 emissions from the 2016v3 platform and are additionally projected to 2032. In 2016v3 platform, emissions for the 2023 ptnonipm sector were set equal to emissions from the 2019 NEI point source emissions file dated March 25, 2022. This inventory was projected to 2026 as part of 2016v3 platform, and then for 2018v2 platform, projected further into 2032. This section describes the projections applied from 2026 to 2032. Details on projected ptnonipm emissions through 2026 are available in the 2016v3 TSD.

The 2032 ptnonipm emissions were projected from the 2016v3 platform year 2026 point source emissions using several growth and projection methods described as here. The projection of oil and gas sources is explained in the oil and gas section.

2032 Point Inventory - inside MARAMA region

2026-to-2032 projection packets for point sources were based on the projection factors provided by MARAMA for the following states: CT, DE, DC, ME, MD, MA, NH, NJ, NY, NC, PA, RI, VT, VA, and WV. The factors were developed using the MARAMA projection tool and by selecting 2026 for the base year and 2032 for the projection year. Unlike in 2016v3 platform, additional projection packets were not used in North Carolina, New Jersey, and Virginia, because those projection packets (originally provided for 2016v1 platform) do not extend beyond 2028. Instead, 2026-to-2032 projections in those three states are based on the MARAMA projection tool. The impact of the MARAMA projection packet on ptnonipm emissions from 2026 to 2032 is shown in Table 4-31.

Table 4-31. Impact of 2026-2032 MARAMA projections on ptnonipm emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	97,728	99,785	2,057	2.1%
NH3	6,273	6,315	43	0.7%
NOX	88,133	89,211	1,077	1.2%
PM10-PRI	33,474	33,693	220	0.7%
PM25-PRI	23,681	23,874	192	0.8%
SO2	50,072	50,021	-50	-0.1%
VOC	77,226	77,425	198	0.3%

2032 Point Inventories - outside MARAMA region

Projection factors were developed by industrial sector from AEO 2022 in order to project emissions from 2026 to 2032. Emissions were mapped to AEO categories by NAICS and SCC (combination of NAICS and SCC first, SCC only after that) and projection factors were created using a ratio between the base year and projection year estimates from each specific AEO category. SCC/NAICS combinations with emissions >100tons/year for any CAP[26] were mapped to AEO sector and fuel. Table 4-32 below details the AEO2022 tables used to map SCCs to AEO categories for the projections of industrial sources. The impact of the projection packets specified by NAICS and SCC from 2026-2032 is shown in Table 4-33 and the impact of the projection packets specified by SCC is shown in Table 4-34.

Table 4-32. Annual Energy Outlook (AEO) 2022 tables used to project industrial sources

AEO 2022 Table #	AEO Table name
2	Energy Consumption by Sector and Source
24	Refining Industry Energy Consumption
25	Food Industry Energy Consumption
26	Paper Industry Energy Consumption
27	Bulk Chemical Industry Energy Consumption
28	Glass Industry Energy Consumption
29	Cement Industry Energy Consumption
30	Iron and Steel Industries Energy Consumption
31	Aluminum Industry Energy Consumption
32	Metal Based Durables Energy Consumption
33	Other Manufacturing Sector Energy Consumption
34	Nonmanufacturing Sector Energy Consumption

Table 4-33. Impact of 2026-2032 industrial projections by NAICS and SCC on ptnonipm emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	179,673	182,335	2,663	1.5%
NH3	2,697	2,761	63	2.3%
NOX	174,429	177,552	3,123	1.8%
PM10-PRI	27,752	28,660	909	3.3%
PM25-PRI	23,822	24,512	690	2.9%
SO2	70,516	70,769	252	0.4%
VOC	12,296	12,662	367	3.0%

[26] The "100 tpy" criterion for this purpose was based on emissions in the emissions values in the 2016 beta platform.

Table 4-34. Impact of 2026-2032 industrial projections by SCC on ptnonipm emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	464,198	476,609	12,411	2.7%
NH3	4,213	4,398	185	4.4%
NOX	321,324	333,674	12,349	3.8%
PM10-PRI	66,072	68,580	2,509	3.8%
PM25-PRI	47,440	49,148	1,708	3.6%
SO2	99,096	104,118	5,023	5.1%
VOC	34,460	35,771	1,311	3.8%

Finished fuel and biorefinery factors

Factors were developed as part of the 2016 platform to project finished fuels and biorefineries to analytic years. Estimates on growth of evaporative emissions from transporting finished fuels are not covered as part of oil and gas projections, e.g., withdrawing fuel from tanks at bulk plants, filling tanks at service stations, etc. For 2016v1 platform, the AEO 2018 was used as a starting point for projecting volumes of finished fuel that would be transported in the analytic years of 2023 and 2028. Then these volumes were used to calculate inventories associated with evaporative emissions in 2016, 2023, and 2028 using the upstream modules. Those emission inventories were mapped to the appropriate SCCs and projection packets were generated using the upstream modules. Because the last analytic year available for the 2016v1 platform was 2028, it was not possible to develop factors specific to 2032. Instead, the portion of the factors effective from 2026 to 2028 were applied for this study and the resulting emissions were held constant at 2028 levels. A set of 2026-to-2028 projection factors was interpolated from the 2023 and 2028 projection factors from 2016v1 platform. Sources within the MARAMA region were projected with MARAMA-provided growth factors. The impact of the finished fuels factors on ptnonipm emissions is shown in Table 4-35 and the impact on biorefinery emissions is shown in Table 4-36.

Table 4-35. Impact of 2026-2028 factors on ptnonipm finished fuel emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
VOC	13,936	13,092	-843	-6.1%

Table 4-36. Impact of 2026-2028 factors on ptnonipm biorefinery emissions

Pollutant	Inventory Emissions	Final Emissions	Emissions Change	Emissions % Change
CO	7,473	7,332	-141	-1.9%
NH3	297	291	-6	-1.9%
NOX	10,197	10,004	-192	-1.9%
PM10-PRI	5,659	5,552	-107	-1.9%
PM25-PRI	4,529	4,444	-85	-1.9%
SO2	3,591	3,523	-68	-1.9%
VOC	13,708	13,449	-259	-1.9%

4.2.3.2 Railroads (rail)

Packets:

Projection_2026_2032_rail_for_2032gg_23sep2022_v0

The starting point for the 2032 rail emissions were the 2026 emissions from the 2016v3 platform. Those emissions were projected from 2026 to 2032 based on AEO2022 growth rates as shown in Table 4-37.

Table 4-37. AEO2022 growth rates for rail sub-groups, 2026 to 2032

Sector	Pollutant	2032
Class I Railroads	NOx	-15.7%
Class I Railroads	PM	-22.9%
Class I Railroads	VOC	-27.3%
Class I Railroads	Others	+0.99%
Class II/III Railroads	All	+0.99%
Commuter/Passenger	All	+14.3%
Rail Yards	All	+0.99%

For 2018v2, CARB provided new locomotive emissions for 2032. For VOC speciation, the EPA preferred augmenting the 2032 CARB inventory (which only included CAPs) with HAPs and using those HAPs for integration, rather than running the California portion of the sector as no-integrate. In addition to updating the nonpoint rail inventory in California, the point rail yard emissions in ptnonipm were also updated to better reflect the new rail yard emissions in the California rail inventory. The overall impact of all projections on the rail emissions are shown in Table 4-38.

Table 4-38. Impact of projections on rail emissions

Pollutant	2026 Emissions	2032 Emissions	Emissions Change
CO	107,420	109,034	1,615
NH3	335	340	5.0
NOX	465,183	413,468	-51,715
PM10-PRI	12,460	10,429	-2,032
PM25-PRI	12,084	10,114	-1,977
SO2	379	384	5.7
VOC	20,621	16,770	-3,851

4.2.3.3 Residential Wood Combustion (rwc)

Packets:

Projection_2017_2032gg_rwc_fromMARAMA_12sep2022_v0

For residential wood combustion, the growth and control factors are computed together into merged factors in the same packet. Emissions for the states of California, Oregon, and Washington are held constant due to regulations in effect in those areas. For the remaining states, RWC emissions from 2017NEI were projected to 2032 using projection factors derived using the MARAMA tool that is based on the projection methodology from EPA's 2011v6.3 platform. The year 2017 was used to represent 2018. The development of projected growth in RWC emissions to year 2032 is based on the projected growth in RWC appliances derived from year 2012 appliance shipments reported in the Regulatory Impact Analysis (RIA) for Proposed Residential Wood Heaters NSPS Revision Final Report available at: http://www2.epa.gov/sites/production/files/2013-12/documents/ria-20140103.pdf. The 2012 shipments are based on 2008 shipment data and revenue forecasts from a Frost & Sullivan Market Report (Frost & Sullivan, 2010). Next, to be consistent with the RIA, growth rates for new appliances for certified wood stoves, pellet stoves, indoor furnaces and OHH were based on forecasted revenue (real GDP) growth rate of 2.0% per year from 2013 through 2025 as predicted by the U.S. Bureau of Economic Analysis (BEA, 2012). While this approach is not perfectly correlated, in the absence of specific shipment projections, the RIA assumes the overall trend in the projection is reasonable. All of the factors in the projection tool are held constant with no additional changes after year 2025. The growth rates for appliances not listed in the RIA (fireplaces, outdoor wood burning devices (not elsewhere classified) and residential fire logs) are estimated based on the average growth in the number of houses between 2002 and 2012, about 1% (U.S. Census, 2012).

In addition to new appliance sales and forecasts extrapolating beyond 2012, assumptions on the replacement of older, existing appliances are needed. Based on long lifetimes, no replacement of fireplaces, outdoor wood burning devices (not elsewhere classified) or residential fire logs is assumed. It is assumed that 95% of new woodstoves will replace older non-EPA certified freestanding stoves (pre-1988 NSPS) and 5% will replace existing EPA-certified catalytic and non-catalytic stoves that currently meet the 1988 NSPS (Houck, 2011).

Equation 4-1 was applied with RWC-specific factors from the rule. EPA RWC NSPS experts assume that 10% of new pellet stoves and OHH replace older units and that because of their short lifespan, that 10% of indoor furnaces are replaced each year. The resulting growth factors for these appliance types varies by appliance type and also by pollutant because the emission rates, from the EPA RWC tool (EPA, 2013rwc), vary by appliance type and pollutant. For EPA certified units, the projection factors for PM are lower than those for all other pollutants. The projection factors also vary because the total number of existing units in 2016 varies greatly between appliance types.

Table 4-39 contains the factors to adjust the emissions from 2017 to 2032 outside of California, Oregon, and Washington, where RWC emissions were held constant at 2017 NEI levels for the years 2017 and 2032 due to the unique control programs that those states have in place. Table 4-40 shows the overall impact of projection on the sector.

Table 4-39. Projection factors for Residential Wood Combustion

SCC	SCC description	Pollutant*	2017-to-2032
2104008100	Fireplace: general		+15.36%
2104008210	Woodstove: fireplace inserts; non-EPA certified		-16.50%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic	PM10-PRI	+3.92%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic	PM25-PRI	+3.92%
2104008220	Woodstove: fireplace inserts; EPA certified; non-catalytic		+7.60%
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic	PM10-PRI	+6.41%
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic	PM25-PRI	+6.41%

SCC	SCC description	Pollutant*	2017-to-2032
2104008230	Woodstove: fireplace inserts; EPA certified; catalytic		+12.47%
2104008310	Woodstove: freestanding, non-EPA certified	CO	-14.70%
2104008310	Woodstove: freestanding, non-EPA certified	PM10-PRI	-15.58%
2104008310	Woodstove: freestanding, non-EPA certified	PM25-PRI	-15.58%
2104008310	Woodstove: freestanding, non-EPA certified	VOC	-13.94%
2104008310	Woodstove: freestanding, non-EPA certified		-14.70%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic	PM10-PRI	+3.92%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic	PM25-PRI	+3.92%
2104008320	Woodstove: freestanding, EPA certified, non-catalytic		+7.60%
2104008330	Woodstove: freestanding, EPA certified, catalytic	PM10-PRI	+6.41%
2104008330	Woodstove: freestanding, EPA certified, catalytic	PM25-PRI	+6.41%
2104008330	Woodstove: freestanding, EPA certified, catalytic		+12.47%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)	PM10-PRI	+29.85%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)	PM25-PRI	+29.85%
2104008400	Woodstove: pellet-fired, general (freestanding or FP insert)		+25.94%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	CO	-83.91%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	PM10-PRI	-82.31%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	PM25-PRI	-82.31%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified	VOC	-84.03%
2104008510	Furnace: Indoor, cordwood-fired, non-EPA certified		-83.91%
2104008530	Furnace: Indoor, pellet-fired, general	PM10-PRI	+29.85%
2104008530	Furnace: Indoor, pellet-fired, general	PM25-PRI	+29.85%
2104008530	Furnace: Indoor, pellet-fired, general		+25.94%
2104008610	Hydronic heater: outdoor	PM10-PRI	-1.83%
2104008610	Hydronic heater: outdoor	PM25-PRI	-1.83%
2104008610	Hydronic heater: outdoor		-2.26%
2104008620	Hydronic heater: indoor	PM10-PRI	-1.83%
2104008620	Hydronic heater: indoor	PM25-PRI	-1.83%
2104008620	Hydronic heater: indoor		-2.26%
2104008630	Hydronic heater: pellet-fired	PM10-PRI	-1.83%
2104008630	Hydronic heater: pellet-fired	PM25-PRI	-1.83%
2104008630	Hydronic heater: pellet-fired		-2.26%
2104008700	Outdoor wood burning device, NEC (fire-pits, chimineas, etc)		+8.19%
2104009000	Fire log total		+8.19%

* If no pollutant is specified, facture is used for any pollutants that do not have a pollutant-specific factor

Table 4-40. Impact of projections on rwc emissions, 2017-2032

Pollutant	Inventory Emissions	Final Emissions	Emissions Change
CO	2,317,024	2,259,199	-57,826
NH3	16,426	16,146	-280
NOX	37,382	38,599	1,217
PM10-PRI	301,157	291,135	-10,022
PM25-PRI	299,911	289,966	-9,945
SO2	8,503	7,687	-816
VOC	319,313	313,588	-5,724

4.2.4 CoST CONTROL Packets (nonpt, np_oilgas, ptnonipm, pt_oilgas, np_solvents)

The final step in the projection of emissions to an analytic year is the application of any control technologies or programs. For analytic-year New Source Performance Standards (NSPS) controls (e.g., oil and gas, Reciprocating Internal Combustion Engines (RICE), Natural Gas Turbines, and Process Heaters), we attempted to control only new sources/equipment using the following equation to account for growth and retirement of existing sources and the differences between the new and existing source emission rates.

$$Qn = Qo \{ [(1 + Pf)\ t - 1]\ Fn + (1 - Ri)\ t\ \ Fe + [1 - (1 - Ri)\ t]\ Fn \} \qquad \textbf{Equation 4-1}$$

where:

Qn = emissions in projection year
Qo = emissions in base year
Pf = growth rate expressed as ratio (e.g., 1.5=50 percent cumulative growth)
t = number of years between base and analytic years
Fn = emission factor ratio for new sources
Ri = retirement rate, expressed as whole number (e.g., 3.3 percent=0.033)
Fe = emission factor ratio for existing sources

The first term in Equation 4-1 represents new source growth and controls, the second term accounts for retirement and controls for existing sources, and the third term accounts for replacement source controls. For computing the CoST % reductions (Control Efficiency), the simplified Equation 4-2 was used for analytic year projections:

$$\text{Control Efficiency}_{202x}(\%) = 100 \times \left(1 - \frac{\left[(Pf_{202x} - 1) \times Fn + (1 - Ri)^{13} + \left(1 - (1 - Ri)^{13}\right) \times Fn\right]}{Pf_{202x}}\right) \qquad \textbf{Equation 4-2}$$

For example, to compute the control efficiency for 2032 from a base year of 2018 the existing source emissions factor (Fe) is set to 1.0; 2032 (the analytic year) minus 2018 (the base year) is 14, and the new source emission factor (Fn) is the ratio of the NSPS emission factor to the existing emission factor.

