Technical Support Document (TSD): Preparation of Emissions Inventories for the 2022v2 North American Emissions Modeling Platform

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Technical Support Document (TSD) Preparation of Emissions Inventories for the 2022v2 North American Emissions Modeling Platform

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Acronyms

AADT	Annual average daily traffic
AE6	CMAQ Aerosol Module, version 6, introduced in CMAQ v5.0
AEO	Annual Energy Outlook
AERMOD	American Meteorological Society/Environmental Protection Agency Regulatory Model
AIS	Automated Identification System
APU	Auxiliary power unit
BEIS	Biogenic Emissions Inventory System
BELD	Biogenic Emissions Land use Database
BenMAP	Benefits Mapping and Analysis Program
BPS	Bulk Plant Storage
BSP	Blue Sky Pipeline
BTP	Bulk Terminal (Plant) to Pump
C1C2	Category 1 and 2 commercial marine vessels
C3	Category 3 (commercial marine vessels)
CAMD	EPA's Clean Air Markets Division
CAM_X	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
pcSOA	Potential combustion Secondary Organic Aerosol
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
POA	Primary Organic Aerosol
ppm	Parts per million
ppmv	Parts per million by volume
PSAT	Particulate Matter Source Apportionment Technology
RACT	Reasonably Available Control Technology
RBT	Refinery to Bulk Terminal
RIA	Regulatory Impact Analysis
RICE	Reciprocating Internal Combustion Engine
RWC	Residential Wood Combustion
RPD	Rate-per-vehicle (emission mode used in SMOKE-MOVES)
RPH	Rate-per-hour for hoteling (emission mode used in SMOKE-MOVES)
RPHO	Rate-per-hour for off-network idling (emission mode used in SMOKE-MOVES)
RPP	Rate-per-profile (emission mode used in SMOKE-MOVES)
RPS	Rate-per-start (emission mode used in SMOKE-MOVES)
RPV	Rate-per-vehicle (emission mode used in SMOKE-MOVES)
RVP	Reid Vapor Pressure
SCC	Source Classification Code
SMARTFIRE2	Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2
SMOKE	Sparse Matrix Operator Kernel Emissions
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), in conjunction with the National Emissions Collaborative, developed an air quality modeling platform for criteria air pollutants that represents the year 2022. The platform is based on the 2020 National Emissions Inventory (2020 NEI) published in April 2023 (EPA, 2023), with many sectors directly developed or adjusted to better reflect 2022 and/or use data specific to the year 2022. The air quality modeling platform consists of all the emissions inventories and ancillary data files used for emissions modeling, as well as the meteorological, initial condition, and boundary condition files needed to run the air quality model. This document focuses on the emissions modeling component of the 2022 air quality modeling platform, including the emission inventories, the ancillary data files, and the approaches used to transform inventories for use in air quality modeling.

The emissions data in the modeling platform include criteria air pollutants and their precursors (CAPs), two groups of hazardous air pollutants (HAPs), and diesel particulate matter. The first group of HAPs are those explicitly used by the chemical mechanism in the Community Multiscale Air Quality (CMAQ) model (Appel, 2018) for ozone/particulate matter (PM): chlorine (Cl), hydrogen chloride (HCl), naphthalene, benzene, acetaldehyde, formaldehyde, and methanol (the last five are abbreviated as NBAFM in subsequent sections of the document). The second group of HAPs consists of over 50 HAPs or HAP groups (such as polycyclic aromatic hydrocarbon groups) that are included in the emissions inventories for the purposes of air quality modeling for a HAP+CAP platform.

Emissions were prepared for the Community Multiscale Air Quality (CMAQ) model version 5.4[1] which is used to model ozone (O_3) particulate matter (PM), and HAP concentrations. CMAQ requires hourly and gridded emissions of the following inventory pollutants: carbon monoxide (CO), nitrogen oxides (NO_X), volatile organic compounds (VOC), sulfur dioxide (SO_2), ammonia (NH_3), primary particulate matter less than or equal to 10 microns (PM_{10}), and individual component species for primary particulate matter less than or equal to 2.5 microns ($PM_{2.5}$). In addition, the Carbon Bond mechanism version 6 (CB6) with chlorine chemistry within CMAQ allows for explicit treatment of the VOC HAPs naphthalene, benzene, acetaldehyde, formaldehyde and methanol (NBAFM), includes anthropogenic HAP emissions of HCl and Cl, and can model additional HAPs as described in Section 3. The short abbreviation for the final modeling case name for this platform was “2022he”, where 2022 is the year modeled, ‘h’ represents that it was based on the 2020 NEI, and ‘e’ represents that it was the fifth version of a 2020 NEI-based platform. A draft version of this case named “2022hd” was first developed and was used for a HAP+CAP model run and for stakeholder review.

This TSD discusses the application of the emissions modeling platform for which CMAQ and the Comprehensive Air Quality Model with Extensions (CAMx) were run. Emissions were also prepared for an air dispersion modeling system: American Meteorological Society/Environmental Protection Agency Regulatory Model (AERMOD) (EPA, 2018). AERMOD was run for 2022 for all NEI HAPs (about 130 more than covered by CMAQ) across all 50 states in a similar way as was done for the 2018 version of AirToxScreen (EPA, 2022a). This TSD does not address the data development for AERMOD. For this platform, CMAQ was not run in Alaska, Hawaii, Puerto Rico and the Virgin Islands but AERMOD was run

[1] CMAQ version 5.4: https://zenodo.org/record/7218076. CMAQ is also available from https://www.epa.gov/cmaq and the Community Modeling and Analysis System (CMAS) Center at: https://www.cmascenter.org.

in this areas. The effort to create the emissions inputs for this study included development of emission inventories to represent emissions during the year of 2022, along with application of emissions modeling tools to convert the inventories into the format and resolution needed by CMAQ and CAMx.

The emissions modeling platform includes point sources, nonpoint sources, onroad mobile sources, nonroad mobile sources, biogenic emissions 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, road type and process, while the NEI emissions are aggregated to vehicle type/fuel type totals and annual temporal resolution. Emissions used in the CMAQ modeling from Canada are provided by Environment and Climate Change Canada (ECCC) and Mexico are mostly provided by SEMARNAT and are not part of the NEI. Year-specific emissions were used for fires, biogenic sources, fertilizer, point sources, and onroad and nonroad mobile sources. Where available, hourly continuous emission monitoring system (CEMS) data were used for electric generating unit (EGU) emissions.

The primary emissions modeling tool used to create the CMAQ model-ready emissions was the Sparse Matrix Operator Kernel Emissions (SMOKE) modeling system. SMOKE version 5.2.1 was used to create CMAQ-ready emissions files for a 12-km grid covering the continental U.S. Additional information about SMOKE is available from http://www.cmascenter.org/smoke.

The gridded meteorological model used to provide input data for the emissions modeling was developed using the Weather Research and Forecasting Model (WRF, https://github.com/wrf-model/WRF/releases) version 4.4.2, Advanced Research WRF core (Skamarock, et al., 2008). The WRF Model is a mesoscale numerical weather prediction system developed for both operational forecasting and atmospheric research applications. The WRF model was run for 2022 over a domain covering the continental U.S. (CONUS) at both 12km resolution and 36km resolution with 35 vertical layers, and also for domains that cover Alaska, Hawaii, and Puerto Rico plus the Virgin Islands. 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 abbreviation “22m.” The full case abbreviation includes this suffix following the emissions portion of the case name to fully specify the abbreviation of the draft case as “2022hd_cb6_22m” and the final case as “2022he_cb6_22m.”

Data files and summaries for this platform are available from this section of the air emissions modeling website https://www.epa.gov/air-emissions-modeling/2022v2-emissions-modeling-platform. The reports folder includes summaries that compare the 2022v1 platform base year emissions (which has the case name of “2022hc”) with the draft (2022hd) and final (2022he) emissions for the 2022v2 platform, 2022v2 emissions by county and month, along with other information.

This document contains four additional sections. Section 2 describes the emission inventories input to SMOKE. Section 3 describes the emissions modeling and the ancillary files used to process the emission inventories into air quality model-ready inputs. Data summaries are provided in Section 4, and Section 5 provides references.

2 Base Year Emissions Inventories and Approaches

This section describes the emissions inventories created for input to SMOKE, which are based on the April 2023 version of the 2020 NEI with updates to reflect emissions in the year 2022. The NEI includes four main data categories: a) nonpoint sources (including fires); b) point sources; c) nonroad mobile sources; and d) onroad mobile sources. For CAPs, the NEI is largely compiled from data submitted by state, local and tribal (S/L/T) agencies. HAP emissions are often generated through augmentation (generated through speciation of relevant CAPs, e.g., VOC and $PM_{2.5}$) by EPA when they are not voluntarily submitted to the NEI by S/L/T agencies. The NEI was compiled using the Emissions Inventory System (EIS). EIS collects and stores facility inventory and emissions data for the NEI and includes hundreds of automated QA checks to improve data quality, and it also supports release point (stack) coordinates separately from facility coordinates. EPA collaboration with S/L/T agencies helped prevent duplication between point and nonpoint source categories such as industrial boilers. The 2020 NEI Technical Support Document describes in detail the development of the 2020 emission inventories and is available at https://www.epa.gov/air-emissions-inventories/2020-national-emissions-inventory-nei-technical-support-document-tsd (EPA, 2023).

A complete set of emissions for all source categories is developed for the NEI every three years, with 2020 being the most recent year represented with a full "triennial" NEI. S/L/T agencies are required to submit all applicable point sources to the NEI in triennial years, including the year 2020. Because only select point source emissions were submitted by S/L/T agencies for 2022, emissions for any point sources not submitted for 2022, and not marked as shutdown, were pulled forward from the 2020 NEI. The SMARTFIRE2 system and the BlueSky Pipeline (https://github.com/pnwairfire/bluesky) emissions modeling system were used to develop the fire emissions. SMARTFIRE2 categorizes all fires as either prescribed burning or wildfire, and the BlueSky Pipeline system includes fuel loading, consumption and emission factor estimates for both types of fires. Onroad and nonroad mobile source emissions were developed for this project using MOVES5 (https://www.epa.gov/moves).

With the exception of fire emissions, Canadian emissions were provided by Environment Canada and Climate Change (ECCC) for the years 2020 and 2023 and most 2022 emissions were developed by interpolating between 2020 and 2023. For point EGUs, instead of interpolating from 2020 and 2023 (which unlike other point sources, has different sources in 2020 vs 2023), the provided 2023 emissions were used as is to represent 2022. For Mexico, year 2016-based inventories from the 2019 emissions modeling platform (EPA, 2022b) were used as the starting point with area, nonroad, and point data for border states (i.e., Baja California, Chihuahua, Coahuila, Nuevo Leon, Sonora, and Tamaulipas) supplemented with data for calendar year 2018, which is newer than the data used in the 2019 platform, developed by SEMARNAT in collaboration with U.S. EPA.

The emissions modeling process was performed using SMOKE v5.2.1. Through this process, the emissions inventories were apportioned into the grid cells used by CMAQ and temporally allocated into hourly values. In addition, the pollutants in the inventories (e.g., NOx, PM and VOC) were split into the chemical species needed by CMAQ. For the purposes of preparing the CMAQ-ready emissions, the NEI emissions were split into emissions modeling platform "sectors"; and emissions from sources other than the NEI are added, such as the Canadian, Mexican, and offshore inventories. Emissions within the emissions modeling platform were separated into sectors for groups of related emissions source categories that were run through the appropriate SMOKE programs, except the final merge, independently from emissions categories in the other sectors. The final merge program called Mrggrid combines low-level sector-specific gridded, speciated and temporalized emissions to create the final CMAQ-ready emissions inputs. For biogenic and fertilizer emissions, the CMAQ model allows for these emissions to be included in the CMAQ-ready emissions inputs, or to be computed within CMAQ itself (the "inline" option). This study used the option to compute biogenic emissions within the model and the CMAQ bidirectional ammonia process to compute the fertilizer emissions.

Following the compilation of the initial draft of the base year emission inventories within the 2022v2 Emissions Modeling Platform, the inventories were posted to the 2022v2 Emissions Modeling Platform EPA website and to the 2022v2 platform Sharepoint site that facilitated the receipt of stakeholder comments. Stakeholders were given the opportunity to comment on the inventory during an approximate 30-day period. Following the comment period, EPA posted responses to the SharePoint site and where possible, EPA incorporated the comments into the inventories prior to finalization. In total, 15 people from 13 individual organizations submitted 30 comments during the base-year emissions review for the 2022v2 platform.

Table 2-1 presents the sectors in the emissions modeling platform used to develop the year 2022 emissions. The sector abbreviations are provided in italics and start with lower case letters; these abbreviations are used in the SMOKE modeling scripts, the inventory file names, and throughout the remainder of this section. Note that while the fires sectors are in nonpoint NEI data category, in the modeling platform they are treated as day-specific point sources. The description column summarizes whether the emissions were updated from the 2022v1 (2022hc) platform. Further details on the changes are provided later in the document.

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

Platform Sector: ***abbreviation***	**NEI Data Category**	**Description and resolution of the data input to SMOKE**
EGU units: ***ptegu***	Point	2022 NEI point source EGUs, replaced with hourly Continuous Emissions Monitoring System (CEMS) values for NO_X and SO_2, and the remaining pollutants temporally allocated according to CEMS heat input where the units are matched to the NEI. Emissions for all sources not matched to CEMS data come from the 2022 NEI point inventory. EGUs closed in 2022 are not part of the inventory. Annual resolution for sources not matched to CEMS data, hourly for CEMS sources. **For 2022v2, CEMS data were updated based on data downloaded on February 19, 2025. Some additional matches to CEMS data were incorporated along with other minor changes.**
Point source oil and gas: ***pt_oilgas***	Point	2022 NEI point sources that include oil and gas production emissions processes for facilities with North American Industry Classification System (NAICS) codes related to Oil and Gas Extraction, Natural Gas Distribution, Drilling Oil and Gas Wells, Support Activities for Oil and Gas Operations, Pipeline Transportation of Crude Oil, and Pipeline Transportation of Natural Gas. Includes U.S. offshore oil production. Annual resolution. **For 2022v2, some sources were updated to correct double counts, closures, outdated and incorrect data, and some other changes.**

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Aircraft and ground support equipment: *airports*	Point	EPA estimated 2022 emissions, including aircraft and airport ground support for the top 51 airports. Smaller airports, including aircraft and airport ground support were projected from 2020 NEI to 2022 based on the 2023 Terminal Area Forecast (TAF). Georgia provided emissions for HJAIA. Annual resolution. **For 2022v2, smaller airports were reprojected from 2020 to 2022 using updated projection factors based on the 2024 TAF, and other updates were incorporated in Georgia and Washington.**
Remaining non-EGU point: *ptnonipm*	Point	All 2022 NEI point source records not matched to the airports, ptegu, or pt_oilgas sectors. Includes 2020 NEI rail yard emissions projected to 2022 using updated R-1 reported yard fuel usage. Annual resolution. **For 2022v2, some changes were implemented based on state comments.**
Livestock: *livestock*	Nonpoint	2022 nonpoint livestock emissions developed using a similar method to 2020 NEI but with adjusted animal counts and using 2022 meteorology. Livestock includes ammonia and other pollutants (except $PM_{2.5}$). County and annual resolution. **For 2022v2, updates were incorporated for Maricopa County.**
Agricultural Fertilizer: *fertilizer*	Nonpoint	2022 agricultural fertilizer ammonia emissions based on bidirectional flux calculations computed inline within CMAQ. **For 2022v2 there were no changes.**
Area fugitive dust: *afdust_adj*	Nonpoint	PM_{10} and $PM_{2.5}$ nonpoint fugitive dust sources including building construction, road construction, agricultural dust from crops, and mining and quarrying which were all held constant. Additional dust sources not held constant include paved road dust and agricultural dust from livestock, where paved road dust emissions were adjusted to 2022 based on VMT and dust from livestock based on animal count differences. The emissions modeling system applies a transportable fraction reduction and zero-out adjustments based on the year-specific gridded hourly meteorology (precipitation and snow/ice cover). County and annual resolution. **For 2022v2, changes were incorporated for Oregon unpaved road dust.**
Biogenic: *beis*	Nonpoint	Year 2022 emissions from biogenic sources. These were left out of the CMAQ-ready merged emissions, in favor of inline biogenic emissions produced during the CMAQ model run itself. Version 4 of the Biogenic Emissions Inventory System (BEIS) was used with Version 6 of the Biogenic Emissions Landuse Database (BELD6). The CMAQ-generated emissions are similar to the biogenic emissions generated through running SMOKE, but they are not exactly the same. Gridded and hourly resolution. **For 2022v2, there were no changes.**
Category 1, 2 CMV: *cmv_c1c2*	Nonpoint	2022 Category 1 (C1) and Category 2 (C2), commercial marine vessel (CMV) emissions based on 2022 Automatic Identification System (AIS) data categorized using SCCs specific to ship type. Point and hourly resolution. **For 2022v2, the factors used to compute HAP emissions were updated but there were no changes to CAPs.**

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Category 3 CMV: ***cmv_c3***	Nonpoint	2022 Category 3 (C3) commercial marine vessel (CMV) emissions based on 2022 AIS data categorized using SCCs specific to ship type. Point and hourly resolution. **For 2022v2, the factors used to compute HAP emissions were updated but there were no changes to CAPs.**
Locomotives : ***rail***	Nonpoint	Class I line haul rail locomotives emissions from 2020 NEI projected to 2022 using R-1 reported fuel usage. County and annual resolution. Class II and III locomotive emissions were projected from 2020 based on the 2021 U.S. Energy Information Administration's Annual Energy Outlook. Commuter rail was projected from 2020 using fuel use per company from the Federal Transit Administration's (FTA) 2022 National Transit Database. Amtrak emissions were adjusted down based on 2020 fuel use reported in Amtrak's FY22 AMTRAK Sustainability Report. County and annual resolution. **For 2022v2, there were no changes.**
Nonpoint source oil and gas: ***np_oilgas***	Nonpoint	2022 well activity data (production and exploration of oil, gas, etc.) run through Oil and Gas tool. Abandoned wells based on 2022, plus other state-specific inputs. County and annual resolution. **For 2022v2, there were changes in multiple states.**
Open Burning: ***openburn***	Nonpoint	This new sector for the 2022v1 platform was split out from the prior nonpt sector and includes emissions from yard waste, land clearing, and residential household waste burning. These are SCCs starting with 261. County and annual resolution. **For 2022v2, some emissions were removed in New Hampshire.**
Residential Wood Combustion: ***rwc***	Nonpoint	2020 NEI nonpoint sources with residential wood combustion (RWC) processes, projected to 2022 with state-level adjustment factors derived from the State Energy Data System (SEDS) plus specific adjustments for California and Idaho. County and annual resolution. **For 2022v2, there were significant changes based on updated data and methods that were developed for the 2023 NEI, along with changes to speciation and spatial surrogates.**
Solvents: ***np_solvents***	Nonpoint	Emissions of solvents based on methods used for the 2020 NEI. 2021 emissions are used to represent 2022. Includes household cleaners, personal care products, adhesives, architectural and aerosol coatings, printing inks, and pesticides. Annual and county resolution. **For 2022v2, cutback asphalt emissions were removed from Maricopa County.**
Remaining nonpoint: ***nonpt***	Nonpoint	Nonpoint sources not included in other platform sectors. Mostly held constant at 2020 levels, but with some SCCs adjusted to 2022 based on population, energy consumption ratios and employment data. County and annual resolution. **For 2022v2, updates were incorporated for Maricopa County, some LADCO states, Georgia, and Delaware, along with some spatial surrogate changes.**

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Nonroad: ***nonroad***	Nonroad	2022 nonroad equipment emissions developed with MOVES5, including the updates made to spatial apportionment that were developed with the 2016v1 platform. MOVES5 was used for all states except California, which submitted their own emissions for 2020 and 2023 that were then interpolated to 2022. County and monthly resolution. **For 2022v2, MOVES5 was used and updates were incorporated for Minnesota, Wisconsin, Utah, and Georgia**
Onroad: ***onroad***	Onroad	Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles for 2022 were developed using VMT from many states, along with VMT data from 2020 NEI projected to 2022 using factors based on FHWA VM-2 data. Includes the following emission processes: exhaust, extended idle, auxiliary power units, evaporative, permeation, refueling, vehicle starts, off network idling, long-haul truck hoteling, and brake and tire wear. MOVES5 was run for 2022 to generate year-specific emission factors. County/gridded and hourly resolution. **For 2022v2, MOVES5 was used along with significantly updated input data including spatial surrogates, temporal profiles, age distributions, and activity data.**
Onroad California: ***onroad_ca_adj***	Onroad	California-provided 2022 emissions for CAPs. VOC HAPs were projected from California-provided 2020 NEI HAP emissions using CAP trends. Onroad mobile source gasoline and diesel vehicles from parking lots and moving vehicles based on Emission Factor (EMFAC), gridded and temporalized based on outputs from MOVES5. County/gridded and hourly resolution. **For 2022v2, temporal and spatial allocation were updated based on MOVES5.**
Point source agricultural fires: ***ptagfire***	Nonpoint	Agricultural fire sources for 2022 developed by EPA as point and day-specific emissions.[2] Includes 2022 satellite data and land use. Florida, Georgia, Idaho, and North Carolina have separate datasets and are removed from the national datasets. Washington has supplemental datasets, to be used along with WA from the national datasets. Agricultural fires are in the nonpoint data category of the NEI, but in the modeling platform, they are treated as day-specific point sources. Point and daily resolution. **For 2022v2, updates were incorporated in multiple states.**
Point source prescribed fires: ***ptfire-rx***	Nonpoint	Point source day-specific prescribed fires for 2022 computed using SMARTFIRE 2 and BlueSky Pipeline. The ptfire emissions were run as two separate sectors: ptfire-rx (prescribed, including Flint Hills / grasslands) and ptfire-wild. Point and daily resolution. **For 2022v2, updates were incorporated in multiple states.**
Point source wildfires: ***ptfire-wild***	Nonpoint	Point source day-specific wildfires for 2022 computed using SMARTFIRE 2 and BlueSky Pipeline. Point and daily resolution. **For 2022v2, updates were incorporated in multiple states.**

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

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Non-US. Fires: ***ptfire_othna***	N/A	Point source day-specific wildfires and agricultural fires outside of the U.S. for 2022. Canadian fires were computed using SMARTFIRE 2 and BlueSky Pipeline. Mexico, Caribbean, Central American, and other international fires, are from v2.5 of the Fire INventory (FINN) from National Center for Atmospheric Research (Wiedinmyer, C., 2023). Point and daily resolution. **For 2022v2, there were no updates.**
Canada Area Fugitive dust sources: ***canada_afdust***	N/A	Area fugitive dust sources from ECCC for 2022 (interpolated between provided 2020 and 2023 emissions) with transport fraction and snow/ice adjustments based on 2022 meteorological data. Annual and province resolution. **For 2022v2, there were no updates.**
Canada Point Fugitive dust sources: ***canada_ptdust***	N/A	Point source fugitive dust sources from ECCC for 2022 (interpolated between provided 2020 and 2023 emissions) with transport fraction and snow/ice adjustments based on 2022 meteorological data. Monthly and province resolution. **For 2022v2, there were no updates.**
Canada and Mexico stationary point sources: ***canmex_point***	N/A	Canada and Mexico point source emissions not included in other sectors. Canada point sources were provided by ECCC for 2020 and 2023; Canadian EGUs from 2023 were used directly, while other Canadian point sources were interpolated from 2020 and 2023 to 2022. Mexico point source emissions for six border states represent 2018 and were developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge (EPA, 2022b). Annual and monthly point resolution. **For 2022v2, new data were incorporated for some states in Mexico.**
Canada and Mexico agricultural sources: ***canmex_ag***	N/A	Canada and Mexico agricultural emissions. Canada emissions were provided by ECCC for 2020 and 2023. Mexico agricultural emissions were provided by SEMARNAT and include updated emissions for six border states representing 2018 developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge. Annual municipio and province resolution. **For 2022v2, new data were incorporated for some states in Mexico.**
Canada low-level oil and gas sources: ***canada_og2D***	N/A	Canada emissions from upstream oil and gas, provided by ECCC for 2020 and 2023 and interpolated to 2022. This sector contains the portion of oil and gas emissions which are not subject to plume rise. The rest of the Canada oil and gas emissions are in the canmex_point sector. Annual province resolution. **For 2022v2, there were no updates.**

Platform Sector: *abbreviation*	NEI Data Category	Description and resolution of the data input to SMOKE
Canada and Mexico nonpoint and nonroad sources: ***canmex_area***	N/A	Canada and Mexico nonpoint source emissions not included in other sectors. Canada: ECCC provided surrogates and 2020 and 2023 inventories, that were interpolated to 2022. Mexico: included updated emissions for six border states representing 2018 developed by SEMARNAT in collaboration with EPA, while emissions for all other states were carried forward from 2019ge. Annual and monthly municipio and province resolution. **For 2022v2, new data were incorporated for some states in Mexico including some spatial surrogate updates.**
Canada onroad sources: ***canada_onroad***	N/A	Canada onroad emissions. 2020 and 2023 Canada inventories provided by ECCC and interpolated to 2022; processed using updated surrogates. Province monthly resolution. **For 2022v2, there were no updates.**
Mexico onroad sources: ***mexico_onroad***	N/A	Mexico onroad emissions. 2020 and 2023 emissions output from MOVES-Mexico were interpolated to 2022. Municipio monthly resolution. **For 2022v2, a new version of MOVES_Mexico was used to compute emissions**

Ocean chlorine emissions were also merged in with the above sectors. 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). Ocean chlorine data at 12 km resolution were available from earlier studies and were not modified other than the name "CHLORINE" was changed to "CL2" because that is the name required by the CMAQ model.