The NSPS are applied to sectors and with the specified retirement rates (R) as follows:

- The Oil and Gas NSPS is applied to the np_oilgas and pt_oilgas sectors with no assumed retirement rate.
- The RICE NSPS is applied to the np_oilgas, pt_oilgas, nonpt, and ptnonipm sectors with an assumed retirement rate of 40 years (2.5%).
- The Gas Turbines NSPS is applied to the pt_oilgas and ptnonipm sectors with an assumed retirement rate of 45 years (2.2%).
- The Process Heaters NSPS is applied to the pt_oilgas and ptnonipm sectors with an assumed retirement rate of 30 years (3.3%).

Table 4-41 shows the values for the emission factors for new sources (Fn) with respect to each NSPS regulation and other conditions within. Further information about the application of NSPS controls can be found in Section 4 of the *Additional Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the Year 2023* technical support document (EPA, 2017).

Table 4-41. Assumed new source emission factor ratios for NSPS rules

NSPS	**Pollutants**	**Applied where?**	**New Source Emission Factor (Fn)**
Oil and Gas	VOC	Storage Tanks: 70.3% reduction in growth-only (>1.0)	0.297
Oil and Gas	VOC	Gas Well Completions: 95% control (regardless)	0.05
Oil and Gas	VOC	Pneumatic controllers, not high-bleed >6scfm or low-bleed: 77% reduction in growth-only (>1.0)	0.23
Oil and Gas	VOC	Pneumatic controllers, high-bleed >6scfm or low-bleed: 100% reduction in growth-only (>1.0)	0.00
Oil and Gas	VOC	Compressor Seals: 79.9% reduction in growth-only (>1.0)	0.201
Oil and Gas	VOC	Fugitive Emissions: 60% Valves, flanges, connections, pumps, open-ended lines, and other	0.40
RICE	NOx	Lean burn: PA, all other states	0.25, 0.606
RICE	NOx	Rich Burn: PA, all other states	0.1, 0.069
RICE	NOx	Combined (average) LB/RB: PA, other states	0.175, 0.338
RICE	CO	Lean burn: PA, all other states	1.0 (n/a), 0.889
RICE	CO	Rich Burn: PA, all other states	0.15, 0.25
RICE	CO	Combined (average) LB/RB: PA, other states	0.575, 0.569
RICE	VOC	Lean burn: PA, all other states	0.125, n/a
RICE	VOC	Rich Burn: PA, all other states	0.1, n/a
RICE	VOC	Combined (average) LB/RB: PA, other states	0.1125, n/a
Gas Turbines	NOx	California and NO_X SIP Call states	0.595
Gas Turbines	NOx	All other states	0.238
Process Heaters	NO_X	Nationally to Process Heater SCCs	0.41

4.2.4.1 Oil and Gas NSPS (np_oilgas, pt_oilgas)

<u>Packets:</u>

Control_2018_2032_Oilgas_NSPS_withNMrule_np_oilgas_for_2032gg_21sep2022_v0
Control_2018_2032_Oilgas_NSPS_withNMrule_pt_oilgas_for_2032gg_21sep2022_v0

New packets to reflect the oil and gas NSPS were developed for the 2018 platform. For oil and gas NSPS controls, except for gas well completions (a 95 percent control), the assumption of no equipment retirements through year 2032 dictates that NSPS controls are applied to the growth component only of any PROJECTION factors. For example, if a growth factor is 1.5 for storage tanks (indicating a 50 percent increase activity), then, using Table 4-41, the 70.3 percent VOC NSPS control to this new growth will result in a 23.4 percent control: 100 *(70.3 * (1.5 -1) / 1.5); this yields an “effective” growth rate (combined PROJECTION and CONTROL) of 1.1485, or a 70.3 percent reduction from 1.5 to 1.0. The impacts of all non-drilling completion VOC NSPS controls are therefore greater where growth in oil and gas production is assumed highest. Conversely, for oil and gas basins with assumed negative growth in activity/production, VOC NSPS controls will be limited to well completions only. These reductions are year-specific because projection factors for these sources are year-specific.

Table 4-42 shows the emission reductions for the oil and gas sectors as a result of applying the oil and gas NSPS. Table 4-43 and Table 4-44 list the SCCs in the np_oilgas and pt_oilgas sectors for which the Oil and Gas NSPS controls were. Note that controls are applied to both production and exploration-related SCCs.)

Table 4-42. Emissions reductions for the oil and gas sectors due to applying the Oil and Gas NSPS

Sector	year	poll	2018gg	2018 pre-CoST emissions	emissions change from 2018	% change
np_oilgas	2032	VOC	2,425,264	2,400,100	-393,671	-16.4%
pt_oilgas	2032	VOC	235,255	237,400	-9,022	-3.8%

Table 4-43. SCCs in np_oilgas for which the Oil and Gas NSPS controls were applied

SCC	PRODUCT	OG_NSPS_SCC	TOOL OR STATE	Source category	SCC Description*
2310010300	OIL	3. Pneumatic controllers: not high or low bleed	TOOL	PRODUCTION	Crude Petroleum;Oil Well Pneumatic Devices
2310010700	OIL	5. Fugitives	TOOL	PRODUCTION	Crude Petroleum;Oil Well Fugitives
2310011020	OIL	1. Storage Tanks	TOOL	PRODUCTION	On-Shore Oil Production;Storage Tanks: Crude Oil
2310011500	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: All Processes
2310011501	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: Connectors
2310011502	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: Flanges
2310011503	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: Open Ended Lines
2310011505	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: Valves
2310011506	OIL	5. Fugitives	TOOL	PRODUCTION	On-Shore Oil Production;Fugitives: Other
2310020700	NGAS	5. Fugitives	TOOL	PRODUCTION	Natural Gas;Gas Well Fugitives
2310021010	NGAS	1. Storage Tanks	TOOL	PRODUCTION	On-Shore Gas Production;Storage Tanks: Condensate
2310021011	NGAS	1. Storage Tanks	TOOL	PRODUCTION	On-Shore Gas Production;Condensate Tank Flaring
2310021300	NGAS	3. Pneumatic controllers: not high or low bleed	TOOL	PRODUCTION	On-Shore Gas Production;Gas Well Pneumatic Devices
2310021310	NGAS	6. Pneumatic Pumps	TOOL	PRODUCTION	On-Shore Gas Production;Gas Well Pneumatic Pumps
2310021500	NGAS	2. Well Completions	TOOL	EXPLORATION	On-Shore Gas Production;Gas Well Completion – Flaring
2310021501	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: Connectors
2310021502	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: Flanges
2310021503	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: Open Ended Lines
2310021505	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: Valves
2310021506	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: Other
2310021509	NGAS	5. Fugitives	TOOL	PRODUCTION	On-Shore Gas Production;Fugitives: All Processes

SCC	PRODUCT	OG_NSPS_SCC	TOOL OR STATE	Source category	SCC Description*
2310021601	NGAS	2. Well Completions	TOOL	EXPLORATION	On-Shore Gas Production;Gas Well Venting - Initial Completions
2310023000	CBM	6. Pneumatic Pumps	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Dewatering Pump Engines
2310023010	CBM	1. Storage Tanks	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Storage Tanks: Condensate
2310023300	CBM	3. Pnuematic controllers: not high or low bleed	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Pneumatic Devices
2310023310	CBM	6. Pneumatic Pumps	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Pneumatic Pumps
2310023509	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives
2310023511	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives: Connectors
2310023512	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives: Flanges
2310023513	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives: Open Ended Lines
2310023515	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives: Valves
2310023516	CBM	5. Fugitives	TOOL	PRODUCTION	Coal Bed Methane Natural Gas;Fugitives: Other
2310023600	CBM	2. Well Completions	TOOL	EXPLORATION	Coal Bed Methane Natural Gas;CBM Well Completion: All Processes
2310030220	NGAS	1. Storage Tanks	TOOL	PRODUCTION	Natural Gas Liquids;Gas Well Tanks - Flashing & Standing/Working/Breathing, Controlled
2310030300	NGAS	1. Storage Tanks	TOOL	PRODUCTION	Natural Gas Liquids;Gas Well Water Tank Losses
2310111401	OIL	6. Pneumatic Pumps	TOOL	PRODUCTION	On-Shore Oil Exploration;Oil Well Pneumatic Pumps
2310111700	OIL	2. Well Completions	TOOL	EXPLORATION	On-Shore Oil Exploration;Oil Well Completion: All Processes
2310121401	NGAS	6. Pneumatic Pumps	TOOL	PRODUCTION	On-Shore Gas Exploration;Gas Well Pneumatic Pumps
2310121700	NGAS	2. Well Completions	TOOL	EXPLORATION	On-Shore Gas Exploration;Gas Well Completion: All Processes
2310321010	NGAS	1. Storage Tanks	STATE	PRODUCTION	On-Shore Gas Production - Conventional;Storage Tanks: Condensate
2310421010	NGAS	1. Storage Tanks	STATE	PRODUCTION	On-Shore Gas Production - Unconventional;Storage Tanks: Condensate

* All SCC descriptions in this table start with "Industrial Processes;Oil and Gas Exploration and Production;"

Table 4-44. SCCs in pt_oilgas for which the Oil and Gas NSPS controls were applied

SCC	Fuel	OG_NSPS_ SCC	NP or PT	SCC Description*
30180010	NGAS	4. Compressor Seals	PT	IP;Chemical Manufacturing;Equipment Leaks;Compressor Seals: Gas Stream
30600801	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pipeline Valves and Flanges
30600802	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Vessel Relief Valves
30600803	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pump Seals w/o Controls
30600804	OIL	4. Compressor Seals	PT	IP;Petroleum Industry;Fugitive Emissions;Compressor Seals
30600805	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Miscellaneous: Sampling/Non-Asphalt Blowing/Purging/etc.
30600806	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pump Seals with Controls
30600811	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pipeline Valves: Gas Streams
30600812	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pipeline Valves: Light Liquid/Gas Streams

SCC	Fuel	OG_NSPS_ SCC	NP or PT	SCC Description*
30600813	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pipeline Valves: Heavy Liquid Streams
30600815	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Open-ended Valves: All Streams
30600816	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Flanges: All Streams
30600817	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pump Seals: Light Liquid/Gas Streams
30600818	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Pump Seals: Heavy Liquid Streams
30600819	OIL	4. Compressor Seals	PT	IP;Petroleum Industry;Fugitive Emissions;Compressor Seals: Gas Streams
30600820	OIL	4. Compressor Seals	PT	IP;Petroleum Industry;Fugitive Emissions;Compressor Seals: Heavy Liquid Streams
30600822	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Vessel Relief Valves: All Streams
30688801	OIL	5. Fugitives	PT	IP;Petroleum Industry;Fugitive Emissions;Specify in Comments Field
31000101	OIL	2. Well Completions	PT	IP;Oil and Gas Production;Crude Oil Production;Well Completion
31000130	OIL	4. Compressor Seals	PT	IP;Oil and Gas Production;Crude Oil Production;Fugitives: Compressor Seals
31000151	OIL	3. Pnuematic controllers: high or low bleed	PT	IP;Oil and Gas Production;Crude Oil Production;Pneumatic Controllers, Low Bleed
31000152	OIL	3. Pnuematic controllers: high or low bleed	PT	IP;Oil and Gas Production;Crude Oil Production;Pneumatic Controllers High Bleed >6 scfh
31000153	OIL	3. Pnuematic controllers: not high or low bleed	PT	IP;Oil and Gas Production;Crude Oil Production;Pneumatic Controllers Intermittent Bleed
31000207	NGAS	5. Fugitives	PT	IP;Oil and Gas Production;Natural Gas Production;Valves: Fugitive Emissions
31000220	NGAS	5. Fugitives	NP_AN D_ PT	IP;Oil and Gas Production;Natural Gas Production;All Equipt Leak Fugitives (Valves, Flanges, Connections, Seals, Drains
31000225	NGAS	4. Compressor Seals	PT	IP;Oil and Gas Production;Natural Gas Production;Compressor Seals
31000231	NGAS	5. Fugitives	PT	IP;Oil and Gas Production;Natural Gas Production;Fugitives: Drains
31000233	NGAS	3. Pnuematic controllers: high or low bleed	PT	IP;Oil and Gas Production;Natural Gas Production;Pneumatic Controllers, Low Bleed
31000235	NGAS	3. Pnuematic controllers: not high or low bleed	PT	IP;Oil and Gas Production;Natural Gas Production;Pneumatic Controllers Intermittent Bleed
31000309	NGAS	4. Compressor Seals	PT	IP;Oil and Gas Production;Natural Gas Processing;Compressor Seals
31000324	NGAS	3. Pnuematic controllers: high or low bleed	NP_AN D_ PT	IP;Oil and Gas Production;Natural Gas Processing;Pneumatic Controllers Low Bleed
31000325	NGAS	3. Pnuematic controllers: high or low bleed	NP_AN D_ PT	IP;Oil and Gas Production;Natural Gas Processing;Pneumatic Controllers, High Bleed >6 scfh
31000326	NGAS	3. Pnuematic controllers: not high or low bleed	PT	IP;Oil and Gas Production;Natural Gas Processing;Pneumatic Controllers Intermittent Bleed
31000506	OIL	1. Storage Tanks	PT	IP;Oil and Gas Production;Liquid Waste Treatment;Oil-Water Separation Wastewater Holding Tanks
31088801	BOTH	5. Fugitives	PT	IP;Oil and Gas Production;Fugitive Emissions;Specify in Comments Field
31088811	BOTH	5. Fugitives	NP_AN D_ PT	IP;Oil and Gas Production;Fugitive Emissions;Fugitive Emissions

SCC	Fuel	OG_NSPS_ SCC	NP or PT	SCC Description*
31700101	NGAS	3. Pnuematic controllers: high or low bleed	PT	IP;NGTS;Natural Gas Transmission and Storage Facilities;Pneumatic Controllers Low Bleed
39090001	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Residual Oil: Breathing Loss
39090002	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Residual Oil: Working Loss
39090003	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Distillate Oil (No. 2): Breathing Loss
39090004	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Distillate Oil (No. 2): Working Loss
39090005	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Oil No. 6: Breathing Loss
39090006	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Oil No. 6: Working Loss
39090007	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Methanol: Breathing Loss
39090008	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Methanol: Working Loss
39090009	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Residual Oil/Crude Oil: Breathing Loss
39090010	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Residual Oil/Crude Oil: Working Loss
39090012	OIL	1. Storage Tanks	PT	IP;In-process Fuel Use;Fuel Storage - Fixed Roof Tanks;Dual Fuel (Gas/Oil): Working Loss
40301001	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 13: Breathing Loss (67000 Bbl. Tank Size)
40301002	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 10: Breathing Loss (67000 Bbl. Tank Size)
40301003	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 7: Breathing Loss (67000 Bbl. Tank Size)
40301004	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 13: Breathing Loss (250000 Bbl. Tank Size)
40301005	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 10: Breathing Loss (250000 Bbl. Tank Size)
40301007	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 13: Working Loss (Tank Diameter Independent)
40301008	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 10: Working Loss (Tank Diameter Independent)
40301009	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Gasoline RVP 7: Working Loss (Tank Diameter Independent)
40301010	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Crude Oil RVP 5: Breathing Loss (67000 Bbl. Tank Size)
40301011	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Crude Oil RVP 5: Breathing Loss (250000 Bbl. Tank Size)
40301012	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Crude Oil RVP 5: Working Loss (Tank Diameter Independent)
40301013	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Jet Naphtha (JP-4): Breathing Loss (67000 Bbl. Tank Size)
40301015	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Jet Naphtha (JP-4): Working Loss (Tank Diameter Independent)
40301019	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Distillate Fuel #2: Breathing Loss (67000 Bbl. Tank Size)
40301021	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Distillate Fuel #2: Working Loss (Tank Diameter Independent)
40301065	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Grade 6 Fuel Oil: Breathing Loss (250000 Bbl. Tank Size)
40301075	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Grade 6 Fuel Oil: Working Loss (Independent Tank Diameter)
40301079	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Grade 1 Fuel Oil: Working Loss (Independent Tank Diameter)
40301097	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Other Liquids: Breathing Loss (67000 Bbl. Tank Size)

SCC	Fuel	OG_NSPS_ SCC	NP or PT	SCC Description*
40301098	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Other Liquids: Breathing Loss (250000 Bbl. Tank Size)
40301099	OIL	1. Storage Tanks	PT	CE;Petroleum Product Storage at Refineries;Fixed Roof Tanks (Varying Sizes);Other Liquids: Working Loss (Tank Diameter Independent)
40388801	OIL	5. Fugitives	PT	CE;Petroleum Product Storage at Refineries;Fugitive Emissions;General
40400300	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank: Flashing Loss
40400301	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank: Breathing Loss
40400302	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank: Working Loss
40400311	OIL	1. Storage Tanks	NP_AND_ PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Condensate, working+breathing+flashing losses
40400312	OIL	1. Storage Tanks	NP_AND_ PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Crude Oil, working+breathing+flashing losses
40400313	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Lube Oil, working+breathing+flashing losses
40400314	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Specialty Chem-working+breathing+flashing
40400315	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Produced Water, working+breathing+flashing
40400316	OIL	1. Storage Tanks	PT	CE;Petroleum Liquids Storage (non-Refinery);Oil and Gas Field Storage and Working Tanks;Fixed Roof Tank, Diesel, working+breathing+flashing losses
40701613	OIL	1. Storage Tanks	PT	CE;Organic Chemical Storage;Fixed Roof Tanks - Alkanes (Paraffins);Petroleum Distillate: Breathing Loss
40701614	OIL	1. Storage Tanks	PT	CE;Organic Chemical Storage;Fixed Roof Tanks - Alkanes (Paraffins);Petroleum Distillate: Working Loss

* For all entries in this table, TOOL OR STATE = STATE and SRC_CAT = PRODUCTION; In the SCC description, IP is an abbreviation for Industrial Processes and CE is an abbreviation for Chemical Evaporation

4.2.4.2 RICE NSPS (nonpt, ptnonipm, np_oilgas, pt_oilgas)

Packets:

Control_2016_2026_RICE_NSPS_nonpt_v2_platform_16jul2021_v0
Control_2026_2032_RICE_NSPS_nonpt_ptnonipm_v2_platform_13aug2021_v0
Control_2018_2032_RICE_NSPS_np_oilgas_for_2032gg_21sep2022_v0
Control_2018_2032_RICE_NSPS_pt_oilgas_for_2032gg_22sep2022_v0

Multiple sectors are affected by the RICE NSPS controls. The packet names include the sectors to which the specific packet applies. For the ptnonipm sector, 2026 emissions from 2016v3 platform were used as the baseline for projections, so RICE NSPS controls only need to be applied beyond 2026 for that sector. The 2026-to-2032 control packets were reused from 2016v2 platform.

For the pt_oilgas and np_oilgas sectors, year-specific RICE NSPS factors were generated for 2032. New growth factors based on AEO2022 and state-specific production data were calculated for the oil and gas sectors which were included in the calculation of the new RICE NSPS control factors, although the actual control efficiency calculation methodology did not change from 2018gf to 2018v2. For RICE NSPS controls, the EPA emission requirements for stationary engines differ according to whether the engine is new or existing, whether the engine is located at an area source or major source, and whether the engine is a compression ignition or a spark ignition engine. Spark ignition engines are further subdivided by power cycle, two-stroke versus four-stroke, and whether the engine is rich burn or lean burn. The NSPS reduction was applied for lean burn, rich burn and “combined” engines using Equation 4-2 and information listed in Table 4-41.

Table 4-45, Table 4-46, Table 4-47 and Table 4-48 show the reductions in emissions in the nonpt, ptnonipm, and np_oilgas and pt_oilgas sectors after the application of the RICE NSPS CONTROL packet. Note that for nonpoint oil and gas, VOC reductions were only appropriate in the state of Pennsylvania. Table 4-49, Table 4-50, and Table 4-51 show the SCCs to which the NSPS controls are applied in the nonpt, ptnonipm, np_oilgas, and pt_oilgas sectors.

Table 4-45. Emissions reductions in nonpt due to RICE NSPS

year	Poll	2018v2 (tons)	Emissions reductions (tons)	% change
2032	CO	1,945,327	-32,620	-1.7%
2032	NOX	750,001	-52,059	-6.9%

Table 4-46. Emissions reductions in ptnonipm due to the RICE NSPS

year	poll	2026gf (tons)	Emissions reductions (tons)	% change
2032	CO	1,380,825	-155	-0.01%
2032	NOX	860,031	-285	-0.03%
2032	VOC	760,436	-1.8	0.00%

Table 4-47. Emissions reductions in np_oilgas due to the RICE NSPS

Year	Poll	2018v2 (tons)	2018 pre-CoST emissions	Emissions reduction	% change
2032	CO	664,681	661,330	-79,455	-12.0%
2032	NOX	670,576	648,890	-113,029	-17.4%
2032	VOC	2,425,264	2,400,113	-534	0.0%

Table 4-48. Emissions reductions in pt_oilgas du to the RICE NSPS

Year	Pollutant	2018	Emissions Reductions	% change
2032	CO	208,810	-18,564	-8.9%
2032	NOX	424,313	-50,961	-12.0%
2032	VOC	235,255	-312	-0.1%

Table 4-49. SCCs and Engine Types where RICE NSPS controls applied for nonpt and ptnonipm

SCC	Lean, Rich, or Combined	SCCDESC
20200202	Combined	Internal Combustion Engines; Industrial; Natural Gas; Reciprocating
20200253	Rich	Internal Combustion Engines; Industrial; Natural Gas; 4-cycle Rich Burn
20200254	Lean	Internal Combustion Engines; Industrial; Natural Gas; 4-cycle Lean Burn
20200256	Lean	Internal Combustion Engines; Industrial; Natural Gas; 4-cycle Clean Burn

SCC	Lean, Rich, or Combined	SCCDESC
20300201	Combined	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Reciprocating
2102006000	Combined	Stationary Source Fuel Combustion; Industrial; Natural Gas; Total: Boilers and IC Engines
2102006002	Combined	Stationary Source Fuel Combustion; Industrial; Natural Gas; All IC Engine Types
2103006000	Combined	Stationary Source Fuel Combustion; Commercial/Institutional; Natural Gas; Total: Boilers and IC Engines

Table 4-50. Non-point Oil and Gas SCCs where RICE NSPS controls are applied

SCC	Lean/ Rich/ Combined	Product	Source Category	SCC_Description
2310000220	Combined	BOTH	EXPLORATION	Industrial Processes;Oil and Gas Exploration and Production;All Processes;Drill Rigs;;
2310000660	Combined	BOTH	EXPLORATION	Industrial Processes;Oil and Gas Exploration and Production;All Processes;Hydraulic Fracturing Engines;;
2310020600	Combined	NGAS	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;Natural Gas;Compressor Engines;;
2310021202	Lean	NGAS	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;On-Shore Gas Production;Natural Gas Fired 4Cycle Lean Burn Compressor Engines 50 To 499 HP;;
2310021251	Lean	NGAS	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;On-Shore Gas Production;Lateral Compressors 4 Cycle Lean Burn;;
2310021302	Rich	NGAS	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;On-Shore Gas Production;Natural Gas Fired 4Cycle Rich Burn Compressor Engines 50 To 499 HP;;
2310021351	Rich	NGAS	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;On-Shore Gas Production;Lateral Compressors 4 Cycle Rich Burn;;
2310023202	Lean	CBM	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;Coal Bed Methane Natural Gas;CBM Fired 4Cycle Lean Burn Compressor Engines 50 To 499 HP;;
2310023251	Lean	CBM	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;Coal Bed Methane Natural Gas;Lateral Compressors 4 Cycle Lean Burn;;
2310023302	Rich	CBM	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;Coal Bed Methane Natural Gas;CBM Fired 4Cycle Rich Burn Compressor Engines 50 To 499 HP;;
2310023351	Rich	CBM	PRODUCTION	Industrial Processes;Oil and Gas Exploration and Production;Coal Bed Methane Natural Gas;Lateral Compressors 4 Cycle Rich Burn;;
2310300220	Combined	NGAS	EXPLORATION	Industrial Processes;Oil and Gas Exploration and Production;All Processes - Conventional;Drill Rigs;;
2310400220	Combined	BOTH	EXPLORATION	Industrial Processes;Oil and Gas Exploration and Production;All Processes - Unconventional;Drill Rigs;;

Table 4-51. Point source SCCs in pt_oilgas sector where RICE NSPS controls applied

SCC	Lean, Rich, or Combined	SCCDESC
20200202	Combined	Internal Combustion Engines; Industrial; Natural Gas; Reciprocating
20200253	Rich	Internal Combustion Engines; Industrial; Natural Gas;4-cycle Rich Burn
20200254	Lean	Internal Combustion Engines; Industrial; Natural Gas;4-cycle Lean Burn
20200256	Combined	Internal Combustion Engines; Industrial; Natural Gas;4-cycle Clean Burn
20300201	Combined	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Reciprocating
31000203	Combined	Industrial Processes; Oil and Gas Production; Natural Gas Production; Compressors (See also 310003-12 and -13)

4.2.4.3 Fuel Sulfur Rules (nonpt)

Packets:

Control_2016_202X_MANEVU_Sulfur_fromMARAMA_v1_platform_22aug2022_nf_v1

The control packet for fuel sulfur rules is the same for all analytic years. Fuel sulfur rules controls are reflected for the following states: Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, Rhode Island, and Vermont. The fuel limits for these states are incremental starting after year 2012, but are fully implemented by July 1, 2018, in these states. The control packet representing these controls was updated by MARAMA for the 2016v1 platform. For 2018v2, states that had fully implemented their controls by 2017 were removed from the control packet (namely Delaware, New York, and Pennsylvania) because 2017 NEI was used for nonpoint emissions.