The emission inventories in SMOKE input formats for the platform are available from EPA's Air Emissions Modeling website: https://www.epa.gov/air-emissions-modeling/2022v2-emissions-modeling-platform. The platform informational text file indicates the zipped files associated with each platform sector. Some emissions data summaries are available with the data files for this platform. The types of reports include state summaries of inventory pollutants and model species by modeling platform sector and county annual totals by modeling platform sector.

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

Point sources are sources of emissions for which specific geographic coordinates (e.g., latitude and 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, waste piles, etc. A unit may have multiple processes (e.g., a boiler that sometimes burns residual oil and sometimes burns natural gas). With a couple of minor exceptions, this section describes only NEI point sources within the contiguous U.S. The offshore oil platform (pt_oilgas sector) and CMV emissions (cmv_c1c2 and cmv_c3 sectors) are processed by SMOKE as point source inventories and are discussed later in this section. A complete NEI is developed every three years. At the time of this writing, 2020 is the most recently finished complete NEI. A comprehensive description about the development of the 2020 NEI is available in the 2020 NEI TSD (EPA, 2023). Point inventories are also available in EIS for non-triennial NEI years such as 2019 and 2021. In the interim year point inventories, states are required to update large sources with the emissions that occurred in that year, while sources not updated by states for the interim year were either carried forward from the most recent triennial NEI or marked as closed and removed.

In preparation for modeling, the complete set of point sources in the NEI was exported from EIS for the year 2022 into the Flat File 2010 (FF10) format that is compatible with SMOKE (see https://cmascenter.org/smoke/documentation/5.1/html/ch06s02s08.html) and was then split into several sectors for modeling. Any sources without specific locations (i.e., the FIPS code ends in 777) were dropped and inventories for the other point source sectors were created from the remaining point sources. The point sectors are: EGUs (ptegu), point source oil and gas extraction-related sources (pt_oilgas), airport emissions (airports), and the remaining non-EGUs (ptnonipm). The EGU emissions were split out from the other sources to facilitate the use of distinct SMOKE temporal processing and future-year projection techniques. The oil and gas sector emissions (pt_oilgas) and airport emissions (airports) were processed separately for the purposes of developing emissions summaries and due to distinct projection techniques from the remaining non-EGU emissions (ptnonipm).

In some cases, data about facility or unit closures are entered into EIS after the inventory modeling flat files have been extracted. Prior to processing through SMOKE, submitted facility and unit closures were reviewed and closed sources were removed from the inventory.

For this platform, an analysis of point source stack parameters (e.g., stack height, diameter, temperature, and velocity) was performed due to the presence of unrealistic and repeated stack parameters. The defaulted values were noticed in data submissions for the states of Illinois, Louisiana, Michigan, Pennsylvania, Texas, and Wisconsin. Where these defaults were detected and deemed to be unreasonable for the specific process, the affected stack parameters were replaced by values from the PSTK file that is input to SMOKE. PSTK contains default stack parameters by source classification code (SCC).

The inventory pollutants processed through SMOKE for input to CMAQ for the ptegu, pt_oilgas, ptnonipm, ptnonipm_hr, and airports sectors included: CO, NO_X, VOC, SO_2, NH_3, PM_{10}, and $PM_{2.5}$ and the following HAPs: HCl (pollutant code = 7647010), Cl (code = 7782505), and several dozen other HAPs listed in Section 3. NBAFM pollutants from the point sectors were utilized.

The ptnonipm, pt_oilgas, and airports sector emissions were provided to SMOKE as annual emissions. The 'ptnonipm_hr' sector is new for the 2022v2 platform. It includes facilities and sources previously in the ptnonipm sector, includes non-EGU sources with hourly emissions data. This includes hourly CEMs data for select non-EGUs, and also hourly emissions data at Taconite mines in Minnesota. For sources in the ptegu sector that could be matched to 2022 CEMS data, hourly CEMS NO_X and SO_2 emissions for 2022 from EPA's Acid Rain Program were used rather than annual inventory emissions. For all other pollutants (e.g., VOC, $PM_{2.5}$, HCl), annual emissions were used as-is from the annual inventory but were allocated to hourly values using heat input from the CEMS data. For the unmatched units in the ptegu sector, annual emissions were allocated to daily values using IPM region- and pollutant-specific profiles, and similarly, region- and pollutant-specific diurnal profiles were applied to create hourly emissions.

The non-EGU, non-hourly, stationary point source (ptnonipm) emissions were used as inputs 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, 2020, …].
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 for all EGU units modeled by EPA's Integrated Planning Model (IPM).
e. Data for airports and rail yards were incorporated.
f. Off-shore platform data were added from the Bureau of Ocean Energy Management (BOEM).

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

- The tribal data, which do not use state/county Federal Information Processing Standards (FIPS) codes in the NEI, but rather use the tribal code, were assigned a state/county FIPS code of 88XXX, where XXX is the 3-digit tribal code in the NEI. This change was made because SMOKE requires all sources to have a state/county FIPS code.
- Sources that did not have specific counties assigned (i.e., the county code ends in 777) were not included in the modeling because it was only possible to know the state in which the sources resided, but no more specific details related to the location of the sources were available.

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

2.1.1 EGU sector (ptegu)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- CEMS data were updated based on data downloaded on February 19, 2025.
- Some additional matches to CEMS data were incorporated along with other minor changes.
- CEMS data matching was improved for units where multiple CEMS units align with a single EIS unit.

General Description

The ptegu sector contains emissions from EGUs in the 2022 point source inventory that could be matched to units found in the National Electric Energy Database System (NEEDS) v6 that is used by the Integrated Planning Model (IPM) to develop projected 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 were placed into the pt_oilgas or ptnonipm sectors. For studies that include analytic years, the sources in the ptegu sector are fully replaced with analytic year emissions computed by IPM or through engineering analysis.

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 analytic year modeling scenarios if emissions for units projected by IPM are not properly matched to the units in the base year point source inventory. For details on the differences in the ptegu sector between the 2022v1, 2022v2 draft, and 2022v2 final cases, see the spreadsheets that compare emissions at facility and unit-level, stack parameters, and locations available in the reports/point area of the 2022v2 FTP site.

The 2022 ptegu emissions inventory is a subset of the point source flat file exported from the Emissions Inventory System (EIS). In the point source flat file, emission records for sources that have been matched to the NEEDS database have a value filled into the IPM_YN column based on the matches stored within EIS. Thus, unit-level emissions were split into a separate EGU flat file for units that have a populated (non-null) ipm_yn field. A populated ipm_yn field indicates that a match was found for the EIS unit in the NEEDS database. Updates were made to the flat file output from EIS as follows:

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

Some units in the ptegu sector are matched to Continuous Emissions Monitoring System (CEMS) data via Office of Regulatory Information System (ORIS) facility codes and boiler IDs. For the matched units, the annual emissions of NO_X and SO_2 in the flat file were replaced with the hourly CEMS emissions in base year modeling. For other pollutants at matched units, the hourly CEMS heat input data were used to allocate the NEI annual emissions to hourly values. All stack parameters, stack locations, and Source Classification Codes (SCCs) for these sources come from the flat file. If CEMS data exists for a unit, but the unit is not matched to the NEI, the CEMS data for that unit were not used in the modeling platform. However, if the source exists in the NEI and is not matched to a CEMS unit, the emissions from that source are still modeled using the annual emission value in the NEI temporally allocated to hourly values.

EIS stores many matches from NEI units to the ORIS facility codes and boiler IDs used to reference the CEMS data. In the flat file, emission records for point sources matched to CEMS data have values filled into the ORIS_FACILITY_CODE and ORIS_BOILER_ID columns. The CEMS data are available at https://campd.epa.gov/data. Many smaller emitters in the CEMS program cannot be matched to the NEI due to differences in the way a unit is defined between the NEI and CEMS datasets, or due to uncertainties in source identification such as inconsistent plant names in the two data systems. In addition, the NEEDS database of units modeled by IPM includes many smaller emitting EGUs that do not have CEMS. Therefore, there will be more units in the ptegu sector than have CEMS data.

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

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

2.1.2 Point source oil and gas sector (pt_oilgas)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Some sources were updated to correct double counts, closures, old data, and some other changes.
- Overall emissions changes were minor. In total, nationwide NOx emissions increased by 98 tons and nationwide VOC emissions decreased by 1,354 tons.

General Description

The pt_oilgas sector was separated from the ptnonipm sector by selecting sources with specific North American Industry Classification System (NAICS) codes shown in Table 2-2. The emissions and other source characteristics in the pt_oilgas sector are submitted by states, while EPA developed a dataset of nonpoint oil and gas emissions for each county in the U.S. with oil and gas activity that was available for states to use. Nonpoint oil and gas emissions can be found in the np_oilgas sector. The pt_oilgas sector includes emissions from offshore oil platforms. Where available, the point source emissions submitted as part of the 2022 NEI process with refinements based on the Collaborative data review process were used. Sources without data submitted for 2022 were projected to 2022 from 2020 NEI emissions, or where applicable, from 2021 NEI emissions. For details on the differences in the pt_oilgas sector between the 2022v1, 2022v2 draft, and 2022v2 final cases, see the spreadsheets that compare emissions at facility and unit-level, stack parameters, and locations available in the reports/point area of the 2022v2 FTP site

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

NAICS	NAICS description
2111	Oil and Gas Extraction
211112	Natural Gas Liquid Extraction (although no emissions for this NAICS code exist in the 2022 inventory)
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

NAICS	NAICS description
48621	Pipeline Transportation of Natural Gas
486210	Pipeline Transportation of Natural Gas

Information on the development of the 2020 NEI oil and gas emissions can be found in Section 13 of the 2020 NEI TSD. The point oil and gas emissions for 2022 by state are shown in Table 2-3.

Table 2-3. Point source oil and gas sector emissions for 2022v2

State	2022 NOx	2022 VOC
Alabama	10,608	1,209
Alaska	38,698	1,730
Arizona	2,374	180
Arkansas	4,029	320
California	2,597	2,264
Colorado	13,359	10,470
Connecticut	59	35
Delaware	6	1
Florida	6,192	696
Georgia	3,114	526
Idaho	1,291	38
Illinois	4,571	1,039
Indiana	949	136
Iowa	3,962	223
Kansas	17,766	3,009
Kentucky	9,201	1,125
Louisiana	27,875	8,243
Maine	32	64
Maryland	186	123
Massachusetts	235	69
Michigan	9,134	990
Minnesota	2,377	172
Mississippi	22,452	1,930
Missouri	2,342	92
Montana	815	1,035
Nebraska	2,757	266
Nevada	236	22
New Jersey	95	94
New Mexico	34,980	63,796
New York	1,072	256
North Carolina	1,681	237
North Dakota	4,197	2,736
Ohio	8,828	1,584
Oklahoma	33,937	26,131

State	2022 NOx	2022 VOC
Oregon	1,019	94
Pennsylvania	3,027	918
Puerto Rico	0	0
Rhode Island	39	25
South Carolina	315	121
South Dakota	358	10
Tennessee	6,452	532
Texas	46,844	20,622
Utah	2,453	652
Virginia	2,725	428
Washington	874	56
West Virginia	8,335	3,263
Wisconsin	429	204
Wyoming	13,165	50,572
Offshore	34,660	30,911
Tribal Data	7,859	2,220

2.1.3 Aircraft and ground support equipment (airports)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Smaller airports were reprojected from 2020 to 2022 using updated projection factors based on the 2024 TAF, an update compared to the 2023 TAF that was used in 2022v1.
- Locations were updated to match latitude and longitudes in EIS as of April 28, 2025.
- Other updates were incorporated in Georgia and Washington.

General Description

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. Additional information about aircraft emission estimates can be found in section 3 of the 2020 NEI TSD (EPA, 2023). EPA ran AEDT for 2022 for the largest (51) airports in the United States. For more information on the estimation of emissions from larger airports, please see, 2022 National Emissions Inventory: Aviation Component (ERG, 2024a). Smaller airport emissions were projected from the 2020 NEI to 2022 using factors derived from the 2024 Terminal Area Forecast (TAF)[3] data. EPA used airport-specific factors where available. In 2022v2, emissions for Hartsfield-Jackson (ATL) airport were updated based on data provided by Georgia EPD based on the AEDT version 3g. Airport emissions were spread out into multiple 12km grid cells when the airport runways were determined to overlap multiple grid cells. Otherwise, airport emissions for a specific airport are confined to one air quality model grid cell. The SCCs included in the airport sector are shown in Table 2-4. Additional information about aircraft

[3] See https://www.faa.gov/data_research/aviation/taf for the 2024 TAF released January 2025

emission estimates can be found in section 3 of the 2020 NEI TSD (EPA, 2023). Additional updates in 2022v2 were to remove military aircraft emissions (SCC=2275001000) from Kenmore Air Harbor (12141411) in Washington and to update locations to match latitudes and longitudes in EIS as of April 28, 2025. For details on the differences in the airports sector between the 2022v1, 2022v2 draft, and 2022v2 final cases, see the spreadsheets that compare emissions at facility and unit-level, stack parameters, and locations available in the reports/point area of the 2022v2 FTP site.

Table 2-4. 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	Total
2270008005	Mobile Sources	Off-highway Vehicle Diesel	Airport Ground Support Equipment	Total
2275001000	Mobile Sources	Aircraft	Military Aircraft	Total
2275020000	Mobile Sources	Aircraft	Commercial Aircraft	Total: All Types
2275050011	Mobile Sources	Aircraft	General Aviation	Piston
2275050012	Mobile Sources	Aircraft	General Aviation	Turbine
2275060011	Mobile Sources	Aircraft	Air Taxi	Piston
2275060012	Mobile Sources	Aircraft	Air Taxi	Turbine
2275070000	Mobile Sources	Aircraft	Auxiliary Power Units	Total

2.1.4 Non-IPM sector (ptnonipm)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Changes were made to one DC rail yard between 2022v1 and v2 due to comments.
- Stack parameter and latitude/longitude location changes available prior to August 12, 2025 were incorporated.
- Added a new sector 'ptnonipm_hr' which includes nonEGUs with hourly emissions data. This includes hourly CEMs data for select nonEGUs, and also hourly emissions data at Taconite mines in Minnesota. The units in the ptnonipm_hr sector had previously been part of the ptnonipm sector.
- Utah provided emissions from trucks at Kennecott mine to be included in 2022v2 final.

General Description

With some exceptions, the ptnonipm sector contains the point sources that are not in the ptegu, pt_oilgas, or airports sectors. For the most part, the ptnonipm sector reflects non-EGU emissions sources and rail yards. However, it is possible that some low-emitting EGUs not matched to units in the NEEDS database or to CEMS data are in the ptnonipm sector. For details on the differences in the ptnonipm sector between the 2022v1 (2022hc), 2022v2 draft (2022hd), and 2022v2 final (2022he) cases, see the spreadsheets that compare emissions at facility and unit-level, stack parameters, and locations available in the reports/point area of the 2022v2 FTP site.

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

The ptnonipm sources (i.e., not EGUs and non -oil and gas sources) were used as-is from the 2022 NEI point inventory following updates from the Collaborative review. Solvent emissions from point sources were removed from the np_solvents sector to prevent double-counting, so that all point sources can be retained in the modeling as point sources rather than as area sources. The modeling was based on the point flat file exported from EIS on August 12, 2025, and included updates from the Collaborative review process for the 2022 base year, and updates specific to ethylene oxide. The np_solvents sector is described in more detail in Section 2.2.6.

Emissions from rail yards are included in the ptnonipm sector. Railyards are from the 2020 NEI railyard inventory with a projection factor applied. Additional information about railyard estimates can be found in section 3 of the 2020 NEI TSD.

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

This section describes the *stationary* nonpoint sources in the NEI nonpoint data category. Locomotives, C1 and C2 CMV, and C3 CMV are included in the NEI nonpoint data category but are mobile sources that are described in Section 2.4. The 2020 NEI TSD includes documentation for the nonpoint data.

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

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

2.2.1 Area fugitive dust sector (afdust)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Changes were incorporated that impact Oregon's unpaved road dust emissions. Specifically, new emissions were submitted by the State that reduced emissions by 46%.

General Description

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. Table 2-5 is a listing of the Source Classification Codes (SCCs) in the afdust sector.

Table 2-5. Afdust sector SCCs

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
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
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
2805100010	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Beef cattle - finishing operations on feedlots (drylots)
2805100020	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Dairy Cattle
2805100030	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Broilers
2805100040	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Layers
2805100050	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Swine
2805100060	Miscellaneous Area Sources	Ag. Production – Livestock	Dust kicked up by Livestock	Turkeys

Area Fugitive Dust Transportable Fraction Adjustments

The afdust sector was separated from other nonpoint sectors to allow for the application of a "transportable fraction" and meteorological/precipitation reductions. These adjustments were applied using a script that applies land use-based gridded transport fractions based on landscape roughness, followed by another script that performs meteorological adjustments 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. For example, less dust would be transported on a forest floor, than would be on an open plain. This methodology is discussed in Pouliot, et al., 2010, and in "Fugitive Dust Modeling for the 2008

Emissions Modeling Platform" (Adelman, 2012). Both the transportable 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 transportable fraction approach is the lack of monthly variability that would be expected with seasonal changes in vegetative cover. While wind speed and direction were not accounted for in the emissions processing, the hourly variability due to soil moisture, snow cover and precipitation were accounted for in the subsequent meteorological adjustment. The factor is treated as a multiplicative factor for the emissions. Thus, if the factor is 1 (i.e., water), the dust emissions are not reduced at all, and if the factor is near 0, the emissions are substantially reduced.

Area Fugitive Dust 2020-2022 Projection Factors

Paved road dust emissions were from the 2020 NEI adjusted to 2022 levels based on changes between 2020 and 2022 VMT. Dust from livestock hooves were also adjusted based on ratios of 2022 to 2020 livestock counts but all other types of dust emissions were held constant from 2020 to 2022. For the fugitive dust emissions compiled into the 2020 NEI, meteorological adjustments were applied to paved and unpaved road SCCs but not transport-related adjustments. This is because the modeling platform applies meteorological adjustments and transportable fraction adjustments based on unadjusted NEI values. For the 2022 platform, the meteorological adjustments that were applied in the NEI for the paved and unpaved road SCCs were backed out and reapplied in SMOKE at an hourly resolution for each grid cell. The FF10 that is run through SMOKE consists of 100% unadjusted emissions, and after SMOKE all afdust sources have both transportable and meteorological adjustments applied according to year 2022 meteorology. The total impacts of the transportable fraction and meteorological adjustments are shown in Table 2-6.

Table 2-6. Total impact of 2022v2 fugitive dust adjustments to the unadjusted inventory

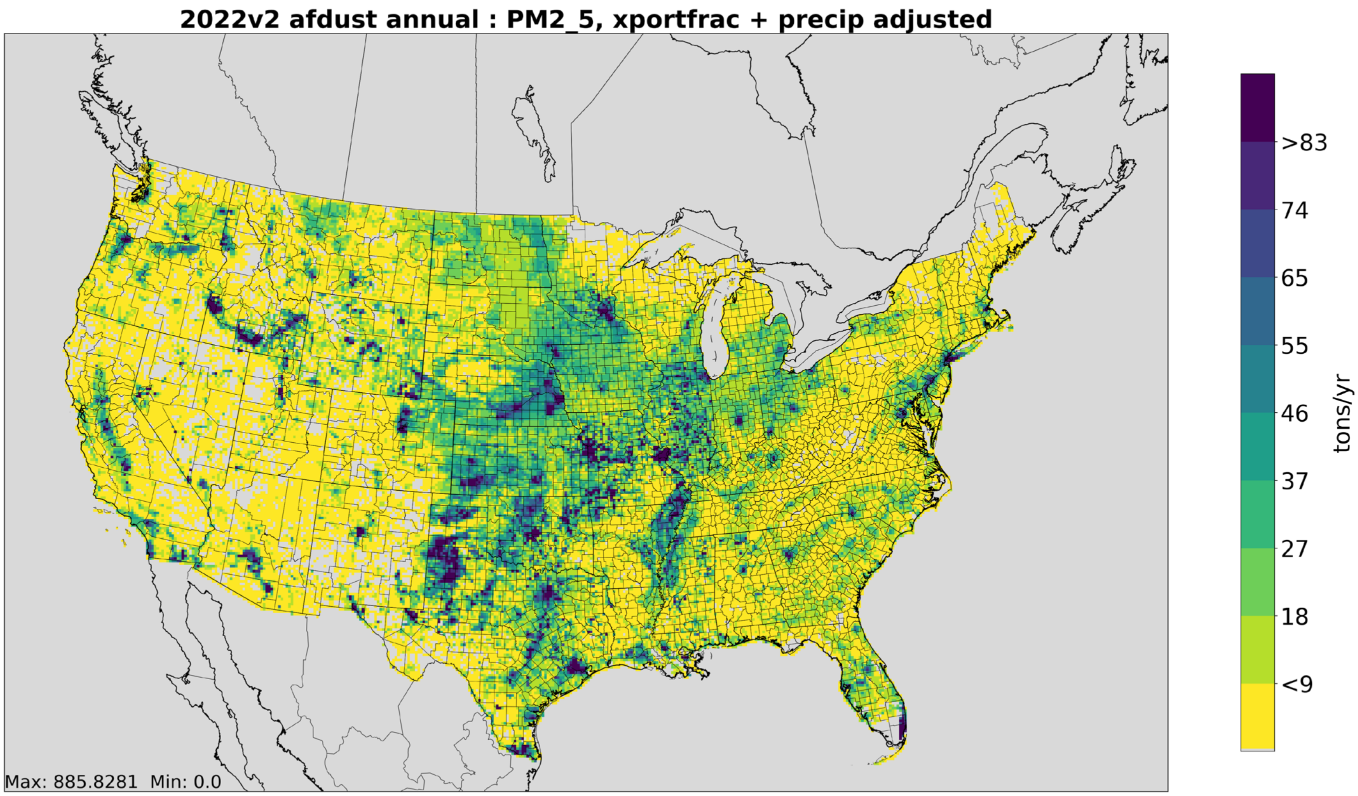
State	Unadjusted PM_{10}	Unadjusted $PM_{2.5}$	Change in PM_{10}	Change in $PM_{2.5}$	PM_{10} Reduction	$PM_{2.5}$ Reduction
Alabama	274,336	35,494	-202,370	-25,973	73.8%	73.2%
Arizona	153,731	20,858	-56,313	-7,483	36.6%	35.9%
Arkansas	398,457	55,506	-276,219	-37,440	69.3%	67.5%
California	336,443	43,093	-141,194	-17,535	42.0%	40.7%
Colorado	276,997	39,377	-145,228	-19,465	52.4%	49.4%
Connecticut	21,526	3,333	-15,606	-2,409	72.5%	72.3%
Delaware	16,535	2,554	-9,629	-1,485	58.2%	58.2%
District of Columbia	3,494	477	-2,325	-318	66.5%	66.6%
Florida	215,212	34,456	-117,215	-18,331	54.5%	53.2%
Georgia	296,225	41,844	-218,951	-30,621	73.9%	73.2%
Idaho	496,108	58,552	-288,360	-32,350	58.1%	55.3%
Illinois	702,578	90,846	-423,467	-53,836	60.3%	59.3%
Indiana	160,577	29,875	-98,424	-18,304	61.3%	61.3%
Iowa	370,922	54,793	-207,350	-29,994	55.9%	54.7%
Kansas	583,732	79,848	-238,579	-31,990	40.9%	40.1%

State	Unadjusted PM_{10}	Unadjusted $PM_{2.5}$	Change in PM_{10}	Change in $PM_{2.5}$	PM_{10} Reduction	$PM_{2.5}$ Reduction
Kentucky	179,629	29,151	-127,895	-20,583	71.2%	70.6%
Louisiana	196,181	29,769	-125,926	-18,865	64.2%	63.4%
Maine	41,717	5,878	-33,150	-4,674	79.5%	79.5%
Maryland	60,743	8,821	-39,057	-5,685	64.3%	64.4%
Massachusetts	63,722	8,640	-46,290	-6,146	72.6%	71.1%
Michigan	293,285	38,837	-199,932	-26,156	68.2%	67.3%
Minnesota	537,979	72,776	-331,440	-43,421	61.6%	59.7%
Mississippi	439,287	52,963	-320,366	-37,939	72.9%	71.6%
Missouri	1,439,199	165,014	-960,867	-108,935	66.8%	66.0%
Montana	498,406	66,114	-321,177	-40,534	64.4%	61.3%
Nebraska	507,702	69,197	-194,207	-25,958	38.3%	37.5%
Nevada	125,368	16,303	-43,345	-5,651	34.6%	34.7%
New Hampshire	16,102	3,307	-12,904	-2,645	80.1%	80.0%
New Jersey	36,477	7,100	-23,640	-4,526	64.8%	63.7%
New Mexico	176,997	22,719	-74,020	-9,334	41.8%	41.1%
New York	264,168	37,984	-196,585	-27,826	74.4%	73.3%
North Carolina	257,146	35,016	-183,489	-24,794	71.4%	70.8%
North Dakota	360,358	55,646	-197,012	-29,402	54.7%	52.8%
Ohio	276,882	43,091	-188,813	-29,160	68.2%	67.7%
Oklahoma	562,803	77,603	-279,109	-37,512	49.6%	48.3%
Oregon	440,531	52,819	-321,308	-36,850	72.9%	69.8%
Pennsylvania	149,280	26,152	-106,530	-18,937	71.4%	72.4%
Rhode Island	6,003	1,006	-4,058	-675	67.6%	67.1%
South Carolina	190,577	25,236	-137,313	-18,038	72.1%	71.5%
South Dakota	210,669	37,092	-95,151	-16,443	45.2%	44.3%
Tennessee	141,443	26,022	-98,464	-18,128	69.6%	69.7%
Texas	1,540,940	214,891	-691,053	-94,831	44.8%	44.1%
Utah	142,084	18,020	-81,037	-9,996	57.0%	55.5%
Vermont	58,010	6,495	-50,080	-5,574	86.3%	85.8%
Virginia	138,872	22,095	-106,660	-17,030	76.8%	77.1%
Washington	174,558	21,778	-101,154	-12,685	57.9%	58.2%
West Virginia	70,339	9,842	-62,594	-8,733	89.0%	88.7%
Wisconsin	202,901	34,398	-135,262	-22,891	66.7%	66.5%
Wyoming	588,124	62,948	-332,646	-35,217	56.6%	55.9%
Domain Total (12km CONUS)	**14,695,356**	**1,995,630**	**-8,663,762**	**-1,153,305**	**59.0%**	**57.8%**

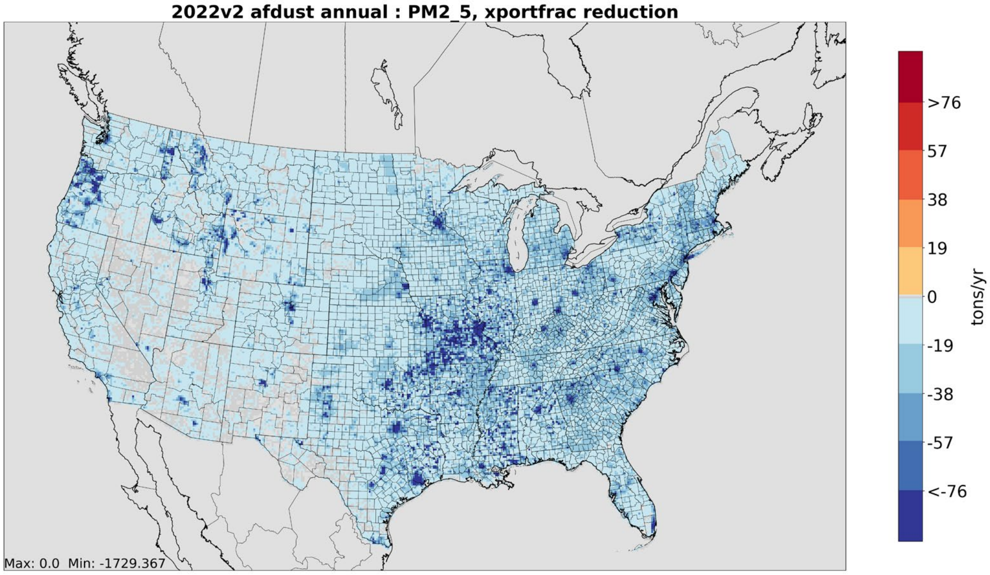
For categories other than paved roads, where states submitted afdust data to the NEI, it was assumed that the state-submitted data were not met-adjusted and therefore the meteorological adjustments were applied.

Figure 2-1 illustrates the impact of each step of the adjustment. The reductions due to the transportable 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.

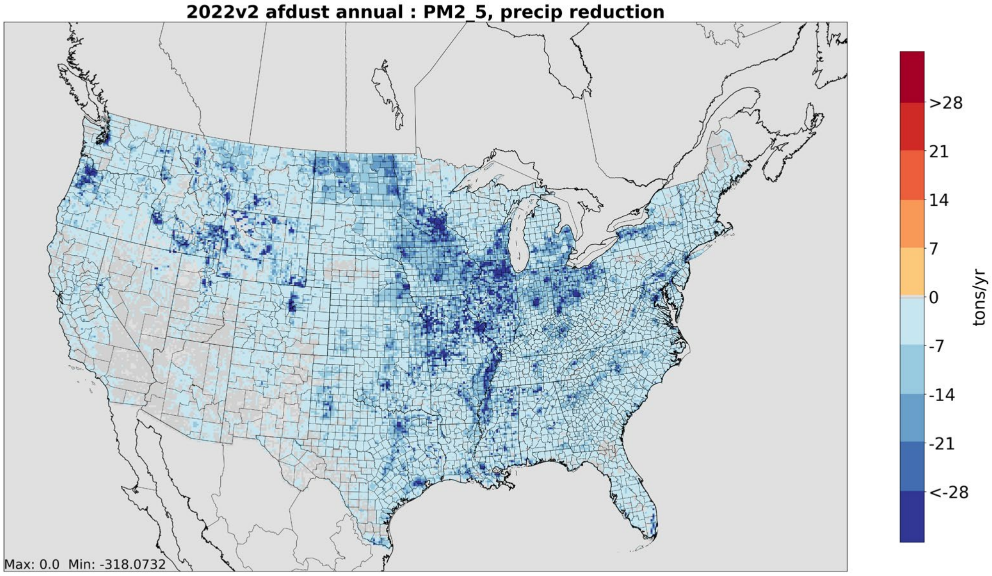
Figure 2-1. Fugitive dust emissions and impact of adjustments due to transportable fraction, precipitation, and cumulative



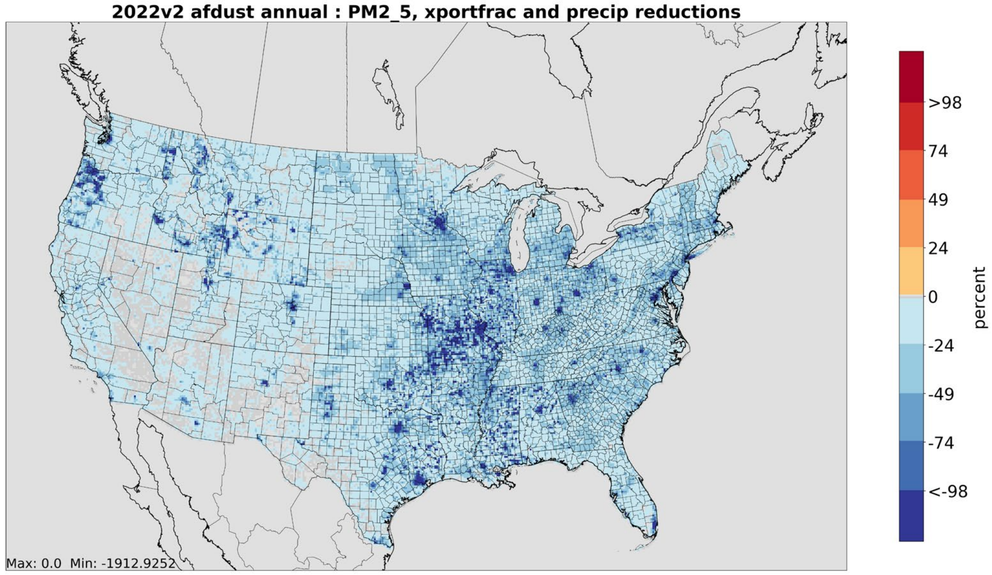
2022v2 afdust annual : PM2_5, xportfrac reduction



2022v2 afdust annual : PM2_5, precip reduction



2022v2 afdust annual : PM2_5, xportfrac and precip reductions



2.2.2 Agricultural Livestock (livestock)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Changes were incorporated for Maricopa County. Specifically, these updates slightly changed VOC emissions for dairy and beef cattle.

General Description

The livestock SCCs are shown in Table 2-7. The livestock emissions 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 all 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 for all pollutants other than $PM_{2.5}$, since $PM_{2.5}$ from dust kicked up from livestock hooves are included in the afdust sector.

Agricultural livestock emissions in the 2022 platform were developed using methods similar to those used to develop the 2020 NEI, which is a mix of state-submitted data and EPA estimates. The 2020 NEI approach for estimating livestock emissions utilizes daily emission factors by animal and county from a model developed by Carnegie Mellon University (CMU) (Pinder, 2004, McQuilling, 2015) and 2020 U.S. Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) survey. Details on the approach used to develop livestock emissions for the 2020 NEI are provided in Section 10 of the 2020 NEI TSD. Animal populations used for estimating livestock emissions came from 2022 USDA survey data (see QuickStats at https://quickstats.nass.usda.gov) for the available counties. The FEM model was run for 2022 using the 2022 animal counts and meteorological data for 2022 to create the emission inventories for the livestock sector.

Table 2-7. SCCs for the livestock sector

SCC	Tier 1 description	Tier 2 description	Tier 3 description	Tier 4 description
2805002000	Miscellaneous Area Sources	Ag. Production – Livestock	Beef cattle production composite	Not Elsewhere Classified
2805007100	Miscellaneous Area Sources	Ag. Production – Livestock	Poultry production - layers with dry manure management systems	Confinement
2805009100	Miscellaneous Area Sources	Ag. Production – Livestock	Poultry production - broilers	Confinement
2805010100	Miscellaneous Area Sources	Ag. Production – Livestock	Poultry production - turkeys	Confinement
2805018000	Miscellaneous Area Sources	Ag. Production – Livestock	Dairy cattle composite	Not Elsewhere Classified
2805025000	Miscellaneous Area Sources	Ag. Production – Livestock	Swine production composite	Not Elsewhere Classified (see also 28-05-039, -047, -053)
2805035000	Miscellaneous Area Sources	Ag. Production – Livestock	Horses and Ponies Waste Emissions	Not Elsewhere Classified
2805040000	Miscellaneous Area Sources	Ag. Production – Livestock	Sheep and Lambs Waste Emissions	Total
2805045000	Miscellaneous Area Sources	Ag. Production – Livestock	Goats Waste Emissions	Not Elsewhere Classified

2.2.3 Agricultural Fertilizer (fertilizer)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

General Description

As described in the 2020 NEI TSD, fertilizer emissions were based on the FEST-C model (https://www.cmascenter.org/fest-c/). Unlike most of the other emissions input to the CMAQ model, fertilizer emissions are computed during a run of CMAQ in bi-directional mode and are output during the model run. The bidirectional version of CMAQ (v5.4) 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 so they can be included in emissions summaries and in other model runs that do not use the bidirectional method.

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

An iterative calculation was applied to estimate fertilizer emissions. First, fertilizer application by crop type was estimated using FEST-C modeled data. To develop the emissions for this platform, CMAQ v5.4 was run with the M3DRY option to develop the fertilizer emissions. Note that this was a different option than was used for the 2020 NEI (see the 2020 NEI TSD for more details).

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 year 2022 using a national 12-km rectangular grid covering the continental U.S. The meteorological parameters in Table 2-8 were used as EPIC model inputs.

Table 2-8. Source of input variables for EPIC

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

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

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

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

Management activity data refers to data used to estimate representative crop management schemes. The USDA Agricultural Resource Management Survey (ARMS, ARMS Farm Financial and Crop Production Practices | Economic Research Service) was used to provide management activity data. These data cover 10 USDA production regions and provide management schemes for irrigated and rain fed hay, alfalfa, grass, barley, beans, grain corn, silage corn, cotton, oats, peanuts, potatoes, rice, rye, grain sorghum, silage sorghum, soybeans, spring wheat, winter wheat, canola, and other crops (e.g., lettuce, tomatoes, etc.).

2.2.4 Nonpoint Oil and Gas Sector (np_oilgas)

2022v2 updates relative to earlier 2022 emissions modeling platforms

The 2022v2 emissions changes for the non-point oil and gas sector included the following:

- Nonroad emissions factor correction which significantly reduced NOX emissions (about 74%) from drill rigs and hydraulic fracturing engines
- Colorado emissions inventory update (submitted by Colorado)
    - NOX up about 5% statewide; VOC emissions reduced about 60%
    - The VOC reduction was mainly due to control devices on storage tanks and pneumatic devices being recognized in 2022he but not in 2022hc
- Removing NH3 emissions from Texas compressor engines (minor change)
- North Dakota dehydrator VOC emissions (SCC 2310021400) were removed from non-point oil and gas sector
- Minor activity updates and emissions impacts
    - Updated with 2022 Kentucky county-level data
    - Updated Arizona to actual oil and gas production for 2022 from state reports; EIA adjustments in 2022v1 no longer used
    - Reassignment of wells within 3 nautical miles of Louisiana's coast
    - Harmonization of oil, natural gas and coal-bed methane well types with the 2023 oil and gas well datasets resulting in minor changes in five states (AL, AZ, CA, LA and MI)
    - The above minor activity changes resulted in minor changes to blowdown/pigging emissions in 2022v2
    - The above minor activity changes resulted in new gridding surrogates, monthly profiles and chemical speciation cross-reference data being generated and used in 2022v2
    - All of these minor activity changes in 2022he resulted in minor changes in emissions in np_oilgas sector

General Description

The nonpoint oil and gas (np_oilgas) sector includes onshore and offshore oil and gas emissions. The EPA estimated emissions for all counties with 2022 oil and gas activity data using the Oil and Gas Tool. The types of sources covered include drill rigs, workover rigs, artificial lift, hydraulic fracturing engines, pneumatic pumps and other devices, storage tanks, flares, truck loading, compressor engines, and dehydrators. Because of the importance of emissions from this sector, special consideration was given to the speciation, spatial allocation, and monthly temporalization of nonpoint oil and gas emissions, instead of relying on older, more generalized profiles.

The 2020 NEI version of the Nonpoint Oil and Gas Emission Estimation Tool (i.e., the "NEI oil and gas tool") populated with 2022-specific activity data and updated with Subpart W data was used to estimate 2022. Year 2022 oil and gas activity data were obtained from the Enverus activity database (www.enverus.com) and supplied by some state air agencies. The NEI oil and gas 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 was used to create a CSV-formatted emissions dataset covering all national nonpoint oil and gas emissions. This dataset was converted to the FF10 format for use in SMOKE modeling. More details on the inputs for and running of the tool for 2020 are provided in the 2020 NEI TSD.

While most states' np_oilgas emissions are from the NEI oil and gas tool, production-related emissions in Oklahoma and Wyoming were projected from 2020NEI to 2022 at the request of those states. These projected emissions were included in 2022v1 and 2022v2 platforms in place of the production emissions from the tool in those two states. Projection factors were provided by the corresponding state agencies; Oklahoma incorporated separate projection factors for oil SCCs, gas SCCs, condensate SCCs, and SCCs with a mix of oil and gas activity, each applied state-wide, while Wyoming used county-specific projection factors for oil, gas, and mixed SCCs.

Table 2-9 shows the nonpoint oil and gas NOx and VOC emissions for 2022 by state. The Colorado emissions in this table include updated emissions for the state developed from the Oil and Gas Tool and state-submitted emissions, along with emissions submitted to the 2020 NEI within the Southern Ute reservation that are still used in this 2022 platform. For spatial allocation purposes, the Southern Ute oil and gas emissions – totaling 11,663 tons/yr of NOx and 879 tons/yr of VOC - were allocated to Colorado counties, with 95% of the emissions in La Plata County (FIPS 08067) and 5% of the emissions in Archuleta County (FIPS 08007).

Table 2-9. Nonpoint oil and gas emissions for 2022v2

State	2022 NOx	2022 VOC
Alabama	3,922	11,656
Alaska	2,777	9,664
Arizona	12	137
Arkansas	4,537	8,524
California	1,202	27,847
Colorado	31,161	22,174
Florida	19	1,123
Georgia	0	0
Idaho	10	99
Illinois	13,849	49,499
Indiana	2,676	13,338
Iowa	0	0
Kansas	22,858	62,635
Kentucky	16,186	42,782
Louisiana	14,001	52,998
Maryland	1	2
Michigan	10,419	13,240
Minnesota	0	0
Mississippi	1,784	17,382
Missouri	232	554
Montana	1,658	31,975
Nebraska	238	1,777
Nevada	3	160
New Mexico	61,889	280,801
New York	880	7,133
North Carolina	0	0

State	2022 NOx	2022 VOC
North Dakota	31,937	221,171
Ohio	2,529	30,870
Oklahoma	36,830	170,061
Oregon	6	20
Pennsylvania	57,413	139,815
South Dakota	190	1,291
Tennessee	1,051	3,272
Texas	236,839	1,338,693
Utah	8,269	69,853
Virginia	3,820	7,883
Washington	0	3
West Virginia	24,863	77,702
Wyoming	841	8,529

A new source was added to the oil and gas sector starting with the 2020 NEI: Pipeline Blowdowns and Pigging (SCC= 2310021801) emissions were estimated using US EPA Greenhouse Gas Reporting Program (GHGRP) data. These Pipeline Blowdowns and Pigging emissions for the year 2022 included county-level estimates of VOC, benzene, toluene, ethylbenzene, and xylene (BTEX). These emissions estimates were calculated outside of the Oil and Gas Tool and submitted to EIS separately from the Oil and Gas Tool emissions. These emissions were considered EPA default emissions and SLTs had the opportunity to submit their own Pipeline Blowdowns and Pigging (e.g., Utah) emissions and/or accept/omit these emissions using the Nonpoint Survey. Unfortunately, these EPA default Pipeline Blowdowns and Pigging emissions did not get into the 2020 NEI release for the states that accepted these emissions due to EIS tagging issues. These emissions were included in this 2022 Emissions Modeling Platform. Table 2-10 shows the emissions totals by state for Pipeline Blowdowns and Pigging sources. Note that Colorado emissions are not included in this table because the inventory provided by Colorado includes these.

An additional new source of abandoned oil and gas well emissions in the USA was added to the oil and gas sector starting with the 2021 modeling platform and also included in this 2022 platform although unchanged from the 2022v1 platform levels. . The term "abandoned wells" encompasses various types of wells:

- Wells with no recent production, and not plugged. Common terms (such as those used in state databases) might include inactive, temporarily abandoned, shut-in, dormant, and idle.
- Wells with no recent production and no responsible operator. Common terms might include orphaned, deserted, long-term idle, and abandoned.
- Wells that have been plugged to prevent migration of gas or fluids.

As of year 2022, there were approximately 3.7 million abandoned wells in the U.S., with around 2.3 million abandoned oil wells, 0.6 million abandoned gas wells, and 0.8 million abandoned dry wells (may be oil or gas wells). Abandoned wells may emit CH_4, CO_2, VOC, and various HAP. These emissions are unchanged from the 2022v1 platform levels.

Estimates of greenhouse gas (GHG) emissions (CH_4 and CO_2) from abandoned wells have been estimated as part of the Inventory of U.S. Greenhouse Gas Emissions and Sinks since 2018. Currently, the inventory from 1990 – 2022 is available[4]. The GHG inventory (GHGI) methodology and estimates of emissions from abandoned wells served as the starting point for development of the VOC and HAP emissions inventory for abandoned wells used in this year 2022 modeling platform. Year 2022 estimates of VOC and BTEX were estimated and used in this 2022 modeling platform.

Table 2-11 shows the emissions totals by state for Pipeline Blowdowns and Pigging sources. The inventories for blowdowns and pigging and abandoned wells are separate from the emissions output from the oil and gas tool.

Table 2-10. State emissions totals for year 2022v2 for pipeline blowdowns and pigging sources

State	VOC (tpy)	Benzene (tpy)	Ethylbenzene (tpy)	Toluene (tpy)	Xylene (tpy)
Alabama	350	1.38	0.07	1.18	0.36
Alaska	14	0.06	0.00	0.06	0.02
Arizona	97	0.44	0.02	0.39	0.11
Arkansas	22	0.01		0.00	0.00
California	146	0.67	0.04	0.59	0.17
Florida	2	0.00	0.00	0.00	0.00
Illinois	209	0.77	0.04	0.68	0.19
Indiana	29	0.05	0.00	0.04	0.01
Kansas	1,326	2.34	0.27	1.98	0.86
Kentucky	657	2.97	0.17	2.65	0.75
Louisiana	366	3.01	0.00	0.30	0.51
Maryland	0	0.00	0.00	0.00	0.00
Michigan	239	1.08	0.06	0.97	0.27
Mississippi	2,162	3.32	0.07	1.28	1.07
Missouri	4	0.00	0.00	0.00	0.00
Montana	147	0.67	0.04	0.59	0.17
Nebraska	57	0.14	0.01	0.17	0.05
New Mexico	1,044				
New York	143	0.65	0.04	0.58	0.16
North Dakota	9	0.04	0.00	0.04	0.01
Ohio	388	1.76	0.10	1.57	0.45
Oklahoma	2,004	1.47	0.09	1.16	0.89
Oregon	8	0.04	0.00	0.03	0.01
Pennsylvania	66	0.30	0.02	0.27	0.08
South Dakota	2	0.01	0.00	0.01	0.00
Tennessee	13	0.06	0.00	0.05	0.02
Texas	9,599	9.05	0.24	3.82	3.23
Utah	18	0.09	0.01	0.08	0.04
Virginia	190	0.86	0.05	0.77	0.22
West Virginia	879	3.99	0.23	3.55	1.01
Wyoming	680	4.19	0.33	2.04	1.34
US total	**20,869**	**39.44**	**1.90**	**24.89**	**12.00**

[4] Inventory of U.S. Greenhouse Gas Emissions and Sinks | US EPA

Table 2-11. State emissions totals for year 2022 for abandoned wells sources

State	2022 VOC (tpy)
Alabama	198
Alaska	64
Arizona	10
Arkansas	794
California	5,357
Colorado	451
Florida	32
Georgia	0
Idaho	0
Illinois	6,738
Indiana	3,326
Iowa	0
Kansas	6,663
Kentucky	12,817
Louisiana	3,195
Maryland	1
Michigan	487
Minnesota	0
Mississippi	749
Missouri	118
Montana	740
Nebraska	141
Nevada	34
New Mexico	348
New York	596
North Carolina	0
North Dakota	401
Ohio	22,286
Oklahoma	8,944
Oregon	3
Pennsylvania	69,730
South Dakota	31
Tennessee	1,329
Texas	31,588
Utah	178
Virginia	69
Washington	3
West Virginia	2,723
Wyoming	552
US Total	**180,694**

Lastly, EPA and the state of Oklahoma, New Mexico and Kansas worked together to exercise the point source subtraction step in the Oil and Gas Tool during the 2022 platform development period. This point source subtraction step is a process used to eliminate possible double counting of sources in the Oil and Gas Tool that are already defined in the point source inventory.

2.2.5 Residential Wood Combustion (rwc)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- For 2022v2, emissions were calculated and allocated based on new methods developed for the 2023 NEI which includes the use of many new SCCs.

General Description

The residential wood combustion (rwc) sector includes residential wood burning devices such as fireplaces, fireplaces with inserts (inserts), free standing woodstoves, pellet stoves, outdoor hydronic heaters (also known as outdoor wood boilers), indoor furnaces, and outdoor burning in firepots and chimeneas. Free standing woodstoves and inserts are further differentiated into three categories: 1) conventional (not EPA certified); 2) EPA certified, catalytic; and 3) EPA certified, noncatalytic. Generally speaking, the conventional units were constructed prior to 1988. Units constructed after 1988 have to meet EPA emission standards and they are either catalytic or non-catalytic. As with the other nonpoint categories, a mix of S/L and EPA estimates were used. The EPA's estimates use updated methodologies for activity data and some changes to emission factors. The source classification codes (SCCs) in the rwc sector are listed in Table 2-12 which shows SCCs new to the 2022v2 platform in *italics*.

For states and counties in which 2020NEI RWC emissions were based on S/L data, 2022v2 platform RWC emissions are adjusted from 2020 NEI using SEDS data for 2021, and converted to 2023NEI-consistent SCCs. This includes Alaska, Minnesota, Oregon, Texas, Vermont, Washington, Maricopa County in Arizona, and Washoe County in Nevada. Additionally, Idaho provided updated RWC emissions data for the final version of 2022v2 platform using the same new SCCs. In California, 2022v2 RWC emissions for SCCs 2104008100 (all pollutants) and 2104008011/2104008021/2104008031 (all pollutants except NH3) are based on data provided by CARB, while all other SCCs in California use EPA estimates.

Some improvements to RWC emissions estimates were developed as part of the 2020 NEI process. 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 were 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 were 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 27 of the 2020 NEI TSD.

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

SCC	Tier 1 Description	Tier 2 Description	Tier 3 Description	Tier 4 Description
2104008011	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Woodstove: non-EPA certified/exempt, <=4FT3*
2104008021	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Woodstove: EPA certified, non-catalytic, single burn rate*
2104008031	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Woodstove: EPA certified, catalytic or hybrid*
2104008100	Stationary Source Fuel Combustion	Residential	Wood	Fireplace: general
2104008300	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: freestanding, general
2104008400	Stationary Source Fuel Combustion	Residential	Wood	Woodstove: pellet-fired, general (freestanding or FP insert)
2104008500	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Furnace: Indoor, cordwood-fired, general*
2104008530	Stationary Source Fuel Combustion	Residential	Wood	Furnace: Indoor, pellet-fired, general
2104008611	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Hydronic heater: outdoor, non-EPA certified*
2104008612	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Hydronic heater: outdoor, EPA certified*
2104008614	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Hydronic heater: indoor, non-EPA certified*
2104008615	*Stationary Source Fuel Combustion*	*Residential*	*Wood*	*Hydronic heater: indoor, EPA certified*
2104008630	Stationary Source Fuel Combustion	Residential	Wood	Hydronic heater: pellet-fired
2104008700	Stationary Source Fuel Combustion	Residential	Wood	Outdoor wood burning device, NEC (fire-pits, chimineas, etc)
2104009000	Stationary Source Fuel Combustion	Residential	Firelog	Total: All Combustor Types

2.2.6 Solvents (np_solvents)

<u>2022v2 updates relative to earlier 2022 emissions modeling platforms</u>

- For 2022v2, cutback asphalt emissions were removed from Maricopa County, per request from the county.

General Description

The np_solvents sector is a diverse collection of emission 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 and feature origins spanning residential, commercial, institutional, and industrial settings. The organic gases that evaporate from these sources often fulfill other functions than acting as a traditional solvent (e.g., propellants, fragrances, emollients). For this reason, the solvents sector is often referred to as "volatile chemical products." The base methodology used to estimate these emissions are unchanged from the 2020 NEI, which is described in Section 32 of the 2020 NEI TSD, including the SCCs that are included in the sector.