Summaries of the sulfur rules by state, with emissions reductions relative to the entire sector emissions and relative to the analytic year emissions for the affected SCCs are provided in Table 4-52, which reflects the impacts of the MARAMA packet only, as these reductions are not estimated in non-MARAMA states. A negligible amount of reductions occur in the pt_oilgas sector. Note that ptnonipm sources are not impacted in 2016v3 platform since the starting point for the analytic year emissions was the 2019 NEI.

Table 4-52. Summary of fuel sulfur rule impacts on nonpoint SO2 emissions for 2032

Pollutant	State	2032 pre-control Emissions (tons)	2032 post-control Emissions (tons)	Change in emissions (tons)	Percent change
NOX	Connecticut	3,356	3,112	-244	-7.3%
NOX	Maine	5,641	5,321	-320	-5.7%
NOX	Massachusetts	8,825	8,354	-472	-5.3%
NOX	New Hampshire	5,996	5,761	-235	-3.9%
NOX	Rhode Island	799	740	-59	-7.4%
NOX	Vermont	802	729	-73	-9.1%
NOX	**Six state total**	**25,419**	**24,017**	**-1,402**	**-5.5%**
SO2	Connecticut	1,313	79	-1,234	-94.0%
SO2	Maine	1,112	35	-1,078	-96.9%

Pollutant	State	2032 pre-control Emissions (tons)	2032 post-control Emissions (tons)	Change in emissions (tons)	Percent change
SO2	Massachusetts	2,090	83	-2,008	-96.0%
SO2	New Hampshire	3,797	19	-3,778	-99.5%
SO2	Rhode Island	336	38	-298	-88.7%
SO2	Vermont	368	25	-344	-93.3%
SO2	**Six state total**	**9,017**	**279**	**-8,739**	**-96.9%**
SO2	**ALL state total**	**167,825**	**159,086**	**-8,739**	**-5.2%**

4.2.4.4 Natural Gas Turbines NO_x NSPS (ptnonipm, pt_oilgas)

Packets:

Control_2018_2032_NG_Turbines_NSPS_pt_oilgas_for_2032gg_22sep2022_v0
Control_2026_2032_NG_Turbines_NSPS_ptnonipm_v2_platform_13aug2021_v0

For ptnonipm, the packet for 2032 was reused from the 2016v2 platform. For pt_oilgas, the packet for 2018v2 is based on updated growth information for that sector from state-historical production data and the AEO2022 production forecast database. The new growth factors were to calculate the new control efficiencies for all analytic year (2032). The control efficiency calculation methodology did not change from the 2016v3 modeling platform to the 2018v2 platform.

Natural Gas Turbines NSPS controls were generated based on examination of emission limits for stationary combustion turbines that are not in the power sector. In 2006, the EPA promulgated standards of performance for new stationary combustion turbines in 40 CFR part 60, subpart KKKK. The standards reflect changes in NOx emission control technologies and turbine design since standards for these units were originally promulgated in 40 CFR part 60, subpart GG. The 2006 NSPSs affecting NO_x and SO_2 were established at levels that bring the emission limits up-to-date with the performance of current combustion turbines. Stationary combustion turbines were also regulated by the NOx State Implementation Plan (SIP) Call, which required affected gas turbines to reduce their NOx emissions by 60 percent. Table 4-53 compares the 2006 NSPS emission limits with the NO_x Reasonably Available Control Technology (RACT) regulations in selected states within the NO_x SIP Call region. More information on the NOx SIP call is available at: https://www.epa.gov/csapr/final-update-nox-sip-call-regulations-emissions-monitoring-provisions-state-implementation. The state NO_x RACT regulations summary (Pechan, 2001) is from a year 2001 analysis, so some states may have updated their rules since that time.

Table 4-53. Stationary gas turbines NSPS analysis and resulting emission rates used to compute controls

NOx Emission Limits for New Stationary Combustion Turbines				
Firing Natural Gas	<50 MMBTU/hr	50-850 MMBTU/hr	>850 MMBTU/hr	
Federal NSPS	100	25	15	ppm
State RACT Regulations	5-100 MMBTU/hr	100-250 MMBTU/hr	>250 MMBTU/hr	

NOx Emission Limits for New Stationary Combustion Turbines				
Connecticut	225	75	75	ppm
Delaware	42	42	42	ppm
Massachusetts	65*	65	65	ppm
New Jersey	50*	50	50	ppm
New York	50	50	50	ppm
New Hampshire	55	55	55	ppm
* Only applies to 25-100 MMBTU/hr				
Notes: The above state RACT table is from a 2001 analysis. The current NY State regulations have the same emission limits.				
New source emission rate (Fn)			NO_X ratio (Fn)	Control (%)
NOx SIP Call states plus CA	= 25 / 42 =		0.595	40.5%
Other states	= 25 / 105 =		0.238	76.2%

For control factor development, the existing source emission ratio was set to 1.0 for combustion turbines. The new source emission ratio for the NOx SIP Call states and California is the ratio of state NOx emission limit to the Federal NSPS. A complicating factor in the above is the lack of size information in the stationary source SCCs. Plus, the size classifications in the NSPS do not match the size differentiation used in state air emission regulations. We accepted a simplifying assumption that most industrial applications of combustion turbines are in the 100-250 MMBtu/hr size range and computed the new source emission rates as the NSPS emission limit for 50-850 MMBtu/hr units divided by the state emission limits. We used a conservative new source emission ratio by using the lowest state emission limit of 42 ppmv (Delaware). This yields a new source emission ratio of 25/42, or 0.595 (40.5 percent reduction) for states with existing combustion turbine emission limits. States without existing turbine NOx limits would have a lower new source emission ratio: the uncontrolled emission rate (105 ppmv via AP-42) divided into 25 ppmv = 0.238 (76.2 percent reduction). This control was then plugged into Equation 4-2 as a function of the year-specific projection factor. Also, Natural Gas Turbines control factors supplied by MARAMA were used within the MARAMA region for 2032. The Natural Gas Turbines control packet for pt_oilgas also includes additional controls for the EPNG Williams facility in Arizona, in order to reduce the post-control facility total of 584.77 tons/yr NOx.

Table 4-54 shows the reduction in NOx emissions after the application of the Natural Gas Turbines NSPS CONTROL packet and include emissions both inside and outside the MARAMA region. Table 4-55 and Table 4-56 list the point source SCCs for which Natural Gas Turbines NSPS controls were applied.

Table 4-54. Emissions reductions due to the Natural Gas Turbines NSPS

Sector	Year	Pollutant	2026gf (tons)	Emissions reduction (tons)	% change
ptnonipm	2032	NOX	860,031	-726	-0.08%
pt_oilgas	2032	NOX	424,313	-13,984	-3.3%

Table 4-55. SCCs in ptnonipm for which Natural Gas Turbines NSPS controls were applied

SCC	SCC Description
20200201	Internal Combustion Engines; Industrial; Natural Gas; Turbine
20200203	Internal Combustion Engines; Industrial; Natural Gas; Turbine: Cogeneration

SCC	SCC Description
20200209	Internal Combustion Engines; Industrial; Natural Gas; Turbine: Exhaust
20200701	Internal Combustion Engines; Industrial; Process Gas; Turbine
20200714	Internal Combustion Engines; Industrial; Process Gas; Turbine: Exhaust
20300203	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine: Cogeneration

Table 4-56. SCCs in pt_oilgas for which Natural Gas Turbines NSPS controls were applied

SCC	**SCC description**
20200201	Internal Combustion Engines; Industrial; Natural Gas; Turbine
20200209	Internal Combustion Engines; Industrial; Natural Gas; Turbine: Exhaust
20300202	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine
20300209	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine: Exhaust
20200203	Internal Combustion Engines; Industrial; Natural Gas; Turbine: Cogeneration
20200714	Internal Combustion Engines; Industrial; Process Gas; Turbine: Exhaust
20300203	Internal Combustion Engines; Commercial/Institutional; Natural Gas; Turbine: Cogeneration

4.2.4.5 Process Heaters NO_x NSPS (ptnonipm, pt_oilgas)

Packets:

Control_2018_2032_Process_Heaters_NSPS_pt_oilgas_for_2032gg_22sep2022_v0
Control_2026_2032_Process_Heaters_NSPS_ptnonipm_v2_platform_13aug2021_v0

For ptnonipm, the packet for 2026 to 2032 was reused from the 2016v2 platform. For pt_oilgas, the packets were newly developed for 2018v2 based on updated information.

Process heaters are used throughout refineries and chemical plants to raise the temperature of feed materials to meet reaction or distillation requirements. Fuels are typically residual oil, distillate oil, refinery gas, or natural gas. In some sense, process heaters can be considered as emission control devices because they can be used to control process streams by recovering the fuel value while destroying the VOC. The criteria pollutants of most concern for process heaters are NO_x and SO_2. In 2018, it is assumed that process heaters have not been subject to regional control programs like the NOx SIP Call, so most of the emission controls put in-place at refineries and chemical plants have resulted from RACT regulations that were implemented as part of SIPs to achieve ozone NAAQS in specific areas, and refinery consent decrees. The boiler/process heater NSPS established NOx emission limits for new and modified process heaters. These emission limits are displayed in Table 4-57.

Table 4-57. Process Heaters NSPS analysis and 2018v2 new emission rates used to estimate controls

NO_X emission rate Existing PPMV (=Fe)	**Natural Draft (fraction)**	**Forced Draft (fraction)**	**Average**
80	0.4	0	
100	0.4	0.5	
150	0.15	0.35	
200	0.05	0.1	
240	0	0.05	

Cumulative, weighted (=Fe)	104.5	134.5	119.5
NSPS Standard	40	60	
New Source NO_X ratio (=Fn)	0.383	0.446	**0.414**
NSPS Control (%)	61.7	55.4	58.6

For computations, the existing source emission ratio (Fe) was set to 1.0. The computed (average) NO_x emission factor ratio for new sources (Fn) is 0.41 (58.6 percent control). The retirement rate is the inverse of the expected unit lifetime. There is limited information in the literature about process heater lifetimes. This information was reviewed at the time that the Western Regional Air Partnership (WRAP) developed its initial regional haze program emission projections, and energy technology models used a 20-year lifetime for most refinery equipment. However, it was noted that in practice, heaters would probably have a lifetime that was on the order of 50 percent above that estimate. Therefore, a 30-year lifetime was used to estimate the effects of process heater growth and retirement. This yields a 3.3 percent retirement rate. This control was then plugged into Equation 4-2 as a function of the year-specific projection factor.

The impact on emissions from applying the process heaters NSPS is shown in Table 4-58. Table 4-59 and Table 4-60 list the point source SCCs for which the Process Heaters NSPS controls were applied.

Table 4-58. Emissions reductions due to the application of the Process Heaters NSPS

Sector	Year	Pollutant	2026gf (tons)	Emissions reduction (tons)	% change
ptnonipm	2032	NOX	860,031	-5,923	-0.7%
pt_oilgas	2032	NOX	424,313	-2,224	-0.5%

Table 4-59. SCCs in ptnonipm for which Process Heaters NSPS controls were applied

SCC	SCC Description*
30190003	IP; Chemical Manufacturing; Fuel Fired Equipment; Process Heater: Natural Gas
30190004	IP; Chemical Manufacturing; Fuel Fired Equipment; Process Heater: Process Gas
30590002	IP; Mineral Products; Fuel Fired Equipment; Residual Oil: Process Heaters
30590003	IP; Mineral Products; Fuel Fired Equipment; Natural Gas: Process Heaters
30600101	IP; Petroleum Industry; Process Heaters; Oil-fired
30600102	IP; Petroleum Industry; Process Heaters; Gas-fired
30600103	IP; Petroleum Industry; Process Heaters; Oil
30600104	IP; Petroleum Industry; Process Heaters; Gas-fired
30600105	IP; Petroleum Industry; Process Heaters; Natural Gas-fired
30600106	IP; Petroleum Industry; Process Heaters; Process Gas-fired
30600107	IP; Petroleum Industry; Process Heaters; Liquified Petroleum Gas (LPG)
30600199	IP; Petroleum Industry; Process Heaters; Other Not Classified
30990003	IP; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Process Heaters
31000401	IP; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000402	IP; Oil and Gas Production; Process Heaters; Residual Oil
31000403	IP; Oil and Gas Production; Process Heaters; Crude Oil
31000404	IP; Oil and Gas Production; Process Heaters; Natural Gas
31000405	IP; Oil and Gas Production; Process Heaters; Process Gas

SCC	SCC Description*
31000406	IP; Oil and Gas Production; Process Heaters; Propane/Butane
31000413	IP; Oil and Gas Production; Process Heaters; Crude Oil: Steam Generators
31000414	IP; Oil and Gas Production; Process Heaters; Natural Gas: Steam Generators
31000415	IP; Oil and Gas Production; Process Heaters; Process Gas: Steam Generators
39900501	IP; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Distillate Oil
39900601	IP; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Natural Gas
39990003	IP; Miscellaneous Manufacturing Industries; Miscellaneous Manufacturing Industries; Natural Gas: Process Heaters

* IP = Industrial Processes

Table 4-60. SCCs in pt_oilgas for which Process Heaters NSPS controls were applied

SCC	SCC Description
30190003	Industrial Processes; Chemical Manufacturing; Fuel Fired Equipment; Process Heater: Natural Gas
30600102	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600104	Industrial Processes; Petroleum Industry; Process Heaters; Gas-fired
30600105	Industrial Processes; Petroleum Industry; Process Heaters; Natural Gas-fired
30600106	Industrial Processes; Petroleum Industry; Process Heaters; Process Gas-fired
30600199	Industrial Processes; Petroleum Industry; Process Heaters; Other Not Classified
30990003	Industrial Processes; Fabricated Metal Products; Fuel Fired Equipment; Natural Gas: Process Heaters
31000401	Industrial Processes; Oil and Gas Production; Process Heaters; Distillate Oil (No. 2)
31000402	Industrial Processes; Oil and Gas Production; Process Heaters; Residual Oil
31000403	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil
31000404	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas
31000405	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas
31000413	Industrial Processes; Oil and Gas Production; Process Heaters; Crude Oil: Steam Generators
31000414	Industrial Processes; Oil and Gas Production; Process Heaters; Natural Gas: Steam Generators
31000415	Industrial Processes; Oil and Gas Production; Process Heaters; Process Gas: Steam Generators
39900501	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Distillate Oil
39900601	Industrial Processes; Miscellaneous Manufacturing Industries; Process Heater/Furnace; Natural Gas

4.2.4.6 Ozone Transport Commission Rules (np_solvents)

Packets:

Control_2016_202X_solvents_OTC_v3_platform_MARAMA_14sep2022_nf_v1

Several MARAMA states have adopted rules reflecting the recommendations of the Ozone Transport Commission (OTC) for reducing VOC emissions from consumer products, architectural and industrial maintenance coatings, and various other solvents. The rules affected 27 different SCCs in the surface coatings (2401xxxxxx), degreasing (2415000000), graphic arts (2425010000), miscellaneous industrial (2440020000), and miscellaneous non-industrial consumer and commercial (246xxxxxxx) categories. The packet applies only to MARAMA states and not all states adopted all rules. This packet applies to emissions in the np_solvents sector. The new SCCs in the solvents sector were added to the packet.