For 2022, all emissions in the np_solvents sector, except asphalt paving, are projected using the 2020 NEI as a base year. This includes State, Locality, and Tribal emissions submissions. Here, the model used to estimate a majority of the nonpoint solvent emissions in the NEI (VCPy) was used to estimate 2021 emissions (2022 usage data were not available). From there a SCC-specific ratio (of 2021 / 2020) was applied to the 2020 NEI. This method ensures that state-submitted emissions magnitudes are preserved. In addition, some updates were made based on comments provided by New Jersey, and asphalt-related SCCs featured temporal profile updates using EIA-based monthly profiles for "asphalt and road oil" by PADD region.

2.2.7 Open burning (openburn)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- For 2022v2, emissions from burning of residential household waste were removed for New Hampshire.

General Description

This new sector for the 2022v1 platform was split out from the nonpt sector and includes emissions from yard waste, land clearing, and residential household waste burning (SCCs starting with 261 as shown in Table 2-13). For 2022v1 and 2022v2, these emissions were held constant at 2020 NEI levels.

Table 2-13. SCCs in the openburn sector

SCC	Description
2610000100	Waste Disposal, Treatment, and Recovery; Open Burning; All Categories; Yard Waste - Leaf Species Unspecified
2610000400	Waste Disposal, Treatment, and Recovery; Open Burning; All Categories; Yard Waste - Brush Species Unspecified
2610000500	Waste Disposal, Treatment, and Recovery; Open Burning; All Categories; Land Clearing Debris
2610030000	Waste Disposal, Treatment, and Recovery; Open Burning; Residential; Household Waste
2610000300	Waste Disposal, Treatment, and Recovery; Open Burning; All Categories; Yard Waste - Weed Species Unspecified (incl Grass)

2.2.8 Nonpoint (nonpt)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- For 2022v2, updates were incorporated for Maricopa County, Michigan, Minnesota, Ohio, Wisconsin, Georgia, and Delaware.
- In Maricopa County, updates reflect a decrease in VOC emissions from commercial cooking.
- In Delaware, updates reflect removal of managed burning of logging debris (2810005000).

- In Michigan, Minnesota, Ohio, and Wisconsin, the county distributions of industrial and commercial/institutional wood fuel combustion emissions within each state were updated.
- In Georgia, industrial and commercial/institutional wood fuel combustion emissions were wholly removed, per the request of the State, as these emissions are reflected in the point inventory.

<u>General Description</u>

The 2022 platform nonpt sector inventory is based on the April 2023 version of the 2020 NEI but adjusted to better reflect 2022 emissions levels as described below. Stationary nonpoint sources that were not subdivided into the afdust, livestock, fertilizer, np_oilgas, rwc or np_solvents sectors were assigned to the "nonpt" sector. Locomotives and CMV mobile sources from the 2020 NEI nonpoint inventory are described with the mobile sources. The types of sources in the nonpt sector include:

- stationary source fuel combustion, including industrial, commercial, and residential and orchard heaters;
- chemical manufacturing;
- industrial processes such as commercial cooking, metal production, mineral processes, petroleum refining, wood products, fabricated metals, and refrigeration;
- storage and transport of petroleum for uses such as portable gas cans, bulk terminals, gasoline service stations, aviation, and marine vessels;
- storage and transport of chemicals;
- waste disposal, treatment, and recovery via incineration, open burning, landfills, and composting; and
- miscellaneous area sources such as cremation, hospitals, lamp breakage, and automotive repair shops.

The nonpt sector includes emission estimates for Portable Fuel Containers (PFCs), also known as "gas cans." The PFC inventory consists of three distinct sources of PFC emissions, further distinguished by residential or commercial use. The three sources are: (1) displacement of the vapor within the can; (2) emissions due to evaporation (i.e., diurnal emissions); and (3) emissions due to permeation. Note that spillage and vapor displacement associated with using PFCs to refuel nonroad equipment are included in the nonroad inventory.

The factors used to adjust the emissions were developed using the datasets as described in Table 2-14. Emissions for SCC groups other than those listed in this table (e.g., waste disposal, treatment and recovery) were held constant at 2020 NEI levels in the 2022 base year inventory.

Table 2-14. Datasets used to develop factors to adjust nonpoint emissions from 2020 to 2022

Source Category Group	2020-2022 Projection Method
All Other Nonpoint Source Fuel Combustion	Apply EIA State Energy Data System energy consumption ratios. Note that 2021 SEDS data are available for all fuels and 2022 data are available for some fuels.
Stage 1 Gasoline Unloading at Service Stations	Apply EIA State Energy Data System Transportation Sector/Motor Gasoline consumption ratios

Source Category Group	2020-2022 Projection Method
Stage 1 Gasoline Unloading at Bulk Terminals/Plants	Apply EIA State Energy Data System Total Motor Gasoline consumption ratios
Aviation Gasoline Stage I and II	Apply EIA State Energy Data System Aviation Gasoline consumption ratios
Pipeline Gasoline	Apply EIA State Energy Data System Total Motor Gasoline consumption ratios
Human Cremation	Estimate 2022 county-level number of cremations from 2022 actual county-level deaths from CDC's Wonder Database and 2022 state-level (projected) cremation rates from National Funeral Directors Association's "Cremation and Burial Report" and apply 2022/2020 county-level cremation ratios to 2020 NEI cremation emissions to compute 2022 cremation emissions
Commercial Cooking	Hold constant
Portable Fuel Containers	Hold constant
Asphalt Paving	Hold constant
Landfills/POTWs	Hold constant
Charcoal Grilling	Hold constant

2.3 Onroad Mobile sources (onroad)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- The 2022v2 draft and final emissions for onroad mobile sources were not changed, but there were substantial differences between the 2022v1 and 2022v2 onroad emissions.
- A new MOVES run was performed using MOVES5.0.0.
  - MOVES5 includes the addition of age IDs 31 to 40 years old in the age distributions.
- VPOP and age distribution were updated using new registrations data obtained for the 2023 NEI from S&P Global Mobility.
- Telematics data from StreetLight were incorporated into new speed distributions and new daily and day-of-week temporal VMT distributions unique to each county. Factors were applied to reduce emissions from gasoline refueling in New Jersey at the request of the state.
- The following changes were made to the 2022v2 CDBs from state-specific submitted data
  - DC provided State II vapor recovery program fractions to populate the countyYear table
  - Georgia provided updated IMCoverage, AVFT, age distribution, VMT, vehicle population, and weekday starts activity for urban core counties.

General Description

Onroad mobile sources 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, compressed natural gas (CNG), or electric 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 for the 2020 NEI, see Section 5 of the 2020 NEI TSD (EPA, 2023).

Although the NEI TSD describes the general process, many updates were made to MOVES input data and the MOVES version used to create emissions for the 2022v2 platform.

The 2022 emissions modeling platform activity data (i.e., vehicle miles traveled (VMT) and vehicle population (VPOP)) were based on data submitted by state and local agencies for the 2020 NEI and for the 2022 platform, as well as data from the Federal Highway Administration (FHWA). VMT were based on county-level VM-2 data by road type from FHWA. For the 2022v2 platform, VPOP was updated to a new dataset as described in the activity data development section below. A new MOVES run for the 2022v2 platform was done using MOVES5 to obtain year-specific emission factors. One of the data updates incorporated into this run was the use of age distributions that go back 40 years for MOVES5, as opposed to 30 years for earlier versions of MOVES. These updated age distributions were computed for each representative county from data by county, model year, and source-type from S&P Global Mobility. Because this data pull was from June of 2023, the age distributions were computed to represent the year 2022. Additional attributes of these data were used to compute vehicle populations and to update fuel splits used in the MOVES run. The updated data also included new splits for short vs long haul vehicles.

Except for California, all onroad emissions were 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 2022 meteorological data. Specifically, EPA used vehicle miles traveled (VMT) and other 2022-specific activity data, along with tools that interface between the MOVES model and 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 emissions modeling platform are more finely resolved than those in the National Emissions Inventory (NEI). The NEI SCCs distinguish vehicles and fuels, while the SCCs used in the model platform also distinguish between emissions processes (i.e., off-network, on-network, and extended idle), and road types.

A significant update for the 2022v2 platform with respect to the MOVES and SMOKE-MOVES runs was the use of telematics data from StreetLight to inform temporal patterns and speed distributions for each county. The day-of-week and diurnal distributions were updated to reflect 2022 levels based on telematics data from Streetlight, as the corresponding data from 2022v1 were based on data from January of 2020. Inspection and maintenance program information was mostly based on the MOVES5 data except where Georgia and Colorado provided updates.

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 2-15 with the corresponding vehicle type from the highway monitoring performance system (HPMS). SMOKE-MOVES was run for specific modeling grids. Emissions for the contiguous U.S. states and Washington, D.C., were computed for a grid covering those areas. Emissions for Alaska, Hawaii, Puerto Rico, and the U.S. Virgin Islands were computed by running SMOKE-MOVES for distinct grids covering each of those regions and are included in the onroad non-Conus sector. In some summary reports these non-CONUS emissions are aggregated with emissions from the onroad sector.

Table 2-15. 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	Other 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 2022-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 were generated were selected according to their state, elevation, fuels, age distribution, ramp fraction, and inspection and maintenance programs. Each county was then mapped to a representative county based on its similarity to the representative county with respect to those attributes. In both the 2022v1 and 2022v2 platforms, there are 259 representative counties in the continental U.S. and a total of 298 including the non-CONUS areas. The only differences between the 2020 and 2022 platforms are a change in Alaska county equivalents which removed one borough (county ID 2261, Valdez-Cordova Census Area) which in 2019 split into two areas (county ID 2063, Chugach Census Area; and county ID 2066, Copper River Census Area), as well as some updates recommended by Texas.

Once representative counties were identified, emission factors were 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 selected the appropriate MOVES emissions rates for each county, hourly temperature, SCC, and speed bin and then multiplied the emission rate by appropriate activity data. For on-roadway emissions, vehicle miles traveled (VMT) is the activity data; off-network processes use vehicle population (VPOP), vehicle starts, and hours of off-network idling (ONI); and hoteling hours are used to develop emissions for extended idling of combination long-haul trucks. These calculations were done for every county and grid cell in the continental U.S. for each hour of the year.

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

1) Determine which counties will be used to represent other counties in the MOVES runs.
2) Determine which months will be used to represent other month's fuel characteristics.

3) Create 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 were processed in six processing streams that were then 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-start (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.

With some exceptions described in the following subsections, the onroad emissions inputs to MOVES for the 2022v2 emissions modeling platform are based on the 2020 NEI, described in more detail in Section 5 of the 2020 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 some other inputs were consistent with those used to compute the 2020 NEI, although many input data sets were updated for the 2022v2 platform. Activity data submitted by states and development of the EPA default activity data sets for VMT, VPOP, hoteling hours, starts, and off-network idling (ONI) hours follows a similar process to the 2020 NEI, but based on 2022-specific VMT and VPOP. Any data carried over from the 2020 NEI are described in detail in the 2020 NEI TSD and supporting documents. Factors were applied in SMOKE-MOVES to reduce emissions from gasoline refueling in New

Jersey at the request of the state. Details regarding the data used to computed onroad mobile source emissions for the 2022v2 platform are described below.

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 was supplemented with data submitted by state and local agencies. In the EPA default dataset, VMT was derived from FHWA's county-level VM-2 data for 2022. EPA default VPOP uses new data for 2022v2 platform, which is based on a draft version of 2023 vehicle population for the upcoming 2023 NEI with MOVES5-compatible fuel splits, and with backcast factors applied for the year 2022. State-submitted VPOP from the 2022v1 platform was retained for the 2022v2 platform, and other aspects of the activity data which are dependent on VPOP (e.g. STARTS, VMT source type and fuel splits) were recomputed using the updated VPOP. As such, except for new state-submitted VMT data in Georgia for 2022v2 platform, overall VMT was unchanged from 2022v1 to 2022v2, but the source type distributions and fuel splits within the VMT did change based on the new VPOP dataset. ONI and HOTELING activity were also recomputed based on the updated VMT. 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)

Activity data submitted by states and development of the EPA default activity data sets for VMT, VPOP, and hoteling hours are described in detail in the 2020 NEI TSD (EPA, 2023) and supporting documents. The process for developing VMT for 2022 is similar to the 2020 NEI process, except starting with 2022-specific VMT from the FHWA VM-2 (county-level and by road type) and VM-4 (distributions of VMT by state and HPMS vehicle type). The year 2022 VM-2 and VM-4 data were combined to create a 2022 VMT dataset by county, HPMS vehicle type, and road type. The new VPOP dataset for the 2022v2 platform was then used to allocate VMT from HPMS vehicle type to MOVES vehicle type, and to different fuel types, resulting in different MOVES vehicle type and fuel type distributions in the 2022v2 platform when compared to the 2022v1 platform. Monthly profiles for 2022 VMT from the 2022v1 platform, based on FHWA's Travel Monitoring and Analysis System (TMAS) data, were retained for the 2022v2 platform. See Section 3.3.8 for more information on the use of TMAS data.

The following states submitted VMT for the 2022v1 platform base year: AK, CO, CT, DE, GA, KS, MA, MI, MD, ME, NC, NH, NJ, NY, OR, PA, SC, TN, TX, UT, VA, WA, WI, WV, and Jefferson Co. KY. For the 2022v2 platform, all state-submitted VMT from the 2022v1 platform was retained from the 2022v1 platform, but with MOVES vehicle type and fuel splits recomputed as appropriate (i.e. where these splits were not directly provided by the states). In addition, new VMT was provided by Georgia for the 2022v2 platform. As in 2022v1 platform, VMT for Colorado are based on EPA default data.

For the 2022v2 platform, vehicle population data were updated based on a draft version of the 2023 NEI VPOP. Adjustment factors were applied to backcast the draft 2023 VPOP to 2022 estimates; those factors are shown in Table 2-16. State-submitted vehicle population from the 2022v1 platform in DE, NY, and WI data were retained in the 2022v2 platform, and new vehicle population was provided by Georgia for the 2022v2 platform. Updated fuel splits based on the EPA default VPOP were applied to the state-submitted VPOP.

Table 2-16. 2023-to-2022 adjustment factors for EPA default vehicle population

Source TypeI D	Source Type Description	Ratio 2022:2023
11	Motorcycle	0.9978
21	Passenger Car	1.0204
31	Passenger Truck	0.9803
32	Light Commercial Truck	0.9803
41	Intercity Bus	0.9780
42	Transit Bus	0.9780
43	School Bus	0.9780
51	Refuse Truck	0.9737
52	Single Unit Short-haul Truck	0.9737
53	Single Unit Long-haul Truck	0.9737
54	Motor Home	0.9737
61	Combination Short-haul Truck	0.9848
62	Combination Long-haul Truck	0.9848

Because vehicle registration data does not contain information on the usage patterns of heavy-duty trucks to distinguish between short- versus long-haul trucks, surrogate information was applied to estimate the population belonging to each category. New for the 2022v2 platform, the data used to split Combination Unit Trucks into short/long haul came from the 2021 Vehicle Inventory and Use Survey (VIUS2021) information at the state level. Combination Unit Truck populations were split into source types 61 and 62 using the VIUS2021 field "CABDAY" where values of "Day Cab" were considered short-haul (61s) and "Sleeper Cab" were considered long-haul (62s). Though the splits varied by state, nationally they averaged 52% short-haul and 48% long-haul. Because the VIUS2021 did not have information on single unit trucks, EPA continued using the prior method for source types 52 and 53 splitting, which was based on the Freight Analysis Framework (FAF) with separate values by four US census regions: midwest, northeast, south, and west. The factors used are shown Table 2-17. The VMT activity data were split into short and long-haul using the same splits as were used for VPOP.

Table 2-17. Fractions of short- and long-Haul VPOP by census region

Truck Type	Census Region	Fraction Short-haul	Fraction Long-haul
Single unit 52/53	Midwest	0.807	0.193
Single unit 52/53	Northeast	0.919	0.081
Single unit 52/53	South	0.860	0.140
Single unit 52/53	West	0.882	0.118
Combination (61/62)	Midwest	0.442	0.558
Combination (61/62)	Northeast	0.448	0.552
Combination (61/62)	South	0.535	0.465
Combination (61/62)	West	0.468	0.532

Speed Activity (SPDIST)

Beginning with SMOKE 4.7, SMOKE-MOVES has used speed distributions similarly to how they are used when running MOVES in inventory mode. The 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. Speed data from the year 2022 StreetLight dataset were used to generate hourly speed profiles by county, road type weekday/weekend and three vehicle classes (i.e., light-duty, commercial medium-duty, and commercial heavy-duty).

Hoteling Hours (HOTELING)

Hoteling hours were computed from the 2022v2 VMT, using a factor of 0.007248 hoteling hours per VMT for combination long haul trucks on restricted highways. This is the same approach as in the 2020 NEI and the 2022v1 platform, except the computation is based on values in the 2022v2 VMT. 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 was last updated during the development of the 2016 platforms. There are 8,760 hours in the year 2022; 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 2022 in all counties, with some exceptions. Also, Texas submitted hoteling activity for 2020 NEI, and their 2020 hoteling activity was projected to 2022 using ratios of 2022 VMT / 2020 VMT for combination long haul trucks.

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 were never reduced below 105,120 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 were never increased in this analysis. For recent NEIs, 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. Reductions were also not applied in Texas, because the hoteling activity in that state are based on state-submitted data.

The final step related to hoteling activity is to split county totals into separate values for extended idling (SCC 2202620153) and Auxiliary Power Units (APUs) (SCC 2202620191). For 2022 modeling with MOVES4, an 9.8% APU split is used nationwide, meaning that during 9.8% 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.

MOVES5 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, MOVES5 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, light duty inspection and maintenance (I/M) programs, and ambient temperatures.

Starts, which are computed as a function of vehicle population, were recomputed for the 2022v2 platform based on the new VPOP for 2022v2. Monthly profiles for starts were retained from 2022v1 platform. The weekday starts provided by Georgia were incorporated.

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 the 2022v2 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.

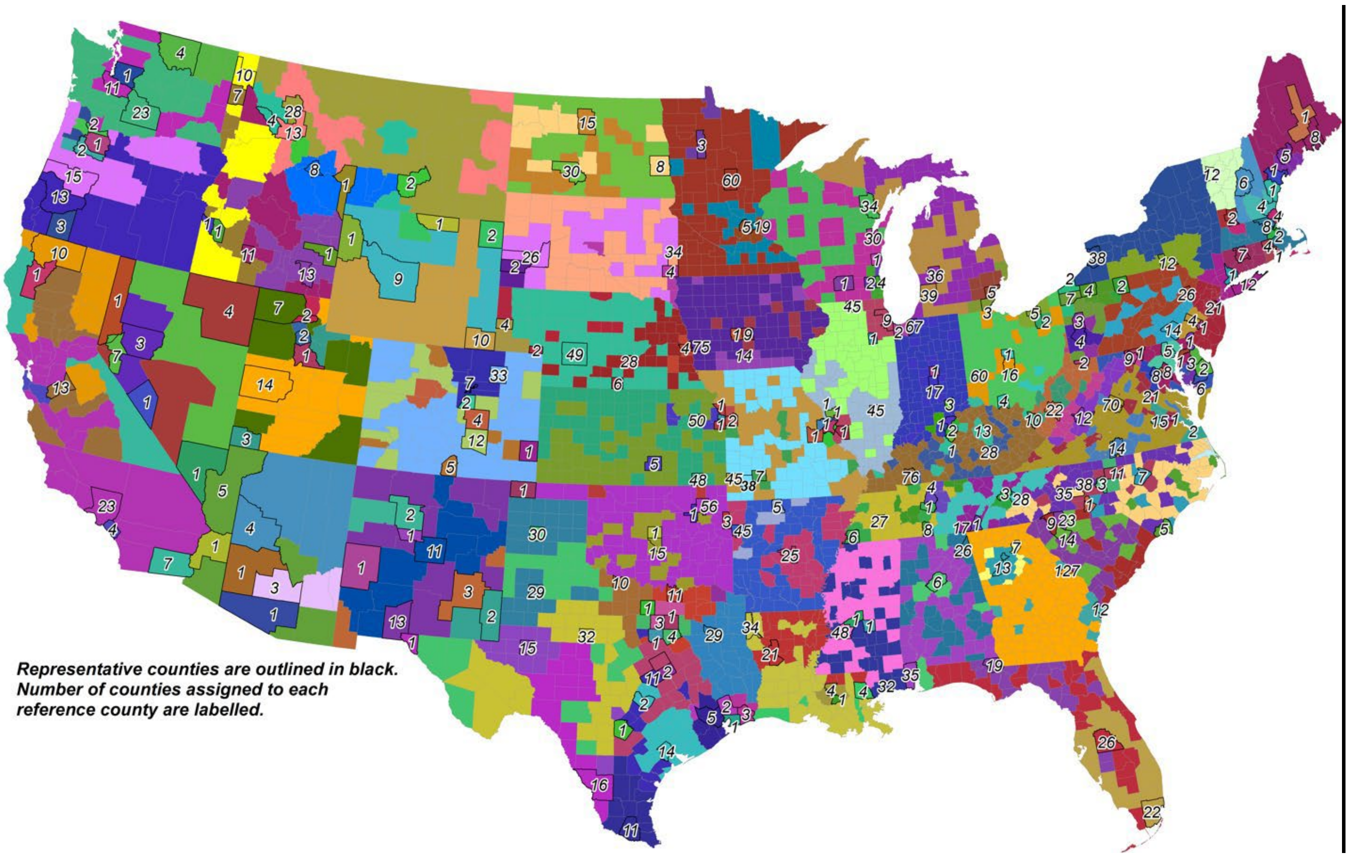
2.3.3 MOVES Emission Factor Table Development

MOVES5 was run in emission rate mode to create emission factor tables for 2022, 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 representing the year 2022. The range of temperatures run along with the average humidities used were specific to the year 2022. The remaining settings for the CDBs are documented in the 2020 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 2022. The MOVES results were post-processed into CSV-formatted emission factor tables that can be read by SMOKE-MOVES. Additionally, MOVES was run for all counties in Alaska, Hawaii, and Virgin Islands, and for a single representative county in Puerto Rico.

The county databases (CDBs) used to run MOVES to develop the emission factor tables were based on those used for the 2020 NEI. The 2022 emissions modeling platform development included an extensive review of the various tables including speed distributions. Each county in the continental U.S. was classified according to its state, altitude (high or low), fuel region, the presence of I/M programs, and the mean light-duty age. A binning algorithm was executed to identify "like counties." The result was 259 representative counties for the CONUS shown in Figure 2-2 along with 39 for Alaska, Hawaii, Puerto Rico, and the US Virgin Islands. The 2022v2 platform representative counties did not change from those used in the 2022v1 platform. The CONUS representation counties for 2022 are the same as those used for 2020 NEI with the exception of Alaska, which, in 2019, removed one borough (county ID 2261, Valdez-Cordova Census Area) and split that into two areas (county ID 2063, Chugach Census Area; and county ID 2066, Copper River Census Area); as well as some updates recommended by Texas.

Age distributions are a key input to MOVES in determining emission rates. Age distributions were updated in the 2022v2 platform based on the S&P Global Mobility data for 2023 using a process similar to that used for the 2020 NEI, although a key difference between 2022v2 and 2020 was that the age distributions go out to 40 years in 2022v2, as compared to 30 years in 2020 NEI. For more information on the process of how age distributions were developed for the 2020 NEI, please see Section 5 of the 2020 NEI TSD. These additional MOVES tables have updated data for the 2022v2 platform: avft, avgspeeddistribution, dayVMTFraction, hourVMTfraction, sourceTypeYear, and souceTypeVMT.

Figure 2-2. Map of 2022 Representative Counties



In emissions modeling platforms for NEI years, adjustment factors to light duty vehicle populations by age are typically computed based on submitted age distributions as compared to the national dataset of vehicles by source type and age. For the 2022v2 platform no adjustment factors were applied because there was no submitted data to compare with the national data. No antique plates were removed for the 2022v2 platform as they have been for recent NEIs. Table 2-18 shows adjustments that were made to age distributions for light-duty vehicles in a few counties that were discovered to have very young fleets. 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.

Table 2-18. Outlier adjustments made for very young light duty vehicles

FIPS code	County	State	Action
8035	Douglas County	CO	Substitute ST 32 age distribution with those from county 8031 from the same MSA (Denver-Aurora-Lakewood; CO)
40109	Oklahoma County	OK	Substitute ST 21 age distribution with those from county 40027 from the same MSA (Oklahoma City; OK)
40143	Tulsa County	OK	Substitute ST 21 and 32 age distributions with those from county 40131 from the same MSA (Tulsa; OK)

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 2022. The CDBs used to run MOVES include the state-specific control measures such as the California low emission vehicle (LEV) program. In addition, the range of temperatures and the average humidities used in the CDBs were specific to the year 2022. 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_adj)

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 submitted onroad emissions for all 2022v1 platform years, including 2022. Since California's 2022 inventory did not contain HAPs, VOC-based speciation factors were used to estimate VOC HAPs for 2022. Other HAPs such as PAHs and metals are not needed for this platform. 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 taken from MOVES for California.

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 were 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. The 2020 California data did not separate off and on-network emissions or extended idling and also 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 were 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 commercial marine CMV emissions (cmv_c1c2 and cmv_c3).

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

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in CAP emissions in 2022v2 relative to earlier 2022 emissions modeling platforms.
- Emission factors for some HAPs were updated for 2022v2 platform.

General Description

The cmv_c1c2 sector contains Category 1 and 2 (C1C2) 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 emissions modeling platform they are provided at the sub-county level (e.g., port shapes) and by SCC and emission type (e.g., hoteling, maneuvering). Starting with the 2021 emissions modeling platform, EPA expanded the list of SCCs. SCCs are now further resolved based on ship type than they were for the 2020 NEI. A list of SCCs for the C1C2 sector can be seen in Table 2-19. For more information on the 2022 CMV C1C2 emissions development, see the supplemental documentation (ERG, 2024b). C1C2 emissions that occur outside of state waters are not assigned to states. For this modeling platform, all CMV emissions in the cmv_c1c2 sector are treated as hourly gridded point sources with stack parameters that should result in them being placed in layer 1.