The OTC also developed a model rule to address VOC emissions from portable fuel containers (PFCs) via performance standards and phased-in PFC replacement that was implemented in two phases. Some states adopted one or both phases of the OTC rule, while others relied on the Federal rule. MARAMA calculated control factors to reflect each state's compliance dates and, where states implemented one or both phases of the OTC requirements prior to the Federal mandate, accounted for the early reductions in the control factors. The rules affected permeation, evaporation, spillage, and vapor displacement for residential (2501011xxx) and commercial (2501012xxx) portable gas can SCCs. This packet applies to the nonpt sector.

MARAMA provided control packets to apply the solvent and PFC rule controls. The 2018v2 OTC packet is based on the packet from the 2016v3 platform, except with controls enacted prior to 2018 (and therefore already reflected in the base year inventory) removed from the packet.

4.2.4.7 Good Neighbor Plan 2015 Ozone NAAQS (ptnonipm, pt_oilgas)

The Good Neighbor Plan for the 2015 ozone NAAQS includes NOx controls for both EGU and non-EGU sources. The regulation ensures that 23 states meet the Clean Air Act's "Good Neighbor" requirements by reducing pollution that significantly contributes to problems attaining and maintaining EPA's health-based air quality standard for ground-level ozone (or "smog"), known as the 2015 Ozone National Ambient Air Quality Standards (NAAQS), in downwind states. The estimated impact of the rule on the non-EGUs modeled in this study is reflect in Table 4-61.

Table 4-61. NOx emissions reductions after application of Good Neighbor Plan control packet

Year	Sector	Pollutant	Uncontrolled Emissions	Emissions Reductio (tons/yr)n	% change
2032	ptnonipm	NOX	90,630	-36,417	-40.2%
2032	pt_oilgas	NOX	51,408	-10,315	-20.1%

4.3 Sectors with Projections Computed Outside of CoST

Projections for sectors not calculated using CoST are discussed in this section.

4.3.1 Nonroad Mobile Equipment Sources (nonroad)

Outside of California and Texas, the MOVES3 model (version 3.0.3) was run for 2032. The fuels used are specific to the analytic year, but the meteorological data represented the year 2018. The 2032 nonroad emissions include all nonroad control programs finalized as of the date of the MOVES3.0.3 release, including most recently:

- Emissions Standards for New Nonroad Spark-Ignition Engines, Equipment, and Vessels: October 2008 (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-nonroad-spark-ignition);
- Growth and control from Locomotives and Marine Compression-Ignition Engines Less than 30 Liters per Cylinder: March 2008 (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-locomotive); and
- Clean Air Nonroad Diesel Final Rule – Tier 4: May 2004 (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-emissions-air-pollution-nonroad-diesel).

The resulting analytic year inventories were processed into the format needed by SMOKE in the same way as the base year emissions.

Inside California and Texas, CARB and TCEQ provided separate datasets for various analytic years. For 2018v2, CARB provided new nonroad inventories for 2032. In Texas, a 2026 nonroad inventory was interpolated from TCEQ-provided 2023 and 2028 inventories, and then the interpolated 2026 emissions were projected to 2032 using 2026-to-2032 trends calculated from MOVES3 emissions in Texas. VOC and $PM_{2.5}$ by speciation profile, and VOC HAPs, were added to all analytic year California and Texas nonroad inventories using the same procedure as for the 2018 inventory, but based on the analytic year MOVES runs instead of the 2018 MOVES run.

4.3.2 Onroad Mobile Sources (onroad)

For 2018v2, MOVES3 was run for 2032 to obtain onroad emission factors that account for the impact of on-the-books rules that are implemented into MOVES3. These include regulations such as:

- Safer Affordable Fuel Efficient (SAFE) Vehicles Final Rule for Model Years 2021-2026 (March 2020);
- Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles – Phase 2 (October 2016);
- Tier 3 Vehicle Emission and Fuel Standards Program (March 2014) (https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-control-air-pollution-motor-vehicles-tier-3);
- 2017 and Later Model Year Light-Duty Vehicle GHG Emissions and Corporate Average Fuel Economy Standards (October 2012);
- Greenhouse Gas Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (September 2011);
- Regulation of Fuels and Fuel Additives: Modifications to Renewable Fuel Standard Program (RFS2) (December 2010); and
- Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Final Rule for Model-Year 2012-2016 (May 2010).

Local inspection and maintenance (I/M) and other onroad mobile programs are included such as: California LEVIII, the National Low Emissions Vehicle (LEV) and Ozone Transport Commission (OTC); LEV regulations, local fuel programs, and Stage II refueling control programs. Note that MOVES3 emission rates for model years 2017 and beyond are equivalent to CA LEVIII rates for NOx and VOC. Therefore, it was not necessary to update the rates used for states that have adopted the rules in 2020 or later years.

An update in 2018v2 was to apply adjustment factors to reflect the impacts of the light duty greenhouse gas rule finalized in the Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards, 86 FR 74434 (December 30, 2021).[27] The adjustment factors that reflect the impacts of the rule on CAPs are shown in Table 4-62. These adjustment factors are intended to represent not only

[27] https://www.govinfo.gov/content/pkg/FR-2021-12-30/pdf/2021-27854.pdf.

the effects of the rule on onroad emissions in 2032, but also ancillary effects on stationary emissions such as increased electricity production for electric vehicles.

Table 4-62. Light duty greenhouse gas rule adjustments for 2032 onroad emissions

Year	Source Type	Fuel Type	CO	VOC	NOx	SO2	PM
2032	Light Truck	Diesel	-13.36%	-35.97%	-27.45%	-31.63%	-50.52%
2032	Light Truck	E85	+0.74%	-0.56%	+1.79%	+119.02%	+3.97%
2032	Light Truck	Gasoline	-0.67%	-10.50%	+1.59%	+169.88%	+0.06%
2032	Passenger Car	Diesel	+2.02%	+2.70%	+6.44%	+351.16%	+6.92%
2032	Passenger Car	E85	+1.89%	+3.21%	+7.61%	+540.54%	+12.99%
2032	Passenger Car	Gasoline	-1.60%	-14.14%	-3.66%	+63.41%	-10.14%

The 2032 emission factors for 2018v2 are the same as those from 2016v2 platform, with the following exceptions. For 2018v2, MOVES3 was run for combination long haul trucks only for 2032 using an updated age distribution, and the resulting emission factors were used. For 2018v2, representative county assignments were adjusted in three North Carolina counties (Lee, Onslow, and Rockingham) to reflect changes in inspection and maintenance programs in those counties. Also, to reflect changes in inspection and maintenance programs in Tennessee, MOVES was rerun for three representative counties in that state (Davidson, Hamilton, and Rutherford).

The fuels used are specific to each analytic year, the age distributions were projected to the analytic year, and the meteorological data represented the year 2018. The resulting emission factors were combined with analytic year activity data using SMOKE-MOVES run in a similar way as the base year. The development of the analytic year activity data is described later in this section. CARB provided separate emissions datasets for each analytic year. The CARB-provided emissions for 2032 were adjusted to match the temporal and spatial patterns of the SMOKE-MOVES based emissions.

Analytic year 2032 VMT was developed as follows:

- VMT were projected from 2018 to 2019 using VMT data from the FHWA county-level VM-2 reports. At the time of this study, these reports were available for each year up through 2019. EPA calculated county-road type factors based on FHWA VM-2 county-level data for 2018 to 2019, and county total factors were applied instead of county-road factors in states with significant changes in road type classifications from year to year.
- Total VMT were held flat from 2019 to 2021 to reflect impacts from the COVID-19 pandemic. For 2021, VMT was re-split by fuel type according to fuel splits from the 2020NEI VMT. During this step, VMT totals by county, source type, and road type were preserved, but fuel splits from 2020NEI were applied and the percentage of electric vehicles increased as a result.
- VMT were then projected from 2021 to 2032 using AEO2022.

Annual VMT data from the AEO2022 reference case by fuel and vehicle type were used to project VMT from 2021 to the projection years. Specifically, the following two AEO2022 tables were used:

- Light Duty (LD): Light-Duty VMT by Technology Type (table #41): https://www.eia.gov/outlooks/aeo/data/browser/#/?id=51-AEO2022&sourcekey=0

- Heavy Duty (HD): Freight Transportation Energy Use (table #49): https://www.eia.gov/outlooks/aeo/data/browser/#/?id=58-AEO2022&cases=ref2022~aeo2020ref&sourcekey=0

To develop the VMT projection factors, total VMT for each MOVES fuel and vehicle grouping was calculated for the years 2021 and 2032 based on the AEO-to-MOVES mappings above. From these totals, 2021-2032 VMT trends were calculated for each fuel and vehicle grouping. Those trends became the national VMT projection factors. The AEO2022 tables include data starting from the year 2021. MOVES fuel and vehicle types were mapped to AEO fuel and vehicle classes. The resulting 2021-to-analytic year national VMT projection factors used for the 2018v2 platform are provided in Table 4-63. These factors were adjusted to prepare county-specific projection factors for light duty vehicles based on human population data available from the BenMAP model by county for the years 2021 and 2032[28] (https://www.woodsandpoole.com/, circa 2015). The purpose of this adjustment based on population changes helps account for areas of the country that are growing more than others.

Table 4-63. Factors used to Project VMT to analytic years

SCC6	description	2021 to 2032 factor
220111	LD gas	1.187
220121	LD gas	1.187
220131	LD gas	1.187
220132	LD gas	1.187
220141	Buses gas	1.296
220142	Buses gas	1.296
220143	Buses gas	1.296
220151	MHD gas	1.296
220152	MHD gas	1.296
220153	MHD gas	1.296
220154	MHD gas	1.296
220161	HHD gas	0.486
220221	LD diesel	1.221
220231	LD diesel	1.221
220232	LD diesel	1.221
220241	Buses diesel	1.131
220242	Buses diesel	1.131
220243	Buses diesel	1.131
220251	MHD diesel	1.131
220252	MHD diesel	1.131
220253	MHD diesel	1.131
220254	MHD diesel	1.131
220261	HHD diesel	1.077
220262	HHD diesel	1.077
220341	Buses CNG	1.108
220342	Buses CNG	1.108
220343	Buses CNG	1.108

[28] The final year of the population dataset used is 2030, and so 2030 population was used to represent 2032.

SCC6	description	2021 to 2032 factor
220351	MHD CNG	1.108
220352	MHD CNG	1.108
220353	MHD CNG	1.108
220354	MHD CNG	1.108
220361	HHD CNG	1.046
220521	LD E-85	0.746
220531	LD E-85	0.746
220532	LD E-85	0.746
220921	LD Electric	6.707
220931	LD Electric	6.707
220932	LD Electric	6.707

Analytic year VPOP data were projected using calculations of VMT/VPOP ratios for each county, based on 2017 NEI with MOVES3 fuels splits. Those ratios were then applied to the analytic year projected VMT to estimate analytic year VPOP. Both VMT and VPOP were redistributed between the light duty car and truck vehicle types (21/31/32) based on light duty vehicle splits from the EPA computed default projection.

Hoteling hours were projected to the analytic years by calculating 2018v2 inventory HOTELING/VMT ratios for each county for combination long-haul trucks on restricted roads only. Those ratios were then applied to the analytic year projected VMT for combination long-haul trucks on restricted roads to calculate analytic year hoteling. Some counties had hoteling activity but did not have combination long-haul truck restricted road VMT in 2018v2; in those counties, the national AEO-based projection factor for diesel combination trucks was used to project 2018v2 hoteling to the analytic years. This procedure gives county-total hoteling for the analytic years. Each analytic year also has a distinct APU percentage based on MOVES input data that was used to split county total hoteling to each SCC; for 2032, the APU percentage is 31.72%.

Analytic year starts were calculated using 2018v2-based VMT ratios:

Analytic year STARTS = Analytic year VMT * (2018 STARTS / 2018 VMT by county+SCC6)

Analytic year ONI activity was calculated using a similar formula:

Analytic year ONI = Analytic year VMT * (2018 ONI / 2018 VMT by county+SCC6)

In California, onroad emissions in SMOKE-MOVES are adjusted to match CARB-provided data using the same procedure described in Section 2.3.3. For 2018v2 platform, CARB provided new EMFAC emissions for 2032.

4.3.3 Sources Outside of the United States (onroad_can, onroad_mex, othpt, canada_ag, canada_og2D, ptfire_othna, othar, othafdust, othptdust)

This section discusses the projection of emissions from Canada and Mexico. Information about the base year inventory used for these projections or the naming conventions can be found in Section 2.7. The Canada and Mexico projections for 2032 are mostly the same as those in the 2016v2 platform, except with new SMOKE runs which map the emissions to 2018 calendar dates. The 2016v2 platform and 2018v2 platform use similar base year inventories in Canada and Mexico, allowing the previously generated 2032 projections from 2016v2 platform to be reused for this study.