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 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 are modeled as point sources but using plume rise parameters that cause the emissions to be released in the ground layer of the air quality model.

The cmv_c1c2 sources within state waters are identified in the inventory with the Federal Information Processing Standard (FIPS) county code for the state and county in which the vessel is registered. The cmv_c1c2 sources that operate outside of state waters but within the Emissions Control Area (ECA) are encoded with a state FIPS code of 85. The ECA areas include parts of the Gulf of Mexico, and parts of the Atlantic and Pacific coasts. The cmv_c1c2 sources are categorized as operating either in-port or underway (i.e., not in-port or docked) and as main and auxiliary engines are encoded using the SCCs listed in Table 2-19. Level 1 and Level 2 descriptions for all of the entries are “Mobile Sources”, and “Marine Vessels, Commercial”, respectively.

Table 2-19. SCCs for the cmv_c1c2 sector

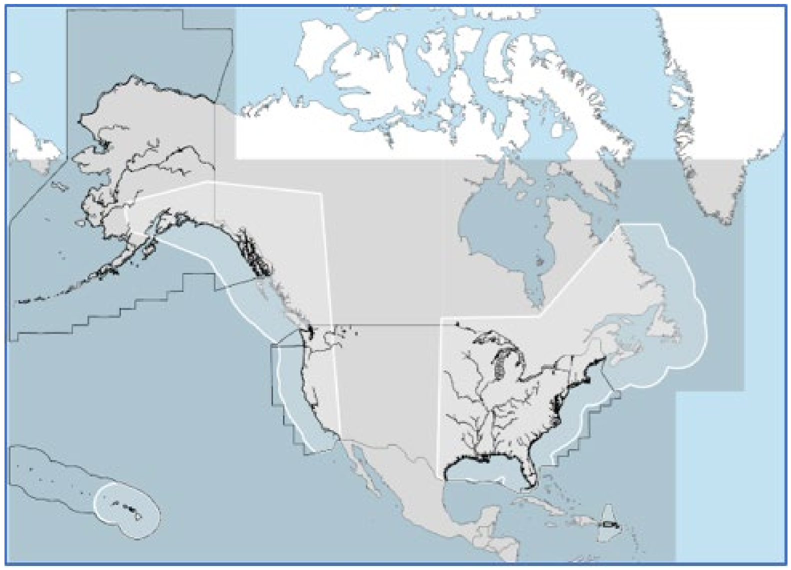
SCC	Level 3 Description	Level 4 Description
2280201113	Diesel Barge	C1C2 Port Emissions: Main Engine
2280202113	Diesel Offshore support	C1C2 Port Emissions: Main Engine
2280203113	Diesel Bulk Carrier	C1C2 Port Emissions: Main Engine
2280204113	Diesel Commercial Fishing	C1C2 Port Emissions: Main Engine
2280205113	Diesel Container Ship	C1C2 Port Emissions: Main Engine
2280206113	Diesel Ferry	C1C2 Port Emissions: Main Engine
2280207113	Diesel General Cargo	C1C2 Port Emissions: Main Engine
2280208113	Diesel Government	C1C2 Port Emissions: Main Engine
2280209113	Diesel Miscellaneous	C1C2 Port Emissions: Main Engine
2280210113	Diesel RollOn RollOff	C1C2 Port Emissions: Main Engine
2280211113	Diesel Tanker	C1C2 Port Emissions: Main Engine
2280212113	Diesel Tour Boat	C1C2 Port Emissions: Main Engine
2280213113	Diesel Tug	C1C2 Port Emissions: Main Engine
2280214113	Diesel Refrigerated	C1C2 Port Emissions: Main Engine
2280215113	Diesel Cruise	C1C2 Port Emissions: Main Engine
2280216113	Diesel Passenger Other	C1C2 Port Emissions: Main Engine
2280201114	Diesel Barge	C1C2 Port Emissions: Auxiliary Engine
2280202114	Diesel Offshore support	C1C2 Port Emissions: Auxiliary Engine
2280203114	Diesel Bulk Carrier	C1C2 Port Emissions: Auxiliary Engine
2280204114	Diesel Commercial Fishing	C1C2 Port Emissions: Auxiliary Engine
2280205114	Diesel Container Ship	C1C2 Port Emissions: Auxiliary Engine
2280206114	Diesel Ferry	C1C2 Port Emissions: Auxiliary Engine
2280207114	Diesel General Cargo	C1C2 Port Emissions: Auxiliary Engine
2280208114	Diesel Government	C1C2 Port Emissions: Auxiliary Engine
2280209114	Diesel Miscellaneous	C1C2 Port Emissions: Auxiliary Engine
2280210114	Diesel RollOn RollOff	C1C2 Port Emissions: Auxiliary Engine
2280211114	Diesel Tanker	C1C2 Port Emissions: Auxiliary Engine
2280212114	Diesel Tour Boat	C1C2 Port Emissions: Auxiliary Engine
2280213114	Diesel Tug	C1C2 Port Emissions: Auxiliary Engine
2280214114	Diesel Refrigerated	C1C2 Port Emissions: Auxiliary Engine
2280215114	Diesel Cruise	C1C2 Port Emissions: Auxiliary Engine
2280216114	Diesel Passenger Other	C1C2 Port Emissions: Auxiliary Engine
2280201123	Diesel Barge	C1C2 Underway emissions: Main Engine
2280202123	Diesel Offshore support	C1C2 Underway emissions: Main Engine
2280203123	Diesel Bulk Carrier	C1C2 Underway emissions: Main Engine
2280204123	Diesel Commercial Fishing	C1C2 Underway emissions: Main Engine
2280205123	Diesel Container Ship	C1C2 Underway emissions: Main Engine
2280206123	Diesel Ferry	C1C2 Underway emissions: Main Engine
2280207123	Diesel General Cargo	C1C2 Underway emissions: Main Engine

SCC	Level 3 Description	Level 4 Description
2280208123	Diesel Government	C1C2 Underway emissions: Main Engine
2280209123	Diesel Miscellaneous	C1C2 Underway emissions: Main Engine
2280210123	Diesel RollOn RollOff	C1C2 Underway emissions: Main Engine
2280211123	Diesel Tanker	C1C2 Underway emissions: Main Engine
2280212123	Diesel Tour Boat	C1C2 Underway emissions: Main Engine
2280213123	Diesel Tug	C1C2 Underway emissions: Main Engine
2280214123	Diesel Refrigerated	C1C2 Underway emissions: Main Engine
2280215123	Diesel Cruise	C1C2 Underway emissions: Main Engine
2280216123	Diesel Passenger Other	C1C2 Underway emissions: Main Engine
2280201124	Diesel Barge	C1C2 Underway emissions: Auxiliary Engine
2280202124	Diesel Offshore support	C1C2 Underway emissions: Auxiliary Engine
2280203124	Diesel Bulk Carrier	C1C2 Underway emissions: Auxiliary Engine
2280204124	Diesel Commercial Fishing	C1C2 Underway emissions: Auxiliary Engine
2280205124	Diesel Container Ship	C1C2 Underway emissions: Auxiliary Engine
2280206124	Diesel Ferry	C1C2 Underway emissions: Auxiliary Engine
2280207124	Diesel General Cargo	C1C2 Underway emissions: Auxiliary Engine
2280208124	Diesel Government	C1C2 Underway emissions: Auxiliary Engine
2280209124	Diesel Miscellaneous	C1C2 Underway emissions: Auxiliary Engine
2280210124	Diesel RollOn RollOff	C1C2 Underway emissions: Auxiliary Engine
2280211124	Diesel Tanker	C1C2 Underway emissions: Auxiliary Engine
2280212124	Diesel Tour Boat	C1C2 Underway emissions: Auxiliary Engine
2280213124	Diesel Tug	C1C2 Underway emissions: Auxiliary Engine
2280214124	Diesel Refrigerated	C1C2 Underway emissions: Auxiliary Engine
2280215124	Diesel Cruise	C1C2 Underway emissions: Auxiliary Engine
2280216124	Diesel Passenger Other	C1C2 Underway emissions: Auxiliary Engine

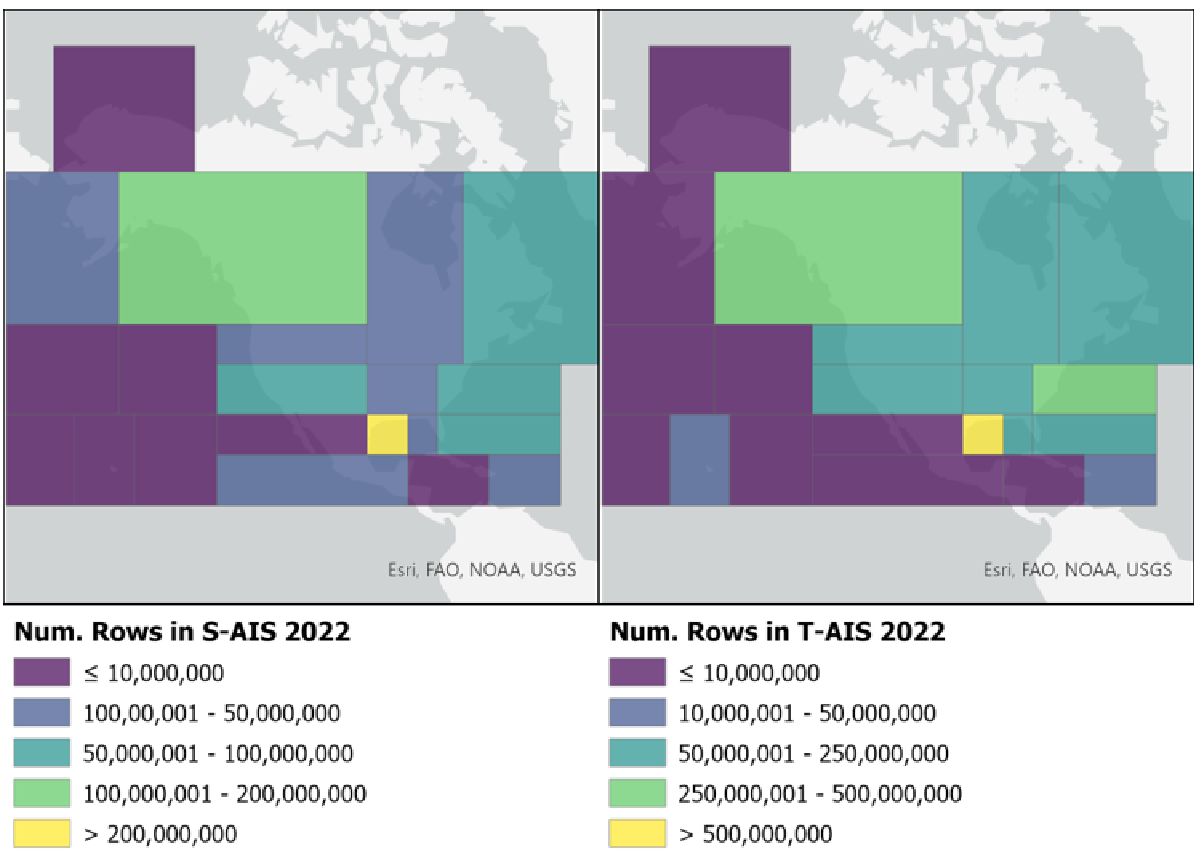
Category 1 and 2 CMV emissions were developed for the 2022 platform and were not based on the 2020 NEI although the methods used to develop the emissions were similar. The emissions were developed based on signals from Automated Identification System (AIS) transmitters. AIS is a tracking system used by vessels to enhance navigation and avoid collision with other AIS transmitting vessels. The USEPA Office of Transportation and Air Quality received AIS data from the U.S. Coast Guard (USCG) to quantify all ship activity which occurred between January 1 and December 31, 2022. During the acquisition of the 2022 AIS data from the U.S. Coast Guard, EPA was made aware of a data quality issue that started in late March and continued through late June of 2022. To address this, emissions were substituted in from the 2021 CMV C1C2 inventory for this period. To ensure coverage for all of the areas needed by the NEI, the requested and provided AIS data extend beyond 200 nautical miles from the U.S. coast. The area covered by the AIS Area, 2022 Modeling Platform Geographical Extent, and U.S. ECA is shown in Figure 2-3 (a). This boundary is roughly equivalent to the border of the U.S Exclusive Economic Zone and the North American ECA, although some non-ECA activity are captured as well. Two types of AIS data were received: satellite (S-AIS) and terrestrial (T-AIS). The distribution of terrestrial and satellite AIS data for the 2022 emissions modeling platform are shown in Figure 2-3 (b). An additional enhancement for the 2022 C1C2 CMV inventory was the development and application of a mask that was applied to remove any emissions over land due to stray AIS signals.

Figure 2-3. Commercial Marine Vessel Boundaries and Automatic Identification System Request Boxes

a) Entire AIS Area (Transparent Gray), 2022 Modeling Platform Geographical Extent (Black Outline), and U.S. ECA (White Outline)



b) Distribution of Terrestrial and Satellite AIS Data



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 with considerably less uncertainty. These AIS data were used to define the locations of individual vessel movements, estimate hours of operation, and quantify propulsion engine loads. The compiled AIS data also included the vessel's International Marine Organization (IMO) number and Maritime Mobile Service Identifier (MMSI); which allowed each vessel to be matched to their characteristics obtained from the Clarksons ship registry (Clarksons, 2021).

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

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

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

Power was 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 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 2022 C1 C2 CMV development documentation (ERG, 2024b) for more details on this process. Following the identification, 236 different vessel types were matched to the C1C2 vessels. Vessel attribute data were 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 2-20. 19,322 vessels were directly identified by their ship and cargo number. The remaining group of miscellaneous ships represent 1.6 percent of the AIS vessels (excluding recreational vessels) for which a specific vessel type could not be assigned.

Table 2-20. Vessel groups in the cmv_c1c2 sector

Vessel Group	2017 Entire Area Ship Count	2020 Entire Area Ship Count	2021 Entire Area Ship Count	2022 Entire Area Ship Count
Bulk Carrier	45	44	46	47
Commercial Fishing	1,686	4,262	5,826	5,859
Container Ship	8	16	11	15
Ferry Excursion	482	724	849	997
General Cargo	1,555	3,451	3,190	3,122
Government	1,368	1,192	1,179	1,216
Miscellaneous	1,810	269	291	300
Offshore support	1,203	1,337	1,416	1,377
Pilot	NA	17	15	15
Reefer	15	13	12	28
Ro Ro	27	218	219	212
Tanker	144	555	591	677
Tug	4,203	5,661	5,299	5,289
Work Boat	83	151	162	168
Total in Inventory:	**12,629**	**17,910**	**19,106**	**19,322**

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 2-19.

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 $PM_{2.5}$.

The stack parameters used for cmv_c1c2 are a stack height of 1 ft, stack diameter of 1 ft, stack temperature of 70°F, and a stack velocity of 0.1 ft/s. These parameters force emissions into layer 1. For the 2022v2 platform, stack grouping was used for all CMV sources to improve CMAQ run-time and file sizes.

For more information on the emission computations for 2022, see the supporting documentation for the development of the [2022 C1C2 CMV emissions] (ERG, 2024). The cmv_c1c2 emissions were aggregated to total hourly values in each grid cell and run through SMOKE as point sources. SMOKE requires an annual inventory file to go along with the hourly data and this file was generated for 2022.

2.4.2 Category 3 Commercial Marine Vessels (cmv_c3)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in CAP emissions in 2022v2 relative to earlier 2022 emissions modeling platforms.
- Emission factors for some HAPs were updated for 2022v2 platform.

General Description

The cmv_c3 sector contains large engine CMV emissions. Category 3 (C3) marine diesel engines at or above 30 liters per cylinder. Typically, these are the largest CMV engines and are 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.

The cmv_c3 sources that operate outside of state waters but within the federal Emissions Control Area (ECA) are encoded with a FIPS state code of 85, with the "county code" digits representing broad regions such as the Atlantic, Gulf of Mexico, and Pacific. The ECA areas include parts of the Gulf of Mexico, and parts of the Atlantic and Pacific coasts. CMV C3 sources around Puerto Rico, Hawaii and Alaska, which are outside the ECA areas, are included in the inventory but are in separate files from the emissions around the continental United States (CONUS). The cmv_c3 sources in the inventory are categorized as operating either in-port or underway and are encoded using the SCCs listed in Table 2-21 and distinguish between diesel and residual fuel, in port areas versus underway, and main and auxiliary engines. The Level 1 and Level 2 descriptions for each of the SCCs are "Mobile Sources" and "Marine Vessels, Commercial", respectively.

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[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.

Table 2-21. SCCs for the cmv_c3 sector

SCC	Level 3 Description	Level 4 Description
2280201313	Diesel Barge	C3 Port Emissions: Main Engine
2280202313	Diesel Offshore support	C3 Port Emissions: Main Engine
2280203313	Diesel Bulk Carrier	C3 Port Emissions: Main Engine
2280204313	Diesel Commercial Fishing	C3 Port Emissions: Main Engine
2280205313	Diesel Container Ship	C3 Port Emissions: Main Engine
2280206313	Diesel Ferry	C3 Port Emissions: Main Engine
2280207313	Diesel General Cargo	C3 Port Emissions: Main Engine
2280208313	Diesel Government	C3 Port Emissions: Main Engine
2280209313	Diesel Miscellaneous	C3 Port Emissions: Main Engine
2280210313	Diesel RollOn RollOff	C3 Port Emissions: Main Engine
2280211313	Diesel Tanker	C3 Port Emissions: Main Engine
2280212313	Diesel Tour Boat	C3 Port Emissions: Main Engine
2280213313	Diesel Tug	C3 Port Emissions: Main Engine
2280214313	Diesel Refrigerated	C3 Port Emissions: Main Engine
2280215313	Diesel Cruise	C3 Port Emissions: Main Engine
2280216313	Diesel Passenger Other	C3 Port Emissions: Main Engine
2280201314	Diesel Barge	C3 Port Emissions: Auxiliary Engine
2280202314	Diesel Offshore support	C3 Port Emissions: Auxiliary Engine
2280203314	Diesel Bulk Carrier	C3 Port Emissions: Auxiliary Engine
2280204314	Diesel Commercial Fishing	C3 Port Emissions: Auxiliary Engine
2280205314	Diesel Container Ship	C3 Port Emissions: Auxiliary Engine
2280206314	Diesel Ferry	C3 Port Emissions: Auxiliary Engine
2280207314	Diesel General Cargo	C3 Port Emissions: Auxiliary Engine
2280208314	Diesel Government	C3 Port Emissions: Auxiliary Engine
2280209314	Diesel Miscellaneous	C3 Port Emissions: Auxiliary Engine
2280210314	Diesel RollOn RollOff	C3 Port Emissions: Auxiliary Engine
2280211314	Diesel Tanker	C3 Port Emissions: Auxiliary Engine
2280212314	Diesel Tour Boat	C3 Port Emissions: Auxiliary Engine
2280213314	Diesel Tug	C3 Port Emissions: Auxiliary Engine
2280214314	Diesel Refrigerated	C3 Port Emissions: Auxiliary Engine
2280215314	Diesel Cruise	C3 Port Emissions: Auxiliary Engine
2280216314	Diesel Passenger Other	C3 Port Emissions: Auxiliary Engine
2280201323	Diesel Barge	C3 Underway emissions: Main Engine
2280202323	Diesel Offshore support	C3 Underway emissions: Main Engine
2280203323	Diesel Bulk Carrier	C3 Underway emissions: Main Engine
2280204323	Diesel Commercial Fishing	C3 Underway emissions: Main Engine
2280205323	Diesel Container Ship	C3 Underway emissions: Main Engine
2280206323	Diesel Ferry	C3 Underway emissions: Main Engine

SCC	Level 3 Description	Level 4 Description
2280207323	Diesel General Cargo	C3 Underway emissions: Main Engine
2280208323	Diesel Government	C3 Underway emissions: Main Engine
2280209323	Diesel Miscellaneous	C3 Underway emissions: Main Engine
2280210323	Diesel RollOn RollOff	C3 Underway emissions: Main Engine
2280211323	Diesel Tanker	C3 Underway emissions: Main Engine
2280212323	Diesel Tour Boat	C3 Underway emissions: Main Engine
2280213323	Diesel Tug	C3 Underway emissions: Main Engine
2280214323	Diesel Refrigerated	C3 Underway emissions: Main Engine
2280215323	Diesel Cruise	C3 Underway emissions: Main Engine
2280216323	Diesel Passenger Other	C3 Underway emissions: Main Engine
2280201324	Diesel Barge	C3 Underway emissions: Auxiliary Engine
2280202324	Diesel Offshore support	C3 Underway emissions: Auxiliary Engine
2280203324	Diesel Bulk Carrier	C3 Underway emissions: Auxiliary Engine
2280204324	Diesel Commercial Fishing	C3 Underway emissions: Auxiliary Engine
2280205324	Diesel Container Ship	C3 Underway emissions: Auxiliary Engine
2280206324	Diesel Ferry	C3 Underway emissions: Auxiliary Engine
2280207324	Diesel General Cargo	C3 Underway emissions: Auxiliary Engine
2280208324	Diesel Government	C3 Underway emissions: Auxiliary Engine
2280209324	Diesel Miscellaneous	C3 Underway emissions: Auxiliary Engine
2280210324	Diesel RollOn RollOff	C3 Underway emissions: Auxiliary Engine
2280211324	Diesel Tanker	C3 Underway emissions: Auxiliary Engine
2280212324	Diesel Tour Boat	C3 Underway emissions: Auxiliary Engine
2280213324	Diesel Tug	C3 Underway emissions: Auxiliary Engine
2280214324	Diesel Refrigerated	C3 Underway emissions: Auxiliary Engine
2280215324	Diesel Cruise	C3 Underway emissions: Auxiliary Engine
2280216324	Diesel Passenger Other	C3 Underway emissions: Auxiliary Engine
2280301313	Residual Barge	C3 Port Emissions: Main Engine
2280302313	Residual Offshore support	C3 Port Emissions: Main Engine
2280303313	Residual Bulk Carrier	C3 Port Emissions: Main Engine
2280304313	Residual Commercial Fishing	C3 Port Emissions: Main Engine
2280305313	Residual Container Ship	C3 Port Emissions: Main Engine
2280306313	Residual Ferry	C3 Port Emissions: Main Engine
2280307313	Residual General Cargo	C3 Port Emissions: Main Engine
2280308313	Residual Government	C3 Port Emissions: Main Engine
2280309313	Residual Miscellaneous	C3 Port Emissions: Main Engine
2280310313	Residual RollOn RollOff	C3 Port Emissions: Main Engine
2280311313	Residual Tanker	C3 Port Emissions: Main Engine
2280312313	Residual Tour Boat	C3 Port Emissions: Main Engine
2280313313	Residual Tug	C3 Port Emissions: Main Engine

SCC	Level 3 Description	Level 4 Description
2280314313	Residual Refrigerated	C3 Port Emissions: Main Engine
2280315313	Residual Cruise	C3 Port Emissions: Main Engine
2280316313	Residual Passenger Other	C3 Port Emissions: Main Engine
2280301314	Residual Barge	C3 Port Emissions: Auxiliary Engine
2280302314	Residual Offshore support	C3 Port Emissions: Auxiliary Engine
2280303314	Residual Bulk Carrier	C3 Port Emissions: Auxiliary Engine
2280304314	Residual Commercial Fishing	C3 Port Emissions: Auxiliary Engine
2280305314	Residual Container Ship	C3 Port Emissions: Auxiliary Engine
2280306314	Residual Ferry	C3 Port Emissions: Auxiliary Engine
2280307314	Residual General Cargo	C3 Port Emissions: Auxiliary Engine
2280308314	Residual Government	C3 Port Emissions: Auxiliary Engine
2280309314	Residual Miscellaneous	C3 Port Emissions: Auxiliary Engine
2280310314	Residual RollOn RollOff	C3 Port Emissions: Auxiliary Engine
2280311314	Residual Tanker	C3 Port Emissions: Auxiliary Engine
2280312314	Residual Tour Boat	C3 Port Emissions: Auxiliary Engine
2280313314	Residual Tug	C3 Port Emissions: Auxiliary Engine
2280314314	Residual Refrigerated	C3 Port Emissions: Auxiliary Engine
2280315314	Residual Cruise	C3 Port Emissions: Auxiliary Engine
2280316314	Residual Passenger Other	C3 Port Emissions: Auxiliary Engine
2280301323	Residual Barge	C3 Underway emissions: Main Engine
2280302323	Residual Offshore support	C3 Underway emissions: Main Engine
2280303323	Residual Bulk Carrier	C3 Underway emissions: Main Engine
2280304323	Residual Commercial Fishing	C3 Underway emissions: Main Engine
2280305323	Residual Container Ship	C3 Underway emissions: Main Engine
2280306323	Residual Ferry	C3 Underway emissions: Main Engine
2280307323	Residual General Cargo	C3 Underway emissions: Main Engine
2280308323	Residual Government	C3 Underway emissions: Main Engine
2280309323	Residual Miscellaneous	C3 Underway emissions: Main Engine
2280310323	Residual RollOn RollOff	C3 Underway emissions: Main Engine
2280311323	Residual Tanker	C3 Underway emissions: Main Engine
2280312323	Residual Tour Boat	C3 Underway emissions: Main Engine
2280313323	Residual Tug	C3 Underway emissions: Main Engine
2280314323	Residual Refrigerated	C3 Underway emissions: Main Engine
2280315323	Residual Cruise	C3 Underway emissions: Main Engine
2280316323	Residual Passenger Other	C3 Underway emissions: Main Engine
2280301324	Residual Barge	C3 Underway emissions: Auxiliary Engine
2280302324	Residual Offshore support	C3 Underway emissions: Auxiliary Engine
2280303324	Residual Bulk Carrier	C3 Underway emissions: Auxiliary Engine
2280304324	Residual Commercial Fishing	C3 Underway emissions: Auxiliary Engine

SCC	Level 3 Description	Level 4 Description
2280305324	Residual Container Ship	C3 Underway emissions: Auxiliary Engine
2280306324	Residual Ferry	C3 Underway emissions: Auxiliary Engine
2280307324	Residual General Cargo	C3 Underway emissions: Auxiliary Engine
2280308324	Residual Government	C3 Underway emissions: Auxiliary Engine
2280309324	Residual Miscellaneous	C3 Underway emissions: Auxiliary Engine
2280310324	Residual RollOn RollOff	C3 Underway emissions: Auxiliary Engine
2280311324	Residual Tanker	C3 Underway emissions: Auxiliary Engine
2280312324	Residual Tour Boat	C3 Underway emissions: Auxiliary Engine
2280313324	Residual Tug	C3 Underway emissions: Auxiliary Engine
2280314324	Residual Refrigerated	C3 Underway emissions: Auxiliary Engine
2280315324	Residual Cruise	C3 Underway emissions: Auxiliary Engine
2280316324	Residual Passenger Other	C3 Underway emissions: Auxiliary Engine

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, 2022. 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.[7] 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 data incorporated into this inventory reflect ship operations within 200 nautical miles of the official U.S. baseline and beyond. Activity data within the border of the U.S Exclusive Economic Zone and the North American ECA are included as well as some activity data outside of the ECA.