For the 2016v1 platform, ECCC provided data from which Canadian analytic year projections could be derived. These data includes emissions for 2015, 2023, and 2028 by pollutant, province, ECCC sub-class code, and other source categories. ECCC sub-class codes are present in most Canadian inventories and are similar to SCC, but more detailed for some types of sources and less detailed for other types of sources. For most Canadian inventories, 2028 emissions inventories were projected from the 2016v2 base year inventory using projection factors based on the ECCC sub-class level data from the 2016v1 platform, except with the 2015-to-2028 trend reduced to a 2016-to-2028 trend (i.e., reduce the total change by 1/13). Some Canadian emissions inventories then received an additional projection from 2028 to 2032, with methodology for the 2032 projections varying by sector. Exceptions to this general procedure are noted below. For example, ECCC sub-class level data could not be used to project inventories where the sub-class codes changed from 2016v1 to 2016v2. Fire emissions in Canada and Mexico in the ptfire_othna sector were not projected.

4.3.3.1 Canadian fugitive dust sources (othafdust, othptdust)

Canadian area source dust (othafdust)

For Canadian area source dust sources, ECCC sub-class level data from 2016v1 platform was used to project the 2016v2 base year inventory to 2028, and emissions from 2028 were used to represent the year 2032. As with the base year, the analytic year dust emissions are pre-adjusted, so analytic year othafdust follows the same emissions processing methodology as the base year with respect to the transportable fraction and meteorological adjustments.

Canadian point source dust (othptdust)

For this study, the base year emissions from the othptdust sector were held flat from the base year to the analytic year.

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

Canada point agriculture and oil and gas emissions

For Canadian agriculture and upstream oil and gas sources, ECCC sub-class level data from 2016v1 platform was used to project the 2016v2 base year inventory to 2028, which was then used to represent the year 2032. This procedure was applied to the entire canada_ag and canada_og2D sectors, and to the oil and gas elevated point source inventory in the othpt sector. For the ag inventories, the sub-class codes are similar in detail to SCCs: fertilizer has a single sub-class code, and animal emissions categories (broilers, dairy, horses, sheep, etc) each have a separate sub-class code.

Airports and other Canada point sources

For the Canada airports inventory in the othpt sector, projection factors to 2028 were based on total airport emissions from the 2016v1 Canada inventory by province and pollutant. 2028 emissions were then used to represent 2032.

During the development of the 2016v1 platform, analytic year projections for stationary point sources (excluding ag) were provided by ECCC for 2023 and 2028 rather than calculated by way of ECCC sub-class code data. Additionally, projection information for many sub-class codes in the 2016v2 base year stationary point inventories was not available in the 2016v1 sub-class code data. Therefore, sub-class code data was not used to project stationary point sources, and instead, those sources were projected using factors based on total stationary (excluding ag and upstream oil and gas) point source emissions from 2016v1 platform for 2015 and 2028, by province and pollutant. This is the same procedure that was used for airports, except using different projection factors based on only the stationary sources. 2028 emissions were used to represent 2032 for these point sources.

Mexico

The othpt sector includes a general point source inventory in Mexico which was updated for 2016v2 platform. Similar to the procedure for projecting Canadian stationary point sources, factors for projecting from 2016 to 2028 were calculated from the 2016v1 platform Mexico point source inventories by state and pollutant and were then applied to the updated base year inventory to create a 2028 point source inventory. Mexico point source emissions for 2028 were used to represent 2032.

4.3.3.3 Nonpoint sources in Canada and Mexico (othar)

Canadian stationary sources

For 2016v1 platform, analytic year projections for stationary area sources in Canada were provided by ECCC for 2023 and 2028 rather than calculated by way of ECCC sub-class code data. Additionally, projection information for many sub-class codes in the 2016v2 base year stationary area source inventory was not available in the 2016v1 sub-class code data. Therefore, sub-class code data was not used to project stationary area sources, and instead, those sources were projected using factors based on total stationary area source emissions from 2016v1 platform for 2015 and 2028, by province and pollutant. This is the same procedure that was used for airports and stationary point sources, except using different projection factors based on only the stationary area sources.

For 2016v1 platform, ECCC provided an additional stationary area source inventory for 2028 representing electric power generation (EPG). According to ECCC, this inventory's emissions do not double count the 2028 point source inventories, and it is appropriate to include this area source EPG inventory in the othar sector as an additional standalone inventory in the analytic years. Therefore, the 2016v1 platform area source EPG inventory was included in the 2018v2 platform analytic year case, with 2028 emissions used to represent 2032.

Canadian mobile sources

Projection information for mobile nonroad sources, including rail and CMV, is covered by the ECCC sub-class level data for 2015 and 2028. ECCC sub-class level data from 2016v1 platform was used to project the 2016v2 base year inventory to 2028. For the nonroad inventory, the sub-class code is analogous to the SCC7 level in U.S. inventories. For example, there are separate sub-class codes for fuels (e.g., 2-stroke gasoline, diesel, LPG) and nonroad equipment sector (e.g., construction, lawn and garden, logging, recreational marine) but not for individual vehicle types within each category (e.g., snowmobiles, tractors). For rail, the sub-class code is closer to full SCCs in the NEI.

Instead of using 2028 mobile source emissions to represent 2032, additional projections out to 2032 were applied to the Canada nonroad and rail inventories. For nonroad, national projection factors by fuel, nonroad equipment sector, and pollutant were calculated from the 2016v2 platform US MOVES runs for

2026 and 2032 (excluding California and Texas for which we did not use MOVES data) and applied to the interpolated 2026 Canada nonroad inventory from 2016v2 platform. The 2026 Canada nonroad inventory was used as the baseline for the 2032 projection rather than 2028, because we did not have a MOVES run for 2028 which is consistent with the 2026 and 2032 MOVES3 runs performed for 2016v2 platform. For rail, factors for projecting 2026 Canadian rail from 2016v2 platform to 2032 were the same as the factors used to project US rail emissions from 2026 to 2030 (used to represent 2032) in that platform, which was based on the 2018 AEO.

Mexico

The othar sector includes two Mexico inventories, a stationary area source inventory and a nonroad inventory. Similar to point, factors for projecting the 2016v2 base year inventories to 2028 were calculated from the 2016v1 platform Mexico area and nonroad inventories by state and pollutant. Separate projections were calculated for the area and nonroad inventories. 2028 emissions were used to represent 2032, including for nonroad (unlike in Canada).

4.3.3.4 Onroad sources in Canada and Mexico (onroad_can, onroad_mex)

For Canadian mobile onroad sources, projection information is covered by the ECCC sub-class level data for 2015, 2023, and 2028. ECCC sub-class level data from 2016v1 platform was used to project the 2016v2 base year inventory to 2028. For the onroad inventory, the sub-class code is analogous to the SCC6+process level in U.S. inventories, in that it specifies fuel type, vehicle type, and process (e.g., brake, tire, exhaust, refueling), but not road type.

Instead of using 2028 mobile source emissions to represent 2032, additional projections out to 2032 were applied to the Canada onroad inventory. National projection factors distinguishing gas from diesel, light duty from heavy duty, refueling from non-refueling, and pollutant were calculated from the 2016v2 platform US MOVES runs for 2026 and 2032 (excluding California for which we did not use MOVES data) and applied to the interpolated 2026 Canada onroad inventory. The 2026 Canada onroad inventory was used as the baseline for the 2032 projection rather than 2028, because we did not have a MOVES3 run for 2028 which is consistent with the 2026 and 2032 MOVES runs performed for 2016v2 platform.

For Mexican mobile onroad sources, MOVES-Mexico was run to create emissions inventories for years 2028 and 2035, with 2032 emissions interpolated between 2028 and 2035. The 2035 MOVES-Mexico run included diesel refueling whereas 2028 did not; thus diesel refueling emissions were excluded from the 2032 interpolation.

5 Emission Summaries

Table 5-1 and Table 5-2 summarize annual emissions by sector for the 2018gg and 2032gg2 cases 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. Table 5-3 provides similar summaries for the 36-km domain (36US3) for 2018 only, as boundary conditions based on 2018 emissions were also used in 2032. 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 how far north and south the grids extend. Note that 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 afdust emissions in the 36km domain are smaller than those in the 12km domain due to how the adjustment factors are computed and the size of the grid cells. The onroad sector totals are post-SMOKE-MOVES totals, representing air quality model-ready emission totals, and include CARB emissions for California. The cmv sectors include U.S. emissions within state waters only; these extend to roughly 3-5 miles offshore and include CMV emissions at U.S. ports. "Offshore" represents CMV emissions that are outside of U.S. state waters. 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 2018v2 platform (https://gaftp.epa.gov/Air/emismod/2018/v2/reports).

Table 5-1. National by-sector CAP emissions for the 2018gg case, 12US1 grid (tons/yr)

Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
afdust_adj				5,691,832	789,322		
airports	489,039	0	131,779	9,813	8,576	16,492	54,939
cmv_c1c2	24,431	86	168,566	4,622	4,480	655	6,674
cmv_c3	15,068	42	114,722	2,380	2,189	4,891	9,311
fertilizer		1,636,229					
livestock		2,582,189					226,398
nonpt	1,927,267	102,898	739,250	572,589	475,154	166,399	818,185
nonroad	10,473,047	1,925	988,078	96,182	90,714	1,372	1,016,057
np_oilgas	661,167	38	668,403	12,669	12,508	55,360	2,414,209
np_solvents	36	58	34	469	448	5	2,336,842
onroad	17,043,371	103,249	2,827,564	207,714	88,309	22,628	1,172,608
pt_oilgas	200,740	434	385,649	13,663	13,047	39,003	232,995
ptagfire	421,836	93,685	17,935	59,968	38,050	7,451	63,726
ptegu	573,335	21,576	1,143,179	157,107	127,072	1,314,836	32,612
ptfire-rx	10,873,070	177,629	182,473	1,168,800	1,001,912	91,868	2,617,765
ptfire-wild	10,275,916	168,798	147,585	1,051,942	891,476	79,478	2,426,465
ptnonipm	1,378,771	60,793	894,993	388,475	242,515	561,234	766,021
rail	117,171	365	570,969	15,494	15,005	727	24,947
rwc	2,160,529	16,413	34,093	300,139	299,278	7,988	323,969
beis	3,902,690		974,463				25,755,648
Con. U.S. Total + beis	**60,537,483**	**4,966,406**	**9,989,734**	**9,753,858**	**4,100,054**	**2,370,387**	**40,299,369**
Can./Mex./Offshore							
Sector	**CO**	**NH3**	**NOX**	**PM10**	**PM2_5**	**SO2**	**VOC**
Canada ag		492,798					105,145
Canada oil and gas 2D	666	7	3,232	185	185	3,933	509,228
Canada othafdust				580,703	90,421		
Canada othar	2,182,369	3,815	306,078	223,090	174,668	16,318	725,957
Canada onroad_can	1,661,932	7,156	331,485	23,592	11,282	1,531	134,046
Canada othpt	1,115,125	19,472	650,660	90,023	43,036	989,829	148,163
Canada othptdust				132,266	46,401		
Canada ptfire_othna	4,679,983	93,406	195,209	671,858	565,668	38,759	1,343,696
Canada CMV	11,104	37	96,622	1,716	1,594	2,941	5,409
Mexico othar	111,429	114,444	54,457	102,675	33,595	1,659	353,294
Mexico onroad_mex	1,821,182	2,918	447,430	15,744	11,158	6,638	159,185
Mexico othpt	140,473	1,168	182,265	50,809	35,368	368,023	37,066
Mexico ptfire_othna	438,065	8,465	17,524	57,762	49,343	3,612	126,265
Mexico CMV	0	0	0	0	0	0	0
Offshore cmv in Federal waters	34,428	133	292,670	7,437	6,886	29,127	16,779
Offshore cmv outside Federal waters	24,283	457	267,502	25,810	23,752	189,097	11,528
Offshore pt_oilgas	51,872	8	49,962	636	635	462	38,833
Non-U.S. Total	**12,272,911**	**744,285**	**2,895,097**	**1,984,306**	**1,093,993**	**1,651,929**	**3,714,595**

Table 5-2. National by-sector CAP emissions for the 2032gg2 case, 12US1 grid (tons/yr)

Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
afdust_adj				5,780,588	809,684		
airports	570,574	0	164,926	10,686	9,373	20,039	63,302
cmv_c1c2	25,299	50	97,145	2,695	2,611	374	3,779
cmv_c3	21,045	59	112,190	3,331	3,064	6,812	13,167
fertilizer		1,636,229					
livestock		2,741,401					239,799
nonpt	1,939,962	104,043	712,933	581,503	492,884	123,628	735,427
nonroad	11,602,438	2,249	565,879	53,184	49,329	1,127	827,539
np_oilgas	621,290	26	568,387	12,497	12,350	76,245	2,283,192
np_solvents	8,409,394	98,770	784,553	188,234	49,249	18,159	518,947
onroad	197,719	352	339,405	15,329	14,443	47,938	237,476
pt_oilgas	421,836	93,685	17,935	59,968	38,050	7,451	63,726
ptagfire	308,100	28,078	383,178	73,294	66,046	294,886	32,246
ptegu	10,873,070	177,629	182,473	1,168,800	1,001,912	91,868	2,617,765
ptfire-rx	10,275,916	168,798	147,585	1,051,942	891,476	79,478	2,426,465
ptfire-wild	1,393,746	68,428	847,781	377,960	240,155	501,935	757,877
ptnonipm	111,045	347	405,629	10,069	9,733	394	15,427
rail	2,091,084	16,135	35,602	290,785	289,904	7,223	318,652
rwc	38	65	38	527	503	6	2,524,685
beis	3,902,690		974,463				25,755,648
Con. U.S. Total + beis	**52,765,247**	**5,136,344**	**6,340,103**	**9,681,390**	**3,980,767**	**1,277,563**	**39,435,120**
Can./Mex./Offshore							
Sector	**CO**	**NH3**	**NOX**	**PM10**	**PM2_5**	**SO2**	**VOC**
Canada ag		667,454					104,909
Canada oil and gas 2D	510	7	1,205	136	136	3,703	470,211
Canada othafdust				711,618	110,490		
Canada other	2,204,204	3,696	224,546	214,031	155,763	16,178	753,048
Canada onroad_can	1,176,889	6,506	156,141	25,861	8,339	847	67,063
Canada othpt	1,169,373	23,880	456,857	77,938	46,049	868,773	163,728
Canada othptdust				132,266	46,401		
Canada ptfire_othna	4,679,983	93,406	195,209	671,858	565,668	38,759	1,343,696
Canada CMV	12,884	43	81,922	1,957	1,816	3,415	6,188
Mexico other	132,253	110,416	75,376	109,103	37,151	2,090	434,481
Mexico onroad_mex	1,595,367	4,193	383,169	20,996	14,140	9,390	173,311
Mexico othpt	136,038	1,524	209,202	66,914	46,178	306,258	51,730
Mexico ptfire_othna	438,065	8,465	17,524	57,762	49,343	3,612	126,265
Mexico CMV	0	0	0	0	0	0	0
Offshore cmv in Federal waters	47,504	177	244,007	9,995	9,221	42,425	23,002
Offshore cmv outside Federal waters	34,333	333	377,167	18,817	17,315	50,004	16,272
Offshore pt_oilgas	51,872	8	49,962	636	635	462	38,833
Non-U.S. Total	**11,679,275**	**920,109**	**2,472,288**	**2,119,885**	**1,108,644**	**1,345,918**	**3,772,736**