The 2022 CMV emissions modeling platform data were computed based on the AIS data from the USGS for the year of 2022. This process is described in more detail in the Category 3 Commercial Marine Vessel 2022 Emissions Inventory (EPA, 2024a). During the acquisition of the 2022 AIS data from the U.S. Coast Guard, EPA was made aware of a data quality issue that started in late March and continued through late June of 2022. To address this, emissions were substituted in from the 2021 CMV C3 inventory for this period. 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 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

[7] 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.

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. An additional enhancement for the 2022 C3 CMV inventory was the development and application of a mask that was applied to remove any emissions over land due to stray AIS signals and interpolated values.

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.

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

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,[8] 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 this annual file was generated for 2022.

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.

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. For the 2022v2 platform, stack grouping was used for all CMV sources to improve CMAQ run-time and file sizes.

International Maritime Organization (IMO) Resolution MSC.99(73).

2.4.3 Railway Locomotives (rail)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

General Description

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. The development of the 2022 rail inventory is summarized here but is described in more detail in the 2022 National Emissions Inventory Locomotive Methodology documentation (ERG, 2024c).

The rail sector emissions for the 2022 emissions modeling platform are based on the 2020 NEI. Projection factors were applied based on fuel use data for Class I locomotives and rail yards. For Class II/III locomotives, activity data for the years 2012, 2017, 2020, and 2022 from the U.S. Energy Information Administration's Annual Energy Outlook was examined. Based on these data, the fuel data used in 2020 was increased across the rail system by 11.6% for the 2022 effort. The 2020 NEI is based on methods developed during the development of the 2017 NEI rail inventory 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 preliminary 2023 national emission tier fleet mix information for Class I railroads. 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 2-22. More detailed information on the development of the 2022 emission modeling platform rail inventory is available in the 2020 NEI TSD and in the 2020 National Emissions Inventory Locomotive Methodology on the 2020 NEI supporting data FTP site.

Table 2-22. 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; included in ptnonipm)

Class I Line-haul Methodology

For the 2020 inventory, the Class I railroads granted EPA permission to use the confidential link-level line haul activity geographic information system (GIS) data layer maintained and updated annually by the Federal Railroad Administration (FRA). At the time of inventory development, 2019 million gross ton (MGT) data was the most recent and complete data available. A map of the Class I railroad lines is shown in Figure 2-4. The dataset contains three columns indicating railroad ownership and nine columns indicating trackage rights for each rail segment. While most rail links have a single owner, some links have up to six different Class 1 railroad companies operating on it. To prepare the FRA data for use in the Class I line haul calculations, all segments associated with a railroad company were extracted to identify the full network for each company. This involved iterating through each of those twelve columns to identify all segments within each railroad company's network. This process was conducted seven times, one for each Class I railroad company. This resulted in a complete inventory of rail links trafficked by each Class I railroads with a record for each link/railroad company combination.

Figure 2-4. 2019 Class I Railroad Line Haul Activity

EPA collected 2020 and 2022 Class I line haul fuel use data from the most recent R-1 submittals from the Surface Transportation Board.[9] Consistent with previous inventory efforts, EPA summed line haul and work train fuel usage, Table 2-23. Projection factors were developed based on the increased fuel use in 2022 and applied to the 2020 emissions.

Table 2-23. 2020 and 2022 R-1 reported locomotive fuel use for Class I railroads

Class I Railroad	2020 Line Haul Fuel Use (gal)*	2022 Line Haul Fuel Use (gal)*
BNSF	1,137,598,007	1,175,184,806
Canadian National (CN)	96,337,392	107,012,486
Canadian Pacific (CPRS)	57,664,407	64,138,533
CSX Transportation (CSXT)	327,917,859	356,002,171
Kansas City Southern (KCS)	55,763,748	64,185,774
Norfolk Southern (NS)	342,470,779	354,139,306
Union Pacific (UP)	773,476,896	839,457,293

* Includes work train fuel usage

The Association of American Railroads (AAR) provided national Class I locomotive tier fleet mix information that reflects engine turnover in the nation. Given the impact of the pandemic in 2020, AAR provided a fleet mix that reflected active locomotives and excluded those that were held in storage. A locomotive's Tier level determines its allowable emission rates based on the year when it was built and/or re-manufactured. More accurate emission factors for each pollutant were calculated based on the percentage of the operating Class I line haul locomotives for each USEPA Tier-level category.

Class II and III Methodology

There are approximately 630 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). Data on Class II and III locomotive operations is publicly available from Bureau of Transportation Statistics' National Transportation Atlas Database (NTAD), along with related data including reporting mark, railroad name, route miles owned or operated, and total route miles of links.

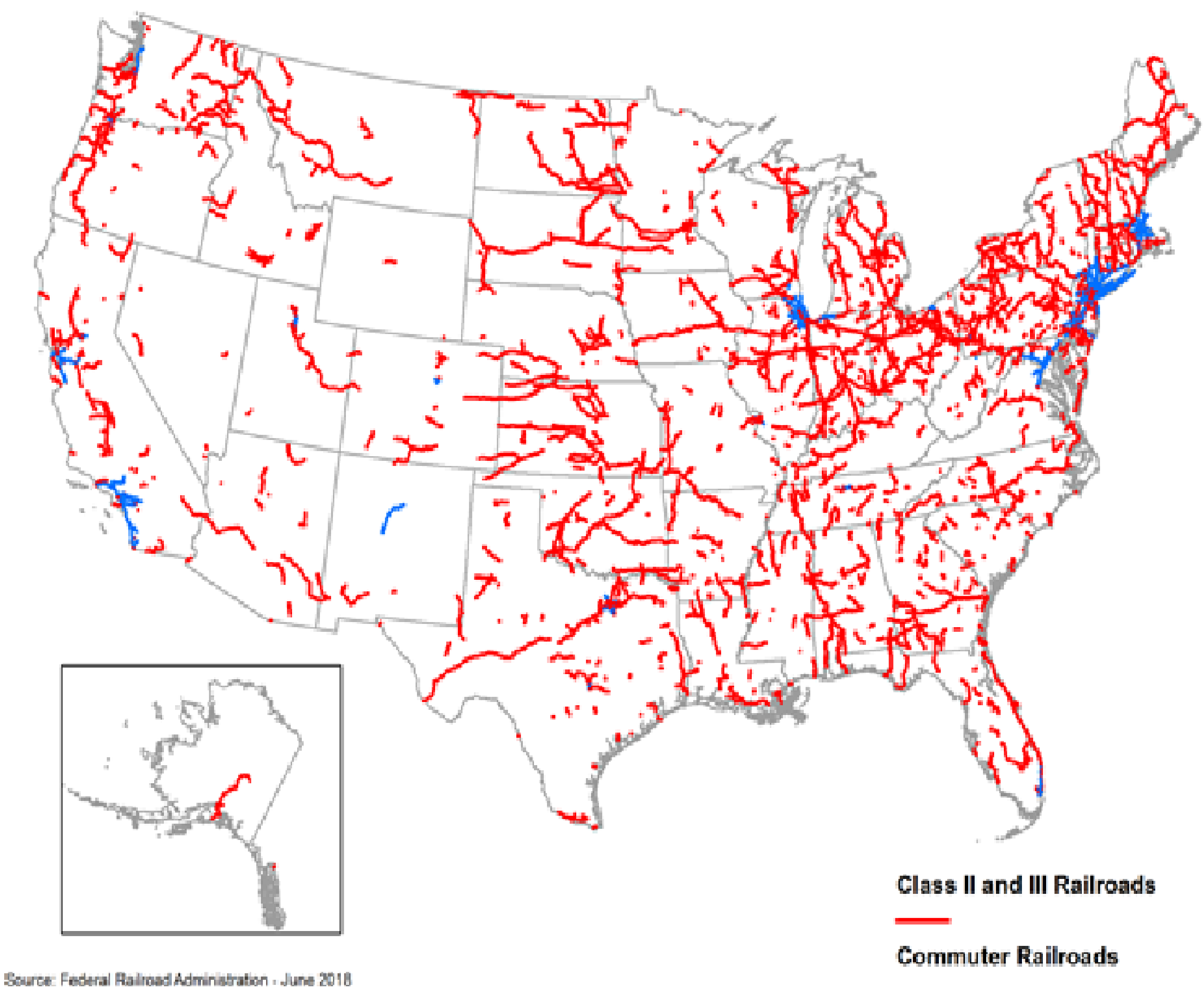
Class II and III railroads are widely dispersed across the country (see Figure 2-5), often utilizing older, higher emitting locomotives than their Class I counterparts. AAR provided a national line-haul tier fleet mix profile for 2020 which reflects the trend toward older engines in this sector as shown in Table 2-24. These data continue to be used for the 2022 platform. The national fleet mix data was then used to calculate weighted average in-use emissions factors for the locomotives operated by the Class II and III railroads. Note that to be consistent with the 2020 inventory, the unweighted emission factors were the same as the Class I line haul due to the conservative use of the EPA's large locomotive conversion factor of 20.8 bhp-hr/gal. Emission factors for PM2.5, SO2, NH3, VOC, and GHGs were calculated in the same manner as those used for Class I line-haul inventory described above.

[9] Surface Transportation Board. Available at https://www.stb.gov/reports-data/economic-data/annual-report-financial-data/ Retrieved 22 June 2021.

Table 2-24. 2020 Class II/III line haul fleet by tier level

Tier	2020 Class II/III Locomotive Count	Percent of Total Fleet
0	1,664	48%
1	31	1%
2	169	5%
3	160	5%
4	64	2%
Not Classified	1,359	39%
Total	**3,447**	**100%**

Figure 2-5. Class II and III Railroads in the United States



For the 2022 inventory, EPA considered activity data for the years 2012, 2017, 2020, and 2022 from the U.S. Energy Information Administration's Annual Energy Outlook, shown in Table 2-25 below.[10] Based on these data, the fuel data used in 2020 was increased across the rail system by 11.6% for the 2022 effort.

Table 2-25. Rail freight values by year (quadrillion BTU)

2012	2017	2020	2022
0.43	0.52	0.44	0.48

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 for 2020 and 2022 were based on data collected by the Federal Transit Administration (FTA) for the National Transit Database and projection factors calculated. These fuel use estimates were replaced with reported fuel use statistics for MBTA (Massachusetts) and Metra (Illinois). 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)

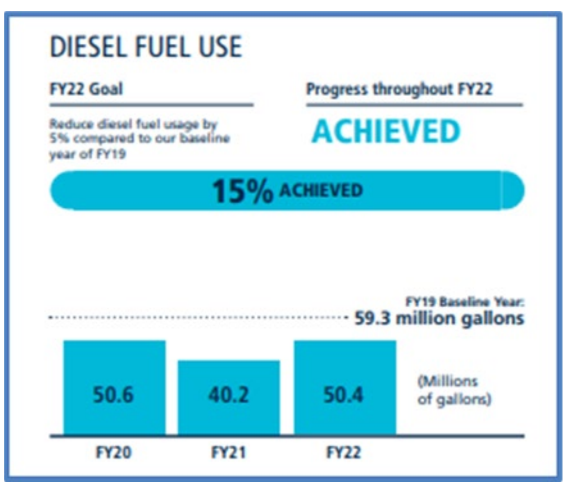
The calculation methodology mimics that used for the Class II and III and commuter railroads with a few modifications. Since link-level activity data for Amtrak was unavailable, the default assumption was made to evenly distribute Amtrak's 2020 reported fuel use across all of it diesel-powered route-miles shown in Figure 2-6.

[10] USEIA, Annual Energy Outlook 2021. Accessed 3 Apr 2024. Available at https://www.eia.gov/outlooks/aeo/data/browser/#/?id=7-AEO2021&cases=ref2021&sourcekey=0

Figure 2-6. Amtrak National Rail Network

For 2022 platform, the 2020 fuel use and emissions were adjusted down based on the fuel use reported in Amtrak's FY22 AMTRAK Sustainability Report as shown in Figure 2-7. The adjustment was applied uniformly, so the spatial representation of the emissions did not change.

Figure 2-7. Amtrak Diesel Fuel Use 2020-2022



Upon receipt of state-provided comments, two adjustments were made to Amtrak emissions. First, Delaware verified that all Amtrak passenger service in/through the state utilize electric locomotives only, so fuel usage and emissions for Delaware SCC 2285002008 were removed. Second, Connecticut confirmed that Amtrak trains operating on electrified lines do not have diesel emissions. The state provided emissions estimates which were used to replace the previously calculated emissions.

Other Data Sources

The 2020 NEI locomotives sector includes data from SLT agency-provided emissions data, and an EPA dataset of locomotive emissions. The following agencies also submitted emissions to locomotive SCCs: Alaska Department of Environmental Conservation; California; Connecticut; District of Columbia; Maricopa County, AZ; Minnesota; North Carolina; Texas; Virginia; Washington; and Washoe County, NV.

2.4.4 Nonroad Mobile Equipment (nonroad)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- For the 2022v2 draft, a new MOVES run was performed using MOVES5; these emissions were retained unchanged in the 2022v2 final emissions in most areas.
- Updated recreational vehicle populations submitted by the Utah Department of Environmental Quality were incorporated.
- At the request of Georgia Environmental Protection Division, the spatial distribution for construction and agricultural equipment was replaced with the values developed during the 2016 Collaborative.
- Emissions from off-highway trucks at mines in Minnesota were incorporated at the request of the Minnesota Pollution Control Agency.
- Improved state-to-county allocation factors for snowmobiles in Minnesota and Wisconsin provided by Wisconsin Department of Natural Resources were applied.

General Description

The mobile nonroad equipment sector includes all mobile source emissions that do not operate on roads, excluding commercial marine vehicles, railways, and aircraft. Types of nonroad equipment include recreational vehicles, pleasure craft, and construction, agricultural, mining, and lawn and garden equipment. Nonroad equipment emissions for 2022v2 were computed by running MOVES5, the most current public version of MOVES available, whereas the 2022v1 emissions were developed using MOVES4. The only change to MOVES5 impacting the nonroad component of the model was updated default fuel characteristics (primarily sulfur levels) for gasoline and marine diesel fuel, based on nationwide retail fuel survey data. Additionally, MOVES5 was run using 2022 meteorological data. MOVES provides a complete set of HAPs and incorporates updated nonroad emission factors for HAPs. MOVES5 was used for all states other than California, which uses their own model. California nonroad emissions were provided by the California Air Resources Board (CARB) for the 2020 NEI, as well as 2023. For the 2022 emissions modeling platform CARB nonroad emissions were interpolated between 2020 and 2023. CARB emissions were used in California for all pollutants except PAHs and CO2, which were taken from MOVES.

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 included in 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, 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 PM2.5 by speciation profile code for the PM2.5 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 PM2.5 called PM25TOTAL was added to the inventory. As with VOC, PM25_####-PM25TOTAL ratios were calculated and applied to PM2.5 emissions in California so that PM2.5 emissions in California can be speciated consistently with other states.

MOVES5 outputs emissions data in county-specific databases, and a post-processing script converts the data into FF10 format. Additional post-processing steps were performed as follows:

- County-specific FF10s were combined into a single FF10 file.
- Emissions were aggregated from the more detailed SCCs modeled in MOVES to the SCCs modeled in SMOKE. A list of the aggregated SMOKE SCCs is in Appendix A of the 2016v1 platform nonroad specification sheet (NEIC, 2019).
- To reduce the size of the inventory, HAPs 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 CAP emissions totaling 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 to VOC_INV so that SMOKE does not speciate both VOC and NONHAPTOG, which would result in a double count.
- PM25TOTAL, referenced above, was also created at this stage of the process.
- Emissions for airport ground support vehicles (SCCs ending in -8005), and oil field equipment (SCCs ending in -10010), were removed from the inventory at this stage, to prevent a double count with the airports and np_oilgas sectors, respectively.
- California emissions from MOVES were deleted and replaced with the CARB-supplied emissions.

National Updates: Agricultural and Construction Equipment Allocation

The modified MOVES default database for that included the refinements made to construction and agricultural sectors in the 2016 platform process (movesdb20220105_nrupdates) and state-submitted inputs in CDBs from the most recent NEI were used to run MOVES-Nonroad to produce emissions for all states other than California. California-submitted emissions were used. Updated *nrsurrogate*, *nrstatesurrogate*, and *nrbaseyearequippopulation* tables, along with instructions for utilizing these tables in MOVES runs, are available for download from EPA's ftp site: https://gaftp.epa.gov/air/emismod/2016/v1/reports/nonroad/). In the 2022v2 platform, these updates to spatial allocation were also reflected in Georgia instead of their submitted values from the 2020 NEI.

Emissions Inside California

California nonroad emissions were provided by CARB for the 2020 NEI and 2023 NEI. The 2022 emissions were interpolated between 2020 and 2023 where pollutants were available in both data sets. 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 HAPs from California were incorporated into speciation similarly to VOC HAPs from MOVES elsewhere, e.g., model species BENZ is equal to HAP emissions for benzene as submitted by CARB. VOC and $PM_{2.5}$ emissions were allocated to speciation profiles. Ratios of VOC ($PM_{2.5}$) by speciation profile to total VOC ($PM_{2.5}$) 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.

State-Submitted Data

The CDBs used to run MOVES-Nonroad to produce emissions for all states other than California were consistent with those used to develop the 2020 NEI. The following states submitted CDBs for the 2020 NEI: Arizona - Maricopa Co.; Connecticut; Georgia; Illinois; Indiana; Michigan; Minnesota; Ohio; Oregon; Texas; Utah; Washington; and Wisconsin.

Following the completion of the MOVES runs, railway maintenance emissions were removed from specific counties / census areas in Alaska because Alaska DEC specified that this type of activity does not happen in those areas. Specifically, emissions from SCCs 2285002015, 2285004015, and 2285006015 were removed from the following counties / census areas: 02013, 02016, 02050, 02060, 02063, 02066, 02070, 02100, 02105, 02110, 02130, 02150, 02158, 02164, 02180, 02185, 02188, 02195, 02198, 02220, 02240, 02275, and 02282. Alaska DEC also specified some counties / census areas in which logging and agricultural emissions do not happen, but the emissions for the specified SCCs were already zero in the specified areas.

For more information on the development of the nonroad emissions inputs for the 2020 NEI see Section 4 of the 2020 NEI TSD.

Nonroad emissions updates made outside of MOVES

After MOVES5 was run to generate nonroad emissions for the 2022v2 platform, two sets of modifications were made to the resulting SMOKE-ready inventory:

- In Minnesota and Wisconsin, emissions from snowmobiles (SCC 2260001020) were recomputed with a more realistic spatial (i.e., county) distribution in each state. Overall emissions totals by state did not change, only the county distributions in each state changed.

- In St Louis County, Minnesota, emissions associated with offroad mining truck activity were provided by Minnesota. Normally, this category of emissions is generated by MOVES under SCC 2270002051, which is then combined with other diesel construction SCCs as part of aggregate SCC 2270002022. To facilitate use of these updated emissions, MOVES-calculated emissions for SCC 2270002051 were removed from MOVES post-processing and were not included in SCC 2270002022, and the Minnesota-provided emissions were added to the SMOKE-ready inventory with SCC 2270002051. They were kept separate rather than combined with 2270002022 to facilitate more detailed spatial allocation of these sources as described in Section 3.4.2.

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

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

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

2022v2 updates relative to earlier 2022 emissions modeling platforms

- Alabama, Mississippi and Texas state agencies provided prescribed burn activity
  - These data were used to generate 2022v2 emissions estimates.
- Removed some satellite-only detected fires on DOI and USFS lands after further examination by these agencies.
- Removed false detects that were over oil and gas operations (DOI lands in New Mexico).
- Improved characterization of several prescribed and wildfires after air quality modeling feedback.
  - Prescribed burns in Minnesota and Texas; Wildfires in New Jersey and Oregon.
- Ditch burns on agricultural lands in the Midwest and in Idaho moved to an agricultural burn SCC from a prescribed burn SCC (used same methodology as in 2023 NEI).
- Moved some satellite detected only fires from prescribed burn to agricultural burn based on landuse analysis.
- Applied pile burn methodology to some prescribed burns in western states based on satellite analysis.
- Duplicate wildland fires in Georgia removed.
- Washington: some prescribed burns moved from pile burns to broadcast burns on federal lands.
- Removed two prescribed burns in New Jersey.
- Minnesota prescribed burn was corrected
- Duplicate fires in North Carolina were removed.
- Pile burns in Georgia with bad coordinates were removed.

General Description

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-rx sector excludes agricultural burning and other open burning sources that are included in the ptagfire, openburn, and nonpt sectors. The ptfire-rx sector includes a new methodology for calculating pile burn emissions with this year 2022 emissions modeling platform. 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 2-26. The ptfire-rx and ptfire-wild inventories include separate SCCs for the flaming and smoldering combustion phases for wildfire and prescribed burns. Note that the prescribed grassland fires for Flint Hills, Kansas has their own SCC (2801500171) in the inventory. Any wild grassland fires were assigned the standard wildfire SCCs shown in Table 2-26. A new source was added to wildland fires for the 2022 platform. This new source was Pile Burns with a SCC = 2810005001. Pile burns have been a burn method used for prescribed burns for many years, but no methodology for estimating the emissions from these burns had been used in previous NEIs or Emissions Modeling Platforms.

Table 2-26. SCCs included in the ptfire sector for the 2022 platform

SCC	Description
2801500171	Agricultural Field Burning - whole field set on fire; Fallow
2810001001	Forest Wildfires; Smoldering; Residual smoldering only (includes grassland wildfires)
2810001002	Forest Wildfires; Flaming (includes grassland wildfires)
2810005001	Prescribed burning; pile burns
2811015001	Prescribed Forest Burning; Smoldering; Residual smoldering only
2811015002	Prescribed Forest Burning; Flaming
2811020002	Prescribed Rangeland Burning

Fire Information Data

Inputs to SMARTFIRE2 for 2022 include:

- The National Oceanic and Atmospheric Administration's (NOAA's) Hazard Mapping System (HMS) fire location information
- Wildland Fire Interagency Geospatial Services (WFIGS) wildland fire perimeter polygons
- The Incident Status Summary, also known as the "ICS-209", used for reporting specific information on fire incidents of significance
- Hazardous fuel treatment reduction polygons for prescribed burns from the Forest Service Activity Tracking System (FACTS)
- Fire activity on federal lands from the United States Department of Interior agencies

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 2022 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 a modified, python-based, Satellite Mapping Automated Reanalysis Tool for Fire Incident Reconciliation version 2 SmartFire2/BlueSky Pipeline (SF2/BSP).

Wildland Fire Interagency Geospatial Services (WFIGS) 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 are based upon input data 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 2022 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 US Forest Service (USFS) compiles a variety of fire information every year. Year 2022 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 Department of Interior (DOI) also compiles wildfire and prescribed burn activity on their federal lands every year. Year 2022 DOI data were acquired from National Fire Plan Operations and Reporting System (NFPORS) and through direct communication with DOI staff and were used for 2022 platform development. The DOI fire information provided fire type, acres burned, latitude-longitude, and start and ending times.

About 30 different states provided fire activity that was used in developing the wildland fire inventory. Table 2-27 below gives a listing of the type of fire activity data provided by each state that participated.

Table 2-27. Types of state-provided fire activity data

SLT	Wildfire	Prescribed burns	RX includes pile burns	Ag burns
Alabama	No	Yes	Yes	Yes
Arizona	No	Yes	Yes	No
Arkansas	Yes	Yes	Yes	Yes
California	Yes	Yes	Yes	No
Colorado	No	Yes	Yes	No

SLT	Wildfire	Prescribed burns	RX includes pile burns	Ag burns
Connecticut	Yes	Yes	No	No
Delaware	No	Yes	No	Few
Florida	Yes	Yes	Yes	Yes
Georgia	Yes	Yes	No	Yes
Idaho	No	No	No	Yes
Iowa	Yes	Yes	Yes	No
Kansas	No	Yes	No	No
Maine	Yes	Few	No	No
Maryland	Yes	Yes	Yes	No
Minnesota	No	Yes	No	No
Mississippi	No	Yes	No	Yes
Missouri	No	Yes	No	Yes
Montana	No	Yes	Yes	No
Nevada	No	Yes	Yes	No
New Jersey	Yes	Yes	No	No
New Mexico	Yes	Yes	No	No
Nez Perce Tribe	No	Yes	Yes	Yes
North Carolina	Yes	Yes	No	No
North Dakota	No	Yes	No	No
Oklahoma	No	Yes	No	No
Oregon	Yes	Yes	Yes	No
Pennsylvania	Yes	Yes	No	No
South Carolina	Yes	Yes	Yes	Yes
Texas	Yes	Yes	Yes	No
Utah	No	Yes	Yes	No
Virginia	Yes	Yes	No	No
Washington	No	Yes	Yes	Yes
Wyoming	Yes	Yes	Yes	No

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 2022 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 PM2.5, VOCs, and CO, at higher rates than flaming combustion. Smoldering combustion is more prevalent with fuels that have low surface-to-volume ratios, high bulk density, and high moisture content. Models sometimes differentiate between smoldering emissions that are lofted with a smoke plume and those that remain near the ground (residual emissions), but for the purposes of the inventory the residual smoldering emissions were allocated to the smoldering SCCs listed in Table 2-26. The lofted smoldering emissions were assigned to the flaming emissions SCCs in Table 2-26.

Figure 2-8 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 BlueSky Pipeline. SMARTFIRE2 is an algorithm and database system that is 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 2022 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 2-8 was used to make fire type assignment by state and by month in conjunction with the default fire type assignments shown in Figure 2-9. The default fire type assignments are the same for both the 2022v1 and 2022v2 platforms.

Figure 2-8. Processing flow for fire emission estimates in the 2022 inventory

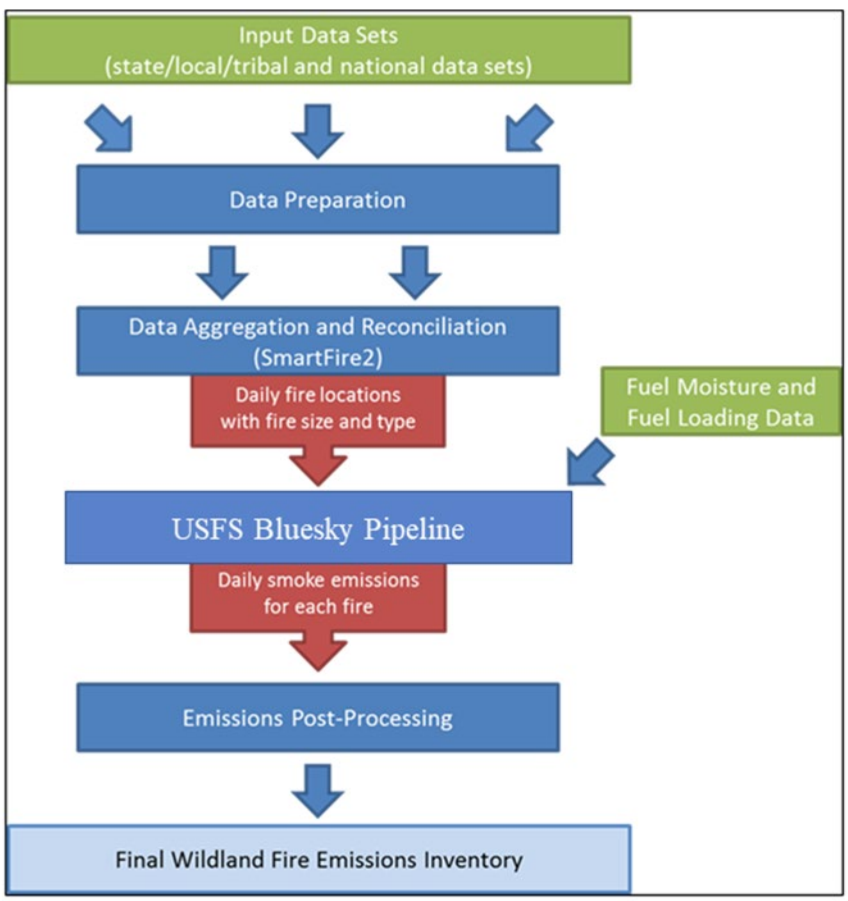
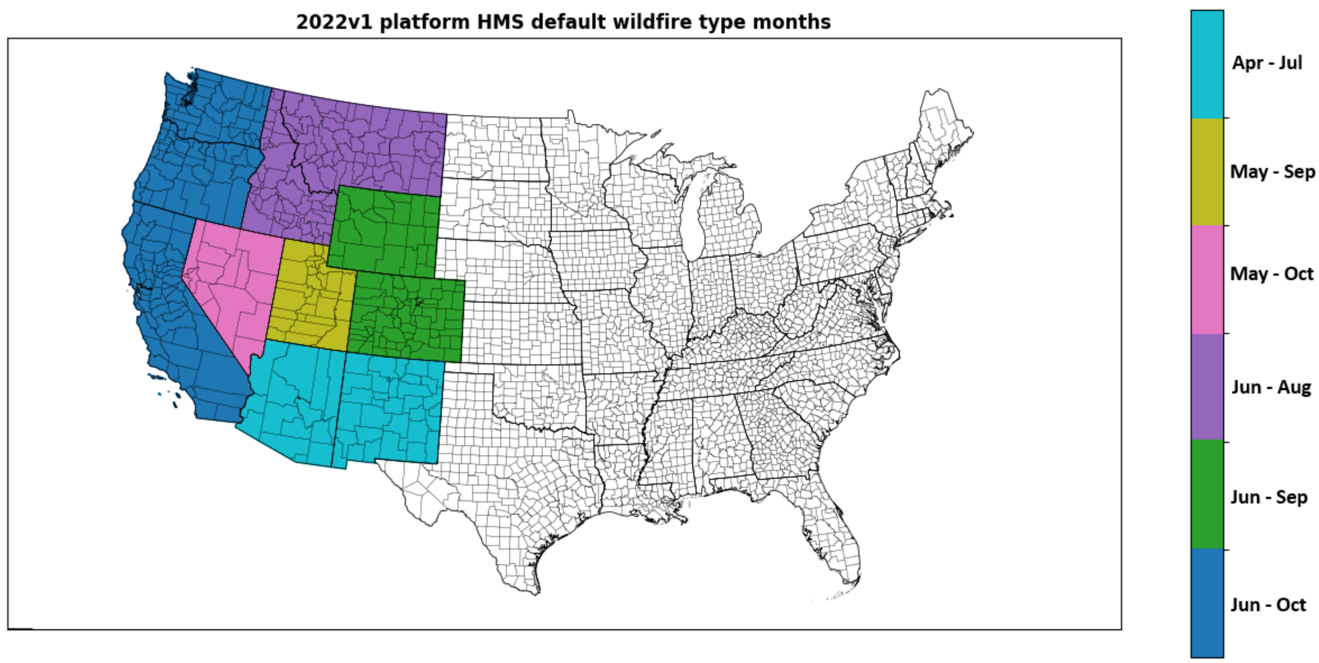
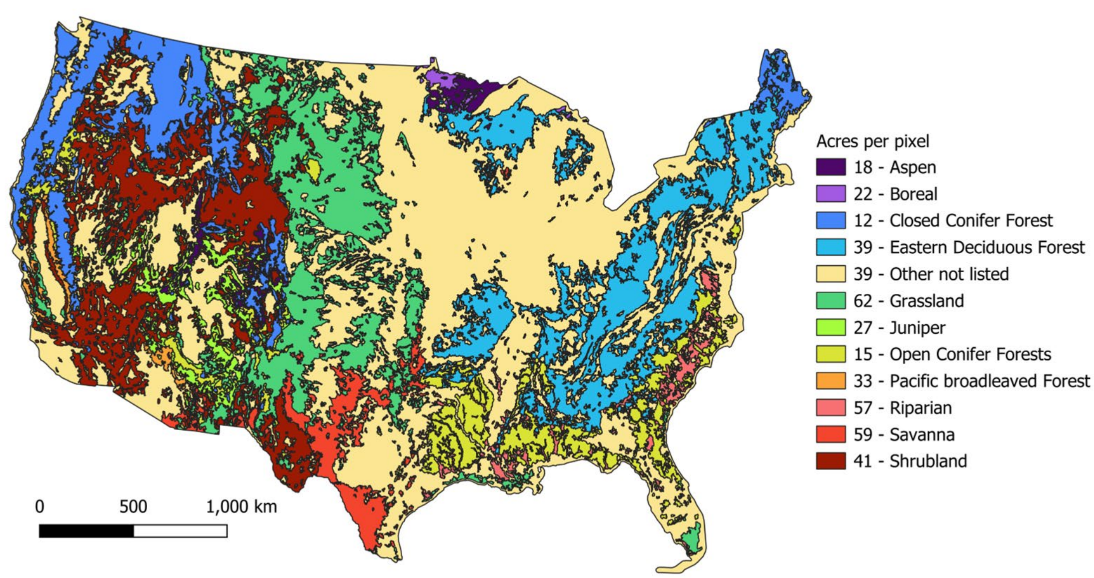


Figure 2-9. Default fire type assignment by state and month where data are only from satellites



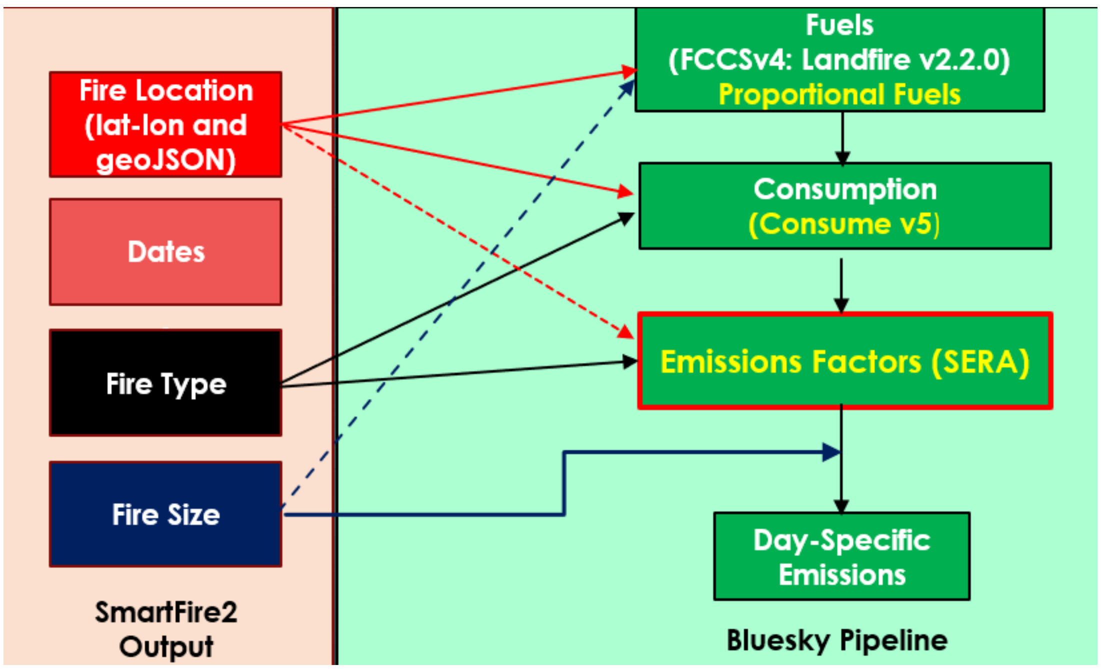
In SMARTFIRE2, there are cases where an HMS satellite detect does not reconcile with any national or SLT agency activity dataset. These HMS-only detected burns are assigned to a fire type according to the land cover, each with a different size assumption. The land cover assumption for each of these detects is shown in Figure 2-10.

Figure 2-10. Default acres burned assumption map for HMS-only detected fires



The second system used to estimate emissions is the BlueSky Modeling Pipeline (BSP). 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 Smoke Emissions Reference Application (SERA) in the BSP generates all the CAP emission factors for wildland fires used in the 2022 study. SERA factors can vary by phase, fire type, region, fuel type and pollutants. SERA emission factors are available here: https://depts.washington.edu/nwfire/sera/index.php. SERA consists of existing peer-reviewed emission factors (EFs) of 276 known air pollutants. The SERA database enables the analysis and summaries of existing EFs, and creation of average EFs to be used in decision support tools for smoke management, including BSP. HAP emission factors were obtained from Urbanski's (2014) work and applied by region and by fire type.

Figure 2-11. Blue Sky Modeling Pipeline

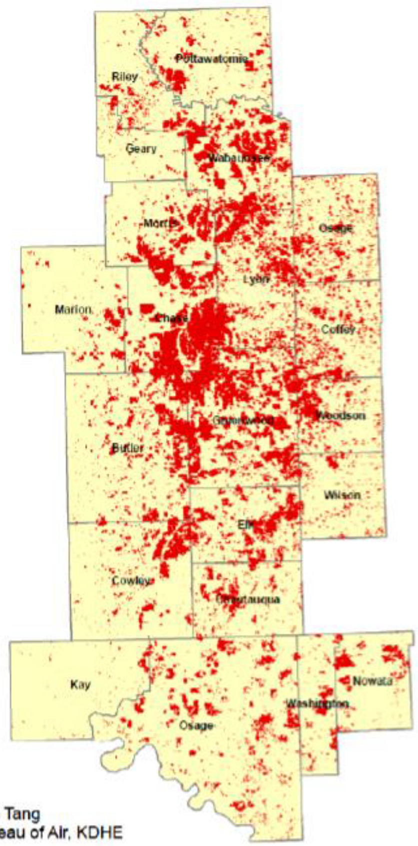


The FCCSv4 cross-reference was implemented along with the LANDFIREv2 (at 120-meter resolution) to provide better fuel bed information for the BlueSky Pipeline (BSP). The LANDFIREv2 was aggregated from the native resolution and projection to 120 meter using a nearest-neighbor methodology. Aggregation and reprojection were required for the proper function on BSP.

The Flint Hills grasslands typically have 1 to 2 million acres of prescribed burns each year usually between late February to early May. Kansas Department of Health Environment provided county acres burned information for these prescribed burns for 2022 (Figure 2-12) that cover most of eastern Kansas and 4 additional counties in eastern Oklahoma. Between February 15-April 30 about 2.1M acres were burned in the Flint Hills. The HMS detects for this time period and for these counties (about 21000 detects) were used to temporally and spatially allocate these prescribed burns and the associated estimated emissions. The emissions estimation process is done outside of BSP using SERA emissions factors, except for PM2.5 where a factor of 12.68 g/kg was used for these Flint Hill burns. The Flint Hills emissions are assigned the SCC 2801500171.

Figure 2-12. Flint Hills Acreage Burned in 2022

Flint Hills Acreage Burned (February 14 – April 30, 2022)



County	Acres Burned
Butler	163,895
Chase	237,442
Chautauqua	57,901
Coffey	85,902
Cowley	88,095
Elk	109,933
Geary	17,035
Greenwood	315,605
Lyon	180,190
Marion	37,483
Morris	96,126
Osage (KS)	83,894
Pottawatomie	59,106
Riley	53,700
Wabaunsee	182,259
Wilson	33,592
Woodson	69,422
Nowata (OK)	43,507
Osage (OK)	156,297
Washington (OK)	30,842
Kay (OK)	10,533
Total	2,112,759

Yao Tang
Bureau of Air, KDHE

In 2022v1 and in the 2020 NEI, HMS detects on or near corn and soybean fields in the Midwest were assumed to be nearby irrigation ditch or other type of ditch burns. These emissions were also estimated outside of BSP using the assumption of fuels being similar to grasses. In 2022v1, these ditch burns were put into the prescribed burn sector (ptfire-rx) and assigned a Rangeland burning SCC 2811020002. In 2022v2, these ditch burns were moved to the agricultural burn sector and leveraged the SCC 2801540000.

The final products from this process were 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).

For the 2022 platform, pile burn (PB) emissions were estimated using a combination of federal, state, local, and tribal activity data. This activity data was supplied in the form of daily estimates of area treated, pile volume, pile dimensions, or mass piled by location, varying by data source. As with the RX and WF S/L/T data, the pile burn data was imported into SF2 so that it could be reconciled with other data sources to avoid duplication of activity and emissions. HMS satellite detects that reconciled only with the location of the PB activity were removed from the BSP workflow as pile burns. The PB activity data was then directly imported into a calculator script that estimates the amount of biomass consumed at each location and the resulting emissions. The consumption calculations made are consistent with those used in the University of Washington pile burn calculator (https://depts.washington.edu/nwfire/piles/). For activity data where only a treated area is provided a default fuel loading of 4.5 tons per acre is used based on an analysis of California and Washington historical pile burn permits. A consumption efficiency of 90% is assumed unless otherwise specified in the activity data. Emissions factors averaged over pile burn studies in the SERA database were applied to estimate CAPs from the consumed piled biomass.

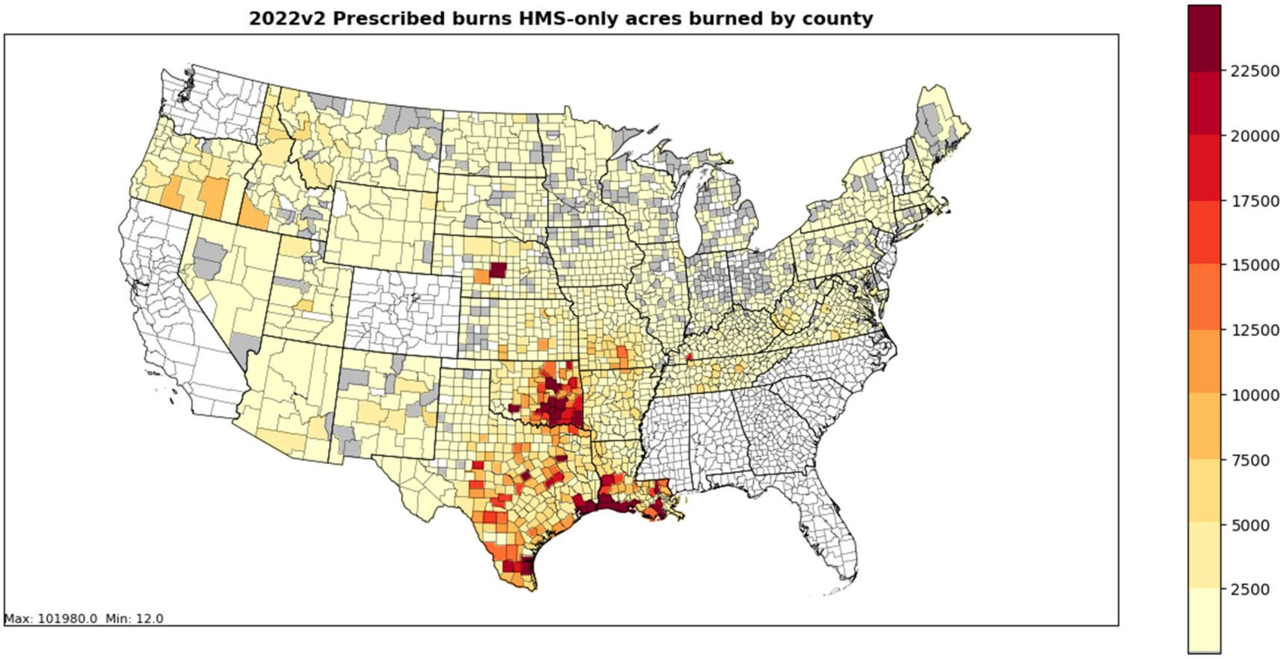
The 2022v2 EMP includes emissions from the 4.5M acres of wildfires plus an estimated 12.7M acres in prescribed burns. Activity data from federal and state agencies yielded about 8.2M acres of prescribed burn land. The remaining 4.5M prescribed burn acres were estimated using a default acre burn assumption were not reconciled with any federal or state agency fire activity data (see Table 2-28). The default acre burn assumption was applied to any HMS detects that did not reconcile with any federal or state agency activity data.

Table 2-28. Number of acres burned from HMS satellite only detected burns in 2022v2

Fire Type	Total Acres Burned	HMS satellite detected only	Reconciled with activity data	% not reconciled with activity in v2
Prescribed burns	12,733,214	4,512,461	8,220,753	35.4%
Wildfires	4,503,624	70,921	4,432,703	1.6%

Most of the 4.5M prescribed burn acres that are estimated using a default acres burn and fire type assumption are located in South Central USA (Texas, Louisiana, Missouri, Oklahoma and Arkansas) as shown in Figure 2-13. Approximately 417,500 tons of primary $PM_{2.5}$ emissions are estimated in 2022v2 from satellite detections labeled as prescribed burns using the fire type assumption method. White areas indicate no HMS-only prescribed burns.

Figure 2-13. 2022v2 annual county acres burned from satellite-only detected burns



2.5.2 Point source Agriculture Fires (ptagfire)

- Ditch burns were moved from the prescribed burn sector to the agricultural burn sector
    - Ditch burns assigned to SCC 2801540000
    - Emissions from ditch burning were added in 2022hd and 2022he for Idaho, Arkansas, Illinois, Indiana, Iowa, Kansas, Kentucky, Michigan, Minnesota, Nebraska, Ohio, Oklahoma, Tennessee, Wisconsin, and Missouri
- Emissions from prescribed rangeland burning (flaming) were added in 2022hd and 2022he for Arizona, Louisiana, Minnesota, New Mexico, Oklahoma, South Dakota, and Wyoming.
- Emissions from prescribed rangeland burning (flaming) increased (~15%) in 2022hd and 2022he for Idaho.
- Emissions from two agricultural field burning SCCs (2801500150, 2801500171) decreased (~13%) in 2022hd and 2022he for Arizona.
- All other state-level changes were very small (< 5%), restricted to agricultural field burning, and only included Arizona, Idaho, Louisiana, Mississippi, Oklahoma, South Dakota, and Wyoming.

General Description

In the NEI, agricultural fires are stored as county-annual emissions and are part of the nonpoint data category. For this 2022 platform, agricultural fires are modeled as day specific fires derived from satellite data for the year 2022 in a similar way to the emissions in ptfire.

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 2022 USDA cropland data layer (CDL). Satellite fire detects over agricultural lands are assumed to be agricultural burns and assigned a crop type based on the CDL 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 120 acres varying by state. Grassland/pasture fires were moved to the ptfire sectors for this 2022 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 2-29.

Table 2-29. 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
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;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
2801500264	Miscellaneous Area Sources; Agriculture Production - Crops - as nonpoint; Agricultural Field Burning - whole field set on fire; DoubleCrop Winter Wheat and Soybeans
2801540000	Miscellaneous Area Sources;Other Combustion;Agricultural Field Burning - Ditch Burning;Unspecified
2811020002	Miscellaneous Area Sources; Other Combustion - as Event; Prescribed Rangeland Burning; Flaming

Another feature of the ptagfire database is that the satellite detections for 2022 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 2022 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.

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 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 2022 agricultural fire inventories include emissions for HAPs, so HAP integration was used for this study.

2.6 Biogenic Sources (beis)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

General Description

Biogenic emissions were computed based on the 2022 meteorology data used for the 2022 platform and were developed using the Biogenic Emission Inventory System version 4 (BEIS4) within CMAQ. BEIS4 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 BEIS4 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). BEIS4 computes the seasonality of emissions using the 1-meter soil temperature (SOIT2) instead of the BIOSEASON file, and canopy temperature and radiation environments are now modeled using the driving meteorological model's (WRF) representation of leaf-area index (LAI) rather than the estimated LAI values from BELD data alone. See these CMAQ Release Notes for technical information on BEIS4: https://github.com/USEPA/CMAQ/wiki/CMAQ-Release-Notes:-Emissions-Updates:-BEIS-Biogenic-Emissions. The variables output from the Meteorology-Chemistry Interface Processor (MCIP) that are used to convert WRF outputs to CMAQ inputs are shown in Table 2-30.