Table 5-3. National by-sector CAP emissions for the 2018gg case, 36US3 grid (tons/yr)

Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
afdust_adj				5,696,028	789,743		
airports	489,904	0	131,938	9,843	8,602	16,517	55,044
cmv_c1c2	24,434	86	168,585	4,623	4,480	655	6,674
cmv_c3	15,289	43	116,700	2,410	2,218	4,964	9,426
fertilizer		1,636,229					
livestock		2,582,191					226,399
nonpt	1,927,717	102,919	740,303	572,647	475,204	166,409	818,460
nonroad	10,477,852	1,925	988,242	96,215	90,744	1,372	1,016,923
np_oilgas	661,167	38	668,403	12,669	12,508	55,360	2,414,209
np_solvents	36	58	34	469	448	5	2,336,846
onroad	17,049,876	103,264	2,828,221	207,767	88,334	22,629	1,173,091
pt_oilgas	200,740	434	385,649	13,663	13,047	39,003	232,995
ptagfire	421,836	93,685	17,935	59,968	38,050	7,451	63,726
ptegu	573,370	21,576	1,143,369	157,110	127,073	1,314,836	32,616
ptfire-rx	10,873,070	177,629	182,473	1,168,800	1,001,912	91,868	2,617,765
ptfire-wild	10,275,916	168,798	147,585	1,051,942	891,476	79,478	2,426,465
ptnonipm	1,378,776	60,793	895,044	388,517	242,526	561,234	766,024
rail	117,171	365	570,969	15,494	15,005	727	24,947
rwc	2,184,698	16,441	34,564	301,273	300,412	8,062	324,549
beis	3,987,520		996,046				26,186,779
36US3 U.S. Total + beis	**60,659,372**	**4,966,472**	**10,016,061**	**9,759,438**	**4,101,784**	**2,370,572**	**40,732,937**
Can./Mex./Offshore							
Sector	**CO**	**NH3**	**NOX**	**PM10**	**PM2_5**	**SO2**	**VOC**
Canada ag		508,077					107,843
Canada oil and gas 2D	730	7	3,538	203	203	4,420	604,562
Canada othafdust				583,720	90,878		
Canada othar	2,342,203	4,111	340,782	236,933	186,083	17,052	763,150
Canada onroad_can	1,731,621	7,433	348,542	24,601	11,819	1,587	139,162
Canada othpt	1,378,449	21,382	831,679	102,194	50,204	1,123,746	203,319
Canada othptdust				129,213	45,052		
Canada ptfire_othna	7,465,807	151,948	311,054	1,066,014	902,171	61,148	2,114,343
Canada CMV	13,594	45	119,577	2,128	1,974	4,035	6,724
Mexico othar	1,638,884	574,281	216,199	451,850	243,750	12,232	1,546,910
Mexico onroad_mex	6,240,630	10,795	1,512,464	80,530	61,809	28,020	553,804
Mexico othpt	426,418	3,532	463,774	198,039	132,579	1,538,614	115,851
Mexico ptfire_othna	5,958,233	101,557	285,718	955,132	629,885	38,914	1,853,619
Mexico CMV	64,665	1	205,403	16,300	15,100	109,886	8,832
Offshore cmv in Federal waters	36,343	161	312,748	9,053	8,374	40,877	17,652
Offshore cmv outside Federal waters	91,453	1,236	1,040,036	95,917	88,271	709,026	41,730
Offshore pt_oilgas	51,872	8	49,962	636	635	462	38,833
Annual Total	**27,440,903**	**1,384,575**	**6,041,477**	**3,952,464**	**2,468,786**	**3,690,018**	**8,116,334**

6 References

Adelman, Z. 2012. *Memorandum: Fugitive Dust Modeling for the 2008 Emissions Modeling Platform*. UNC Institute for the Environment, Chapel Hill, NC. September 28, 2012.

Adelman, Z. 2016. *2014 Emissions Modeling Platform Spatial Surrogate Documentation*. UNC Institute for the Environment, Chapel Hill, NC. October 1, 2016. Available at https://gaftp.epa.gov/Air/emismod/2014/v1/spatial_surrogates/.

Adelman, Z., M. Omary, Q. He, J. Zhao and D. Yang, J. Boylan, 2012. "A Detailed Approach for Improving Continuous Emissions Monitoring Data for Regulatory Air Quality Modeling." Presented at the 2012 International Emission Inventory Conference, Tampa, Florida. Available from http://www.epa.gov/ttn/chief/conference/ei20/index.html#ses-5.

Appel, K.W., Napelenok, S., Hogrefe, C., Pouliot, G., Foley, K.M., Roselle, S.J., Pleim, J.E., Bash, J., Pye, H.O.T., Heath, N., Murphy, B., Mathur, R., 2018. Overview and evaluation of the Community Multiscale Air Quality Model (CMAQ) modeling system version 5.2. In Mensink C., Kallos G. (eds), Air Pollution Modeling and its Application XXV. ITM 2016. Springer Proceedings in Complexity. Springer, Cham. Available at https://doi.org/10.1007/978-3-319-57645-9_11.

Bash, J.O., Baker, K.R., Beaver, M.R., Park, J.-H., Goldstein, A.H., 2016. Evaluation of improved land use and canopy representation in BEIS with biogenic VOC measurements in California. Available from http://www.geosci-model-dev.net/9/2191/2016/.

BEA, 2012. "2013 Global Outlook projections prepared by the Conference Board in November 2012". U.S. Bureau of Economic Analysis. Available from: http://www.conference-board.org/data/globaloutlook.cfm.

Bullock Jr., R, and K. A. Brehme (2002) "Atmospheric mercury simulation using the CMAQ model: formulation description and analysis of wet deposition results." Atmospheric Environment 36, pp 2135–2146. Available at https://doi.org/10.1016/S1352-2310(02)00220-0.

California Air Resources Board (CARB): ORGPROF - Organic chemical profiles for source categories, 2018. https://ww2.arb.ca.gov/speciation-profiles-used-carb-modeling .

California Air Resources Board (CARB): 2005 Architectural Coatings Survey – Final Report, 2007.

California Air Resources Board (CARB): 2010 Aerosol Coatings Survey Results, 2012.

California Air Resources Board (CARB): 2014 Architectural Coatings Survey - Draft Data Summary, 2014.

California Air Resources Board (CARB): Final 2015 Consumer & Commercial Product Survey Data Summaries, 2019.

Coordinating Research Council (CRC). Report A-100. Improvement of Default Inputs for MOVES and SMOKE-MOVES. Final Report. February 2017. Available at http://crcsite.wpengine.com/wp-content/uploads/2019/05/ERG_FinalReport_CRCA100_28Feb2017.pdf.

Coordinating Research Council (CRC). Report A-115. Developing Improved Vehicle Population Inputs for the 2017 National Emissions Inventory. Final Report. April 2019. Available at http://crcsite.wpengine.com/wp-content/uploads/2019/05/CRC-Project-A-115-Final-Report_20190411.pdf.

Drillinginfo, Inc. 2015. "DI Desktop Database powered by HPDI." Currently available from https://www.enverus.com/.

England, G., Watson, J., Chow, J., Zielenska, B., Chang, M., Loos, K., Hidy, G., 2007. "Dilution-Based Emissions Sampling from Stationary Sources: Part 2-- Gas-Fired Combustors Compared with Other Fuel-Fired Systems," Journal of the Air & Waste Management Association, 57:1, 65-78, DOI: 10.1080/10473289.2007.10465291. Available at https://www.tandfonline.com/doi/abs/10.1080/10473289.2007.10465291.

EPA, 2017. Light-Duty Vehicle, Light-Duty Truck, and Medium-Duty Passenger Vehicle Tier 2 Exhaust Emission Standards. Office of Transportation and Air Quality, Ann Arbor, MI 48105. Available at: https://www.epa.gov/emission-standards-reference-guide/epa-emission-standards-light-duty-vehicles-and-trucks-and.

EPA, 2008. Regulatory Impact Analysis: Control of Emissions of Air Pollution from Locomotive Engines and Marine Compression Ignition Engines Less than 30 Liters Per Cylinder. EPA420-R-08-001. Available at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P10023S4.PDF?Dockey=P10023S4.PDF.

EPA, 2012d. Preparation of Emission Inventories for the Version 5.0, 2007 Emissions Modeling Platform Technical Support Document. Available from: https://www.epa.gov/air-emissions-modeling/2007-version-50-technical-support-document.

EPA, 2013rwc. "2011 Residential Wood Combustion Tool version 1.1, September 2013", available from US EPA, OAQPS, EIAG.

EPA, 2015b. Draft Report Speciation Profiles and Toxic Emission Factors for Nonroad Engines. EPA-420-R-14-028. Available at https://cfpub.epa.gov/si/si_public_record_Report.cfm?dirEntryId=309339&CFID=83476290&CFTOKEN=35281617.

EPA, 2015c. Speciation of Total Organic Gas and Particulate Matter Emissions from On-road Vehicles in MOVES2014. EPA-420-R-15-022. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100NOJG.pdf.

EPA, 2016. SPECIATE Version 4.5 Database Development Documentation, U.S. Environmental Protection Agency, Office of Research and Development, National Risk Management Research Laboratory, Research Triangle Park, NC 27711, EPA/600/R-16/294, September 2016. Available at https://www.epa.gov/sites/production/files/2016-09/documents/speciate_4.5.pdf.

EPA, 2017. Additional Updates to Emissions Inventories for the Version 6.3, 2011 Emissions Modeling Platform for the Year 2023 technical support document. Available at: https://www.epa.gov/sites/production/files/2017-11/documents/2011v6.3_2023en_update_emismod_tsd_oct2017.pdf.

EPA, 2018. AERMOD Model Formulation and Evaluation Document. EPA-454/R-18-003. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina 27711. Available at https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100UT95.PDF.

EPA, 2018. 2014 National Emission Inventory, version 2 Technical Support Document. U.S. Environmental Protection Agency, OAQPS, Research Triangle Park, NC 27711. Available at: https://www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-technical-support-document-tsd.

EPA, 2019. Final Report, SPECIATE Version 5.0, Database Development Documentation, Research Triangle Park, NC, EPA/600/R-19/988. Available at https://www.epa.gov/air-emissions-modeling/speciate-51-and-50-addendum-and-final-report.

EPA, 2020. Population and Activity of Onroad Vehicles in MOVES3. EPA-420-R-20-023. Office of Transportation and Air Quality. US Environmental Protection Agency. Ann Arbor, MI. November 2020. Available under the MOVES3 section at https://www.epa.gov/moves/moves-technical-reports.

EPA, 2021. Technical Support Document (TSD) Preparation of Emissions Inventories for the 2016v2 North American Emissions Modeling Platform. Available at https://www.epa.gov/air-emissions-modeling/2016v2-platform.

EPA, 2021b. 2017 National Emission Inventory: January 2021 Updated Release, Technical Support Document. U.S. Environmental Protection Agency, OAQPS, Research Triangle Park, NC 27711. Available at: https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-technical-support-document-tsd.

EPA, 2021c. Technical Support Document (TSD) Preparation of Emissions Inventories for the 2016v1 North American Emissions Modeling Platform. Available at https://www.epa.gov/air-emissions-modeling/2016-version-1-technical-support-document.

EPA, 2021d. 2017 National Emissions Inventory (NEI), Research Triangle Park, NC, January 2021. https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data.

EPA, 2022a. Technical Support Document (TSD) Preparation of Emissions Inventories for the 2018 North American Emissions Modeling Platform. EPA-454/B-22-005. Available at https://www.epa.gov/air-emissions-modeling/2018-emissions-modeling-platform.

EPA, 2022b. 2019 National Emissions Inventory (NEI) Technical Support Document: Point Data Category, Research Triangle Park, NC. EPA-454/R-22-001. Available at: https://www.epa.gov/air-emissions-modeling/2019-nei-technical-support-documentation.

EPA, 2023a. Technical Support Document (TSD) Preparation of Emissions Inventories for the 2016v3 North American Emissions Modeling Platform. EPA-454/B-23-002. Available at https://www.epa.gov/air-emissions-modeling/2016v3-platform.

EPA, 2023b. 2020 National Emissions Inventory (NEI), Research Triangle Park, NC, March 2023. https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-data.

ERG, 2014a. Develop Mexico Future Year Emissions Final Report. Available at https://gaftp.epa.gov/air/emismod/2011/v2platform/2011emissions/Mexico_Emissions_WA%204-09_final_report_121814.pdf.

ERG, 2016b. "Technical Memorandum: Modeling Allocation Factors for the 2014 Oil and Gas Nonpoint Tool." Available at https://gaftp.epa.gov/air/emismod/2014/v1/spatial_surrogates/oil_and_gas/.

ERG, 2017. "Technical Report: Development of Mexico Emission Inventories for the 2014 Modeling Platform." Available at https://gaftp.epa.gov/Air/emismod/2014/v2/2014fd/emissions/EPA%205-18%20Report_Clean%20Final_01042017.pdf.

ERG, 2018. Technical Report: "2016 Nonpoint Oil and Gas Emission Estimation Tool Version 1.0". Available at https://gaftp.epa.gov/air/emismod/2016/v1/reports/2016%20Nonpoint%20Oil%20and%20Gas%20Emission%20Estimation%20Tool%20V1_0%20December_2018.pdf.

ERG, 2019a. "2017 Nonpoint Oil and Gas Emission Estimation Tool Revisions" Available from: https://gaftp.epa.gov/air/nei/2017/doc/supporting_data/nonpoint/2017%20Oil%20and%20Gas%20Memos.zip.

ERG, 2019b. Category 1 and 2 Commercial Marine Emissions Inventory. Available from: https://www.epa.gov/sites/default/files/2019-11/cmv_methodology_documentation.zip.

ERG, 2019c. 2016 versus 2017 entrance and clearance data. Available from:https://gaftp.epa.gov/Air/emismod/2016/v2/reports/cmv/EandC_2016_to_2017_Activity_Ratios.pdf.

ERG, 2021. "Historical Nonpoint Oil and Gas Emission Inventory Development for 2018".

The Freedonia Group, 2016. Solvents, Industry Study #3429.

Foley et al., 2023. 2002–2017 anthropogenic emissions data for air quality modeling over the United States. Available at https://www.sciencedirect.com/science/article/pii/S2352340923001403?via%3Dihub.

Frost & Sullivan, 2010. "Project: Market Research and Report on North American Residential Wood Heaters, Fireplaces, and Hearth Heating Products Market (P.O. # PO1-IMP403-F&S). Final Report April 26, 2010", pp. 31-32. Prepared by Frost & Sullivan, Mountain View, CA 94041.

Gkatzelis, G.I., Coggon, M.M., McDonald, B.C., Peischl, J., Aikin, K.C., Gilman, J.B., Trainer, M., Warneke, C. Identifying Volatile Chemical Product Tracer Compounds in US Cities. Environ. Sci. Technol. 2021, 55 (1), 188−199.

Houck, 2011. "Dirty- vs. Clean-Burning? What percent of freestanding wood heaters in use in the U.S. today are still old, uncertified units?" Hearth and Home, December 2011.

Hutchins, M.L., Holkzworth, R.H., Brundell, J.B., and Rodger, C.J., 2012. Relative detection efficiency of the World Wide Lightning Location Network. Available from http://wwlln.net/publications/Hutchins_Detection_Efficiency_RadioSci_2012.pdf.

Kang et al., 2022. Assessing the Impact of Lightning NOx Emissions in CMAQ using Lightning Flash Data from WWLLN over the Contiguous United States. Available from https://doi.org/10.3390/atmos13081248.

Khare, P., and Gentner, D. R., 2018. Considering the future of anthropogenic gas-phase organic compound emissions and the increasing influence of non-combustion sources on urban air quality, Atmos Chem Phys, 18, 5391-5413, 10.5194/acp-18-5391-2018.

Luecken D., Yarwood G, Hutzell WT, 2019. Multipollutant modeling of ozone, reactive nitrogen and HAPs across the continental US with CMAQ-CB6. Atmospheric environment. 2019 Mar 15;201:62-72.

Mansouri, K., Grulke, C. M., Judson, R. S., and Williams, A. J., 2018. OPERA models for predicting physicochemical properties and environmental fate endpoints, J Cheminformatics, 10, 10.1186/s13321-018-0263-1.

McCarty, J.L., Korontzi, S., Jutice, C.O., and T. Loboda. 2009. The spatial and temporal distribution of crop residue burning in the contiguous United States. Science of the Total Environment, 407 (21): 5701-5712. Available at https://www.sciencedirect.com/science/article/abs/pii/S1352231008000137?via%3Dihub.

MDNR, 2008. "A Minnesota 2008 Residential Fuelwood Assessment Survey of individual household responses". Minnesota Department of Natural Resources. Available from http://files.dnr.state.mn.us/forestry/um/residentialfuelwoodassessment07_08.pdf.

NCAR, 2016. FIRE EMISSION FACTORS AND EMISSION INVENTORIES, FINN Data. downloaded 2014 SAPRC99 version from https://www.acom.ucar.edu/Data/fire/.

NESCAUM, 2006. "Assessment of Outdoor Wood-fired Boilers". Northeast States for Coordinated Air Use Management (NESCAUM) report. Available from http://www.nescaum.org/documents/assessment-of-outdoor-wood-fired-boilers/2006-1031-owb-report_revised-june2006-appendix.pdf.

NYSERDA, 2012. "Environmental, Energy Market, and Health Characterization of Wood-Fired Hydronic Heater Technologies, Final Report". New York State Energy Research and Development Authority (NYSERDA). Available from: https://www-nyserda-ny-gov.webpkgcache.com/doc/-/s/www.nyserda.ny.gov/-/media/Project/Nyserda/Files/Publications/Research/Environmental/Wood-Fired-Hydronic-Heater-Tech-Summary.pdf.

Pechan, 2001. E.H. Pechan & Associates, Inc., Control Measure Development Support—Analysis of Ozone Transport Commission Model Rules, Springfield, VA, prepared for the Ozone Transport Commission, Washington, DC, March 31, 2001. Available at https://otcair.org/upload/Documents/Reports/Control%20Measure%20Development%20Support.pdf.

Pouliot, G., H. Simon, P. Bhave, D. Tong, D. Mobley, T. Pace, and T. Pierce. 2010. "Assessing the Anthropogenic Fugitive Dust Emission Inventory and Temporal Allocation Using an Updated Speciation of Particulate Matter." International Emission Inventory Conference, San Antonio, TX. Available at http://www3.epa.gov/ttn/chief/conference/ei19/session9/pouliot_pres.pdf.

Pouliot, G. and J. Bash, 2015. Updates to Version 3.61 of the Biogenic Emission Inventory System (BEIS). Presented at Air and Waste Management Association conference, Raleigh, NC, 2015.

Pouliot G, Rao V, McCarty JL, Soja A. Development of the crop residue and rangeland burning in the 2014 National Emissions Inventory using information from multiple sources. Journal of the Air & Waste Management Association. 2017 Apr 27;67(5):613-22.

Pye, H. O. T.; Pouliot, G. A., 2012. Modeling the role of alkanes, polycyclic aromatic hydrocarbons, and their oligomers in secondary organic aerosol formation. Environ. Sci. Technol. 2012, 46, 6041−6047.

Raffuse, S., D. Sullivan, L. Chinkin, S. Larkin, R. Solomon, A. Soja, 2007. Integration of Satellite-Detected and Incident Command Reported Wildfire Information into BlueSky, June 27, 2007. Available at: http://getbluesky.org/smartfire/docs.cfm.

Ramboll (Shah, T., Yarwood G.,) and EPA (Eyth, A., Strum, M), 2017. COMPOSITION OF ORGANIC GAS EMISSIONS FROM FLARING NATURAL GAS, Presented at the 2017 International Emission Inventory Conference, August 18, 2017. Available at https://www.epa.gov/sites/production/files/2017-11/documents/organic_gas.pdf. Additional Memo from Ramboll Environ to EPA (same title as presentation) dated September 23, 2016.

Ramboll, 2020. https://github.com/CMASCenter/Speciation-Tool/blob/master/docs/Ramboll_sptool_mapping_updates_AE7_AE8_24Mar2020_final_full.pdf.

Reichle, L., R. Cook, C. Yanca, D. Sonntag, 2015. "Development of organic gas exhaust speciation profiles for nonroad spark-ignition and compression-ignition engines and equipment", Journal of the Air & Waste Management Association, 65:10, 1185-1193, DOI: 10.1080/10962247.2015.1020118. Available at https://doi.org/10.1080/10962247.2015.1020118.

Reff, A., Bhave, P., Simon, H., Pace, T., Pouliot, G., Mobley, J., Houyoux. M. "Emissions Inventory of PM2.5 Trace Elements across the United States", Environmental Science & Technology 2009 43 (15), 5790-5796, DOI: 10.1021/es802930x. Available at https://doi.org/10.1021/es802930x.

Sarwar, G., S. Roselle, R. Mathur, W. Appel, R. Dennis, "A Comparison of CMAQ HONO predictions with observations from the Northeast Oxidant and Particle Study", Atmospheric Environment 42 (2008) 5760–5770). Available at https://doi.org/10.1016/j.atmosenv.2007.12.065.

Schauer, J., G. Lough, M. Shafer, W. Christensen, M. Arndt, J. DeMinter, J. Park, "Characterization of Metals Emitted from Motor Vehicles," Health Effects Institute, Research Report 133, March 2006. Available at https://www.healtheffects.org/publication/characterization-metals-emitted-motor-vehicles.

Seltzer, K. M., Pennington, E., Rao, V., Murphy, B. N., Strum, M., Isaacs, K. K., and Pye, H. O. T., 2021. Reactive organic carbon emissions from volatile chemical products, Atmos. Chem. Phys., 21, 5079–5100, https://doi.org/10.5194/acp-21-5079-2021.

Skamarock, W., J. Klemp, J. Dudhia, D. Gill, D. Barker, M. Duda, X. Huang, W. Wang, J. Powers, 2008. A Description of the Advanced Research WRF Version 3. NCAR Technical Note. National Center for Atmospheric Research, Mesoscale and Microscale Meteorology Division, Boulder, CO. June 2008. Available at: https://opensky.ucar.edu/islandora/object/technotes:500.

Sullivan D.C., Raffuse S.M., Pryden D.A., Craig K.J., Reid S.B., Wheeler N.J.M., Chinkin L.R., Larkin N.K., Solomon R., and Strand T. (2008) Development and applications of systems for modeling emissions and smoke from fires: the BlueSky smoke modeling framework and SMARTFIRE: 17th International Emissions Inventory Conference, Portland, OR, June 2-5.

Swedish Environmental Protection Agency, 2004. Swedish Methodology for Environmental Data; Methodology for Calculating Emissions from Ships: 1. Update of Emission Factors.

U.S. Census Bureau, Economy Wide Statistics Division, 2018. County Business Patterns, 2018. https://www.census.gov/programs-surveys/cbp/data/datasets.html.

U.S. Bureau of Labor Statistics, 2020. Producer Price Index by Industry, retrieved from FRED, Federal Reserve Bank of St. Louis. https://fred.stlouisfed.org/categories/31.

U.S. Census Bureau, 2011 Paint and Allied Products - 2010, MA325F(10). https://www.census.gov/data/tables/time-series/econ/cir/ma325f.html.

U.S. Census Bureau, 2021. 2018 Annual Survey of Manufacturers (ASM), Washington D.C., USA. https://www.census.gov/data/developers/data-sets/Annual-Survey-of-Manufactures.html.

U.S. Department of Transportation and the U.S. Department of Commerce, 2015. 2012 Commodity Flow Survey, EC12TCF-US. https://www.census.gov/library/publications/2015/econ/ec12tcf-us.html.

U.S. Energy Information Administration, 2019. The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, Washington, DC. https://www.eia.gov/petroleum/wells/.

Wang, Y., P. Hopke, O. V. Rattigan, X. Xia, D. C. Chalupa, M. J. Utell. (2011) "Characterization of Residential Wood Combustion Particles Using the Two-Wavelength Aethalometer", Environ. Sci. Technol., 45 (17), pp 7387–7393. Available at https://doi.org/10.1021/es2013984.

Weschler, C. J., and Nazaroff, W. W., 2008. Semivolatile organic compounds in indoor environments, Atmos Environ, 42, 9018-9040.

Wiedinmyer, C., 2001. NCAR BVOC Enclosure Database. National Center for Atmospheric Research, Boulder, CO.

Wiedinmyer, C., S.K. Akagi, R.J. Yokelson, L.K. Emmons, J.A. Al-Saadi[3], J. J. Orlando[1], and A. J. Soja. (2011) "The Fire INventory from NCAR (FINN): a high resolution global model to estimate the emissions from open burning", Geosci. Model Dev., 4, 625-641. http://www.geosci-model-dev.net/4/625/2011/ doi:10.5194/gmd-4-625-2011.

Wilson, Barry Tyler; Lister, Andrew J.; Riemann, Rachel I.; Griffith, Douglas M. 2013a. Live tree species basal area of the contiguous United States (2000-2009). Newtown Square, PA: USDA Forest Service, Rocky Mountain Research Station. https://doi.org/10.2737/RDS-2013-0013.

Wilson, Barry Tyler; Woodall, Christopher W.; Griffith, Douglas M. 2013b. Forest carbon stocks of the contiguous United States (2000-2009). Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. https://doi.org/10.2737/RDS-2013-0004.

WRAP / Ramboll, 2019. Revised Final Report: Circa-2014 Baseline Oil and Gas Emission Inventory for the WESTAR-WRAP Region, September 2019. Available at: http://www.wrapair2.org/pdf/WRAP_OGWG_Report_Baseline_17Sep2019.pdf.

WRAP / Ramboll, 2020. Revised Final Report: 2028 Future Year Oil and Gas Emission Inventory for WESTAR-WRAP States – Scenario #1: Continuation of Historical Trends http://www.wrapair2.org/pdf/WRAP_OGWG_2028_OTB_RevFinalReport_05March2020.pdf .

Yarwood, G., J. Jung, , G. Whitten, G. Heo, J. Mellberg, and M. Estes,2010: Updates to the Carbon Bond Chemical Mechanism for Version 6 (CB6). Presented at the 9th Annual CMAS Conference, Chapel Hill, NC. Available at https://www.cmascenter.org/conference/2010/abstracts/emery_updates_carbon_2010.pdf.

Zhu, Henze, et al, 2013. "Constraining U.S. Ammonia Emissions using TES Remote Sensing Observations and the GEOS-Chem adjoint model", Journal of Geophysical Research: Atmospheres, 118: 1-14. Available at https://doi.org/10.1002/jgrd.50166.

United States Environmental Protection Agency	Office of Air Quality Planning and Standards Air Quality Assessment Division Research Triangle Park, NC	Publication No. EPA-454/B-23-003 September 2023