Table 2-30. Meteorological variables required by BEIS4

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

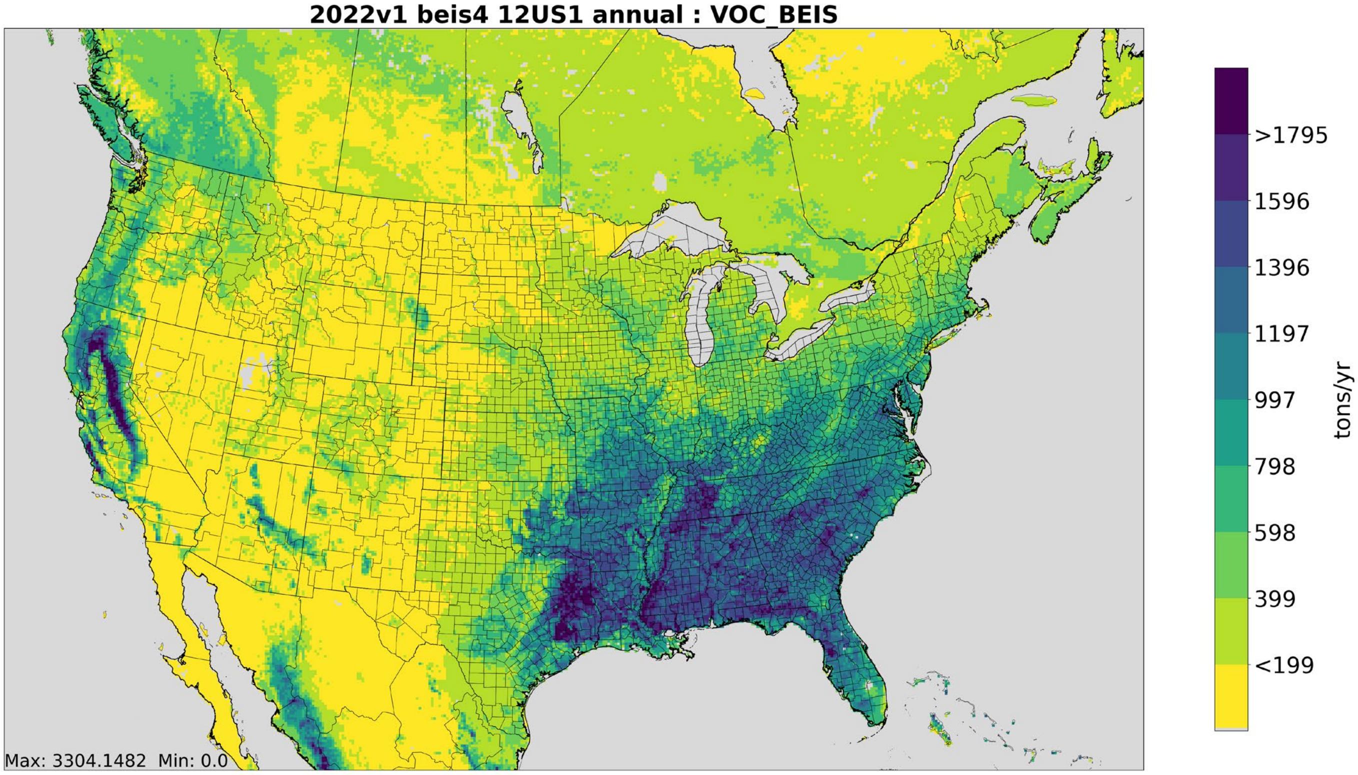
Variable	Description
SLYTP	soil texture type by USDA category
SOIM1	volumetric soil moisture in top cm
SOIT1	soil temperature in top cm
TEMPG	skin temperature at ground
USTAR	cell averaged friction velocity
RADYNI	inverse of aerodynamic resistance
TEMP2	temperature at 2 m
WSAT_PX	soil saturation from (Pleim-Xiu Land Surface Model) PX-LSM

The Biogenic Emissions Landcover Database version 6 (BELD6) was used as the input gridded land use information in generating the biogenic emissions estimates. There are now two different BELD6 datasets that are input into BEIS4. The gridded landuse and the other is the gridded dry leaf biomass (grams/m^2) values for various vegetation types. The BELD6 includes the following datasets:

- High resolution tree species and biomass data from Wilson et al. 2013a, and Wilson et al. 2013b for which species names were changed from non-specific common names to scientific names
- Tree species biogenic volatile organic carbon (BVOC) emission factors for tree species were taken from the NCAR Enclosure database (Wiedinmyer, 2001)
    - https://www.sciencedirect.com/science/article/pii/S1352231001004290
- Agricultural land use from US Department of Agriculture (USDA) crop data layer
- 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)
- 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).
    -

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. Figure 2-14 provides an annual estimate of the biogenic VOC emissions in year 2022 from BEIS4.

Figure 2-14. Annual biogenic VOC BEIS4 emissions for the 12US1 domain



2.7 Sources Outside of the United States

The emissions from Canada and Mexico are included as part of the emissions modeling sectors: canmex_point, canmex_area, canada_afdust, canada_ptdust, canada_onroad, mexico_onroad, canmex_ag, and canada_og2D. The canmex_ag sector is processed as a separate sector for reporting and tracking purposes, and unlike in other recent emissions platforms, the Canada ag sources are area sources in this platform rather than pre-gridded point sources. As in prior platforms, fugitive dust emissions in Canada are represented as both area sources (canada_afdust sector, formerly "othafdust") and point sources (canada_ptdust sector, formerly "othptdust"). Due to the large number of individual points, low-level oil and gas emissions in Canada are processed separately from the canmex_point sector to reduce the number of individual points to track within CMAQ, and also to reduce the size of the model-ready emissions files.

Canadian emissions in these sectors were generally taken from 2020 and 2023 inventories provided by Environment and Climate Change Canada (ECCC), interpolated to 2022. ECCC provided the inventories listed below. The sectors in which they were incorporated are listed and the inventories are also described.

- Agricultural livestock and fertilizer, area source format (canmex_ag sector)
- Surface-level oil and gas emissions in Canada (canada_og2D sector)
- Agricultural fugitive dust, point source format (canada_ptdust sector)
- Other area source dust (canada_afdust sector)
- Onroad (canada_onroad sector)

- Nonroad and rail (canmex_area sector)
- Airports (canmex_point sector)
- Other area sources (canmex_area sector)
- Other point sources (canmex_point sector)

The 2022 CMV data included coastal waters of Canada and Mexico with emissions derived from AIS data. These emissions were used for all areas of Canada and Mexico 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.

Other than the CB6 species present in the speciated point source data, there are no explicit HAP emissions in these Canadian inventories. In addition to emissions inventories, the ECCC 2020 dataset also included shapefiles for creating spatial surrogates. These surrogates were used for this study.

While emissions in the 2020 platform were adjusted at the monthly level to reflect COVID pandemic effects, no such adjustments were made for 2022 modeling.

2.7.1 Point Sources in Canada and Mexico (canmex_point)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- New data were incorporated for five states in Mexico: Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas.

General Description

Canadian point source inventories provided by ECCC include emissions for airports and other point sources. The Canadian industrial point source inventory is pre-speciated for the CB6 chemical mechanism. All Canada point source emissions were interpolated from 2020 and 2023 inventories to 2022 except for the point EGU inventory, for which the 2023 inventory was used directly. This is because for point EGUs, the ECCC inventories contain different facilities in different years, making an interpolation difficult.

Point sources in Mexico were compiled in two parts. In the 2022v1 platform, emissions inventories representing 2018 developed through a collaboration between EPA and SEMARNAT were used for the six Mexico border states: Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas. In the 2022v2 platform, year 2018 emissions for point sources were used for the additional states of Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas. Mexico inventories for all other states were based on inventories projected from the Inventario Nacional de Emisiones de Mexico, 2016 (Secretaría de Medio Ambiente y Recursos Naturales (SEMARNAT)), projected to 2019 as part of the 2019 emissions modeling platform. For the emissions carried forward from the 2019 platform, 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, 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 (canada_afdust, canada_ptdust)

<u>2022v2 updates relative to earlier 2022 emissions modeling platforms</u>

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

<u>General Description</u>

Fugitive dust sources of particulate matter emissions excluding land tilling from agricultural activities, were provided by Environment and Climate Change Canada (ECCC) for 2020 and 2023 and were interpolated to 2022 for this study. Dust emissions resulting from land tilling due to agricultural activities and livestock were provided as part of the ECCC area source dust inventory. The provided wind erosion emissions were removed. The ECCC point source dust inventory includes emissions from road dust. 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.

2.7.3 Agricultural Sources in Canada and Mexico (canmex_ag)

<u>2022v2 updates relative to earlier 2022 emissions modeling platforms</u>

- New data were incorporated for some states in Mexico: Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas.

<u>General Description</u>

Agricultural emissions from Canada and Mexico, excluding fugitive dust, are included in the canmex_ag sector. Canadian agricultural emissions were provided by Environment and Climate Change Canada (ECCC) as part of their 2020 and 2023 emission inventories (interpolated to 2022). Unlike in recent platforms, Canadian agricultural were not represented as point sources, instead they were represented as area sources and gridded using spatial surrogates. In Mexico, agricultural sources in the 2022v1 platform were based on new emissions inventories representing 2018 for the six Mexico border states (Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas), and for the 2022v2 platform 2018 emissions were used for these additional states: Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas. Emissions for all other states are from the 2019 emissions platform (SEMARNAT-provided 2016, projected to 2019).

2.7.4 Surface-level Oil and Gas Sources in Canada (canada_og2D)

<u>2022v2 updates relative to earlier 2022 emissions modeling platforms</u>

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

<u>General Description</u>

Canadian point source inventories provided by ECCC included oil and gas emissions and were interpolated between 2020 and 2023 for 2022. A very large number of these oil and gas point sources are surface level emissions, appropriate to be modeled in layer 1. Reducing the size of the canmex_point sector improves air quality model run time because plume rise calculations are needed for fewer sources, so these surface level oil and gas sources were placed into the canada_og2D sector for layer 1 modeling.

2.7.5 Nonpoint and Nonroad Sources in Canada and Mexico (canmex_area)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- New data were incorporated for some states in Mexico: Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas.

General Description

ECCC provided year 2020 and 2023 at the Canada province, and in some cases sub-province, resolution emissions from for nonpoint and nonroad sources (canmex_area). 2022 was interpolated from the 2020 and 2023 emissions. The nonroad sources were monthly while the nonpoint and rail emissions were annual.

In Mexico, nonroad and nonpoint sources the 2022v1 platform emissions were based on new emissions inventories representing 2018 for the six Mexico border states (Baja California, Sonora, Chihuahua, Coahuila, Nuevo Leon, and Tamaulipas) and in 2022v2 2018 data were used for these additional states: Baja California Sur, Durango, San Luis Potosi, Sinaloa, and Zacatecas. Emissions for all remaining states are from the 2019 emissions platform (SEMARNAT-provided 2016, projected to 2019).

2.7.6 Onroad Sources in Canada and Mexico (canada_onroad, mexico_onroad)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms for canada_onroad.
- For mexico_onroad, a new version of MOVES_Mexico was used to compute emissions.

General Description

The onroad emissions for Canada and Mexico are in the canada_onroad and mexico_onroad sectors, respectively. ECCC provided year 2020 and 2023 at the Canada province, and in some cases sub-province resolution. 2022 was interpolated from the 2020 and 2023 emissions.

For Mexico onroad emissions, an updated version of the MOVES model for Mexico was run for the 2022v2 platform. This new version provided the same VOC HAPs and speciated VOCs as the previous version of the MOVES-Mexico model. . This includes NBAFM plus several other VOC HAPs such as toluene, xylene, and ethylbenzene. 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). The new version of MOVES-Mexico includes three new source types unique to Mexico: 22 (Taxis), 44 (Microbus Colectivos), and 45 (Metrobus).

In addition to the new emissions based on the MOVES-Mexico model, the Mexico onroad emissions for 2022v2 platform also incorporate three sets of adjustments which were applied after the MOVES model was run:

- A correction factor of 0.84964 was applied to all on-network emissions from light duty cars and trucks (MOVES source types 21, 22, 31, and 32), to account for a VMT correction;
- The correction factors listed in Table 2-31 were applied to all VOC-related emissions (total VOC, speciated VOC, and all VOC HAPs); and
- The correction factors listed in Table 2-32 were applied to particulate sulfate emissions (PSO4) in all Mexico municipios except for those in and around Mexico City, Monterrey, and Guadalajara.

Emissions for the 2022v2 draft platform (2022hd case) include only the first two sets of adjustment factors listed above, while emissions for the 2022v2 final platform (2022he case) includes all three sets of adjustments.

Table 2-31. VOC adjustment factors applied to Mexico onroad emissions

Source Type	Source Type Description	VOC Correction Factor
11	Motorcycle	1.0000
21	Passenger Car	0.9999
22	Taxis	1.0000
31	Passenger Truck	0.9874
32	Light Commercial Truck	0.9937
41	Intercity Bus	0.7478
42	Transit Bus	0.6863
43	School Bus	0.7706
44	Microbuses Colectivos	1.0000
45	Metrobus	1.0000
51	Refuse Truck	1.0000
52	Single Unit Short-haul Truck	0.6094
53	Single Unit Long-haul Truck	0.6385
61	Combination Short-haul Truck	0.4676
62	Combination Long-haul Truck	0.4962

Table 2-32. PSO4 adjustment factors applied to Mexico onroad emissions in most municipios

Source Type	Source Type Description	PSO4 Correction Factor
11	Motorcycle	1.0000
21	Passenger Car	0.9999
22	Taxis	1.0000
31	Passenger Truck	0.9776
32	Light Commercial Truck	0.9888
41	Intercity Bus	0.5528
42	Transit Bus	0.4437
43	School Bus	0.5932
44	Microbuses Colectivos	1.0000
45	Metrobus	1.0000
51	Refuse Truck	1.0000

Source Type	Source Type Description	PSO4 Correction Factor
52	Single Unit Short-haul Truck	0.3075
53	Single Unit Long-haul Truck	0.3591
61	Combination Short-haul Truck	0.0560
62	Combination Long-haul Truck	0.1068

2.7.7 Fires in Canada and Mexico (*ptfire_othna*)

2022v2 updates relative to earlier 2022 emissions modeling platforms

- There were no changes in 2022v2 relative to earlier 2022 emissions modeling platforms.

General Description

Annual 2022 wildland fire emissions for Mexico, Canada, Central America, and Caribbean nations are included in the ptfire_othna sector. Canadian fire activity was developed by processing the Canadian Wildland Fire Information System's National Burned Area Composite (NBAC) and NOAA's Hazard Mapping System (HMS) through SMARTFIRE 2.[11] Emissions were estimated from the wildland fire activity using BlueSky pipeline with Canadian Fire Behavior Prediction (FBP) fuel beds mapped to Fuel Characteristic Classification System (FCCS) fuel beds. Fires in Mexico, Central America, and the Caribbean, were developed from the Fire Inventory from NCAR (FINN) v2.5 daily fire emissions for 2022 (Wiedinmyer, 2023). 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.

2.7.8 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 volcanic mercury emissions that were used in the recent modeling platforms were not included in this 2022v1 platform because no HAP+CAP modeling was performed. The emissions were originally developed for a 2002 multipollutant modeling platform with coordination and data from Christian Seigneur and Jerry Lin for 2001 (Seigneur et. al, 2004 and Seigneur et. al, 2001). The volcanic emissions from the most recent eruption were not included in the because they have diminished by the year 2019. Thus, no volcanic emissions were included.

Because of mercury bidirectional flux within the latest version of CMAQ, no natural mercury emissions are included in the emissions merge step for HAP+CAP platforms.

[11] See https://www.cmascenter.org/conference/2023/slides/2023-10-18-1350-2021-Canada-WF-Updates-CMAS.pptx.

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, pollutant, and spatial resolution into the hourly, speciated, gridded and vertical resolution required by the air quality model. Emissions modeling includes temporal allocation, spatial allocation, and pollutant speciation. Emissions modeling sometimes includes the vertical allocation (i.e., plume rise) of point sources, but many air quality models also perform this task because it greatly reduces the size of the input emissions files if the vertical layers of the sources are not included.

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

3.1 Emissions Modeling Overview

SMOKE was used to process the raw emissions inventories into emissions inputs for each modeling sector into a format compatible with CMAQ. SMOKE executables and source code are available from the Community Multiscale Analysis System (CMAS) (cmascenter.org/SMOKE). 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.

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 speciation of biogenic emissions is done within the Tmpbeis3 program and not as a separate SMOKE step. The "Inventory resolution" column shows the inventory temporal resolution from which SMOKE needs to calculate hourly emissions. Note that for some sectors (e.g., onroad, beis), there is no input inventory; instead, activity data and emission factors are used in combination with meteorological data to compute hourly emissions.

Table 3-1. Key emissions modeling steps by sector

Platform sector	Spatial	Speciation	Inventory resolution	Plume rise
afdust_adj	Surrogates	Yes	annual	
airports	Point	Yes	annual	None
beis	Pre-gridded land use	in BEIS4	computed hourly in CMAQ	
fertilizer	EPIC	No	computed hourly in CMAQ	
Livestock	Surrogates	Yes	daily	
cmv_c1c2	Point	Yes	hourly	in-line
cmv_c3	Point	Yes	hourly	in-line
nonpt	Surrogates & area-to-point	Yes	annual	
nonroad	Surrogates & area-to-point	Yes	monthly	
np_oilgas	Surrogates	Yes	annual	
np_solvents	Surrogates	Yes	annual	
openburn	Surrogates	Yes	annual	
onroad	Surrogates	Yes	monthly activity, computed hourly	
onroad_ca_adj	Surrogates	Yes	monthly activity, computed hourly	
canada_onroad	Surrogates	Yes	monthly	
mexico_onroad	Surrogates	Yes	monthly	
canada_afdust	Surrogates	Yes	annual	
canmex_area	Surrogates	Yes	annual & monthly	
canmex_point	Point	Yes	annual & monthly	in-line
canada_ptdust	Point	Yes	monthly	None
canada_og2D	Point	Yes	annual	None
canmex_ag	Surrogates	Yes	annual	
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
ptnonipm_hr	Point	Yes	hourly	in-line
rail	Surrogates	Yes	annual	
rwc	Surrogates	Yes	annual	

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. 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.

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

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

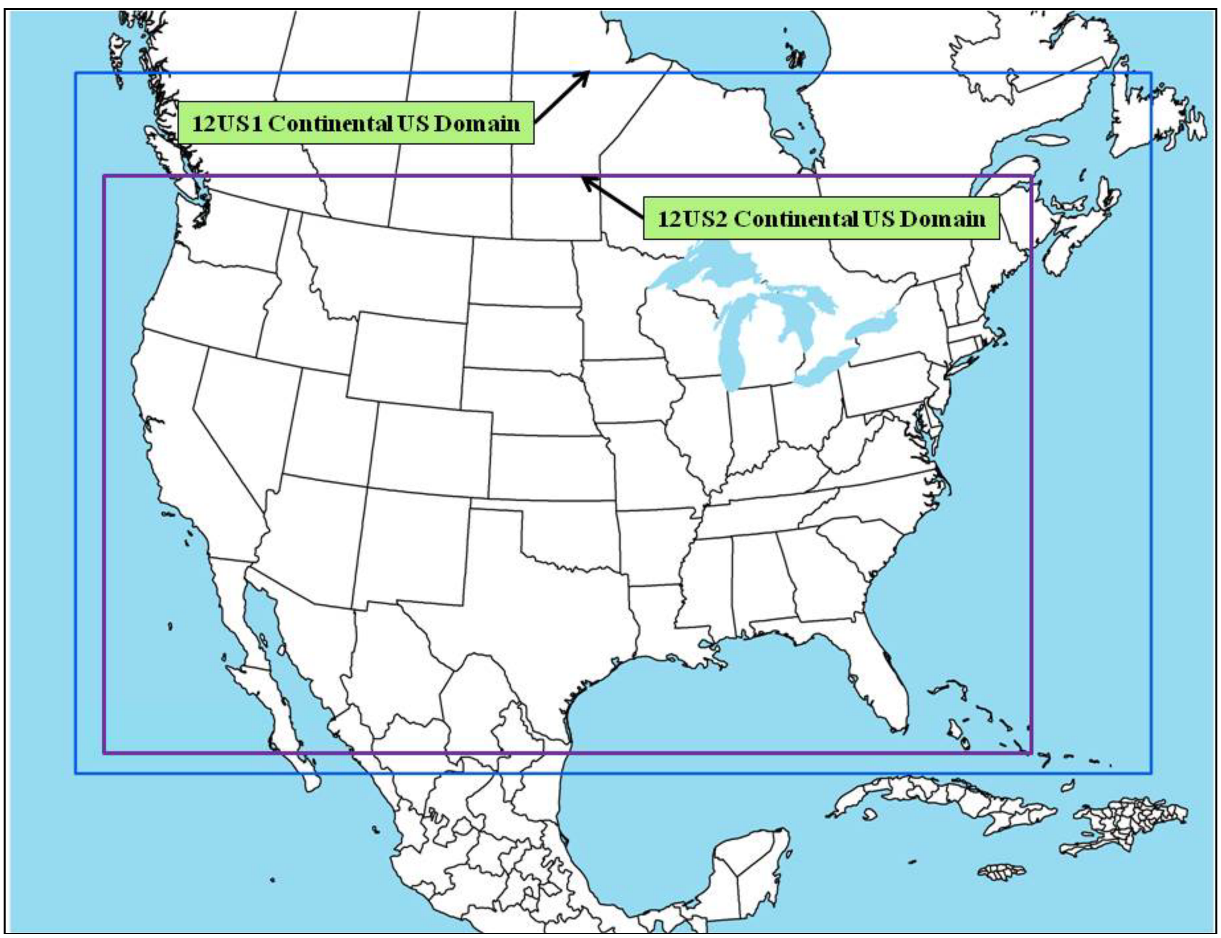
For this study, SMOKE was run for the larger 12-km CONtinental United States "CONUS" modeling domain (12US1) shown in Figure 3-1, but the air quality model was run on the smaller 12-km domain (12US2). More specifically, SMOKE was run on the 12US1 domain and emissions were extracted from 12US1 data files to create 12US2 emissions. The grids used a Lambert-Conformal projection, with Alpha = 33, Beta = 45 and Gamma = -97, with a center of X = -97 and Y = 40. In addition, SMOKE-MOVES was run for grids over Alaska, Hawaii, and Puerto Rico plus the Virgin Islands and CMV emissions were developed for those grids. Later sections provide details on the spatial surrogates and area-to-point data used to accomplish spatial allocation with SMOKE. Table 3-2 describes the grids. WRF, SMOKE, and CMAQ all presume the Earth is a sphere with a radius of 6370000 m.

Table 3-2. Descriptions of the platform grids

Common Name	Grid Cell Size	Description	Grid name	Parameters listed in SMOKE grid description (GRIDDESC) file: projection name, xorig, yorig, xcell, ycell, ncols, nrows, nthik
Continental 12km grid	12 km	Entire conterminous US plus some of Mexico/Canada	12US1	'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
Alaska 9km	9 km	9 km Alaska grid with parts of Canada	9AK1	LAM_36N_155W', -1107000, -1134000, 9000, 9000, 312, 252, 1
Hawaii 3km	3 km	Small 3 km Hawaii	3HI1	LAM_21N_157W', -391500, -346500, 3000, 3000, 225, 201, 1
Puerto Rico & Virgin Islands 3km	3 km	Small 3 km covering Puerto Rico and the Virgin Islands	3PR1	LAM_18N_66W', -274500, -202500, 3000, 3000, 150, 150, 1

Figure 3-1. CMAQ Air quality modeling domains for this platform

12US1 and 12US2



3.2 Chemical Speciation

Chemical speciation involves the process of translating emissions from the inventory into the chemical mechanism-specific "model species" needed by an air quality model. Using the CB6R5_AE7 chemical mechanism as an example, these model species either represent explicit chemical compounds (e.g., acetone, benzene, ethanol) or groups of species (i.e., "lumped species;" e.g., PAR, OLE, KET). Table 3-3 lists the model species generated by SMOKE for this mechanism and Table 3-4 lists additional model species that are generated when performing toxics modeling. Note that Table 3-3 through Table 3-4 are unchanged between the 2022v1 and 2022v2 platforms.

Table 3-3. Emission model species produced for CB6R5_AE7 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
VOC	CAT1	Methyl-catechols
VOC	CH4	Methane
VOC	CRES	Cresols
VOC	CRON	Nitro-cresols
VOC	ETH	Ethene
VOC	ETHA	Ethane
VOC	ETHY	Ethyne
VOC	ETOH	Ethanol
VOC	FACD	Formic acid
VOC	FORM	Formaldehyde
VOC	GLY	Glyoxal
VOC	GLYD	Glycolaldehyde
VOC	IOLE	Internal olefin carbon bond (R-C=C-R)
VOC	ISOP	Isoprene
VOC	ISPD	Isoprene Product
VOC	IVOC	Intermediate volatility organic compounds
VOC	KET	Ketone Groups
VOC	MEOH	Methanol

Inventory Pollutant	Model Species	Model species description
VOC	MGLY	Methylglyoxal
VOC	NAPH	Naphthalene
VOC	NVOL	Non-volatile compounds
VOC	OLE	Terminal olefin carbon bond (R-C=C)
VOC	PACD	Peroxyacetic and higher peroxycarboxylic acids
VOC	PAR	Paraffin carbon bond
VOC	PRPA	Propane
VOC	SESQ	Sesquiterpenes (from biogenic emissions only)
VOC	SOAALK	Secondary Organic Aerosol (SOA) tracer
VOC	TERP	Terpenes (from biogenic emissions 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

Table 3-4. Additional HAP gaseous model species generated for toxics modeling

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

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

The TOG and $PM_{2.5}$ profiles used to speciate emissions are part of the SPECIATE v5.3 database (https://www.epa.gov/air-emissions-modeling/speciate). The SPECIATE database is developed and maintained by the EPA's Office of Research and Development (ORD), Office of Transportation and Air Quality (OTAQ), and the Office of Air Quality Planning and Standards (OAQPS), in cooperation with Environment Canada (EPA, 2016). These profiles are processed using the EPA's S2S-Tool (https://github.com/USEPA/S2S-Tool) to generate the GSPRO and GSCNV files needed by SMOKE. As with previous platforms, some Canadian point source inventories are provided from Environment Canada as pre-speciated emissions. Speciation profiles (GSPRO files) and cross-references (GSREF files) for this platform are available in the SMOKE input files for the platform.

3.2.1 VOC speciation

The base emissions inventory for this modeling platform includes total VOC and individual HAP emissions. Often, individual HAPs are components of VOC (HAP-VOC), and these HAP-VOCs are included ("integrated") in the speciation process. This HAP integration is performed in a way to ensure double counting of emitted mass does not occur and requires specific data processing by the S2S-Tool and user input in SMOKE.

To incorporate HAP emissions from the base inventory into the modeling platform, one of two methods are performed. (1) Integrate, HAP-use is a method where the mass of integrated HAP-VOCs is summed and subtracted from VOC, and the residual mass (NONHAPVOC) is speciated using a renormalized speciation profile that does not include the integrated HAP-VOCs (they are subtracted from the profile and then the profile is renormalized to 100%). (2) No-Integrate, HAP-use is a method where the mass of VOC is speciated using a speciation profile that does not include the integrated HAP-VOCs (they are subtracted from the profile and the profile is not renormalized to 100%). In this scenario, the HAP-VOC and VOC portions of the inventory are difficult to harmonize, and it is assumed that the proportions of HAPs from these sources are adequately captured in the speciation profile used to speciate the VOC emissions (which is why there is no renormalization). Separately, HAPs can be introduced into a modeling platform using speciation profiles. In this scenario, HAP-VOC emissions are "generated" through VOC speciation and are not incorporated from the base inventory. This method is called "Criteria" speciation. An illustration of these methods is shown in Figure 3-2 and the integration methods used for this platform for each sector are shown in Table 3-5.

Figure 3-2. Process of integrating HAPs and speciating VOC in a modeling platform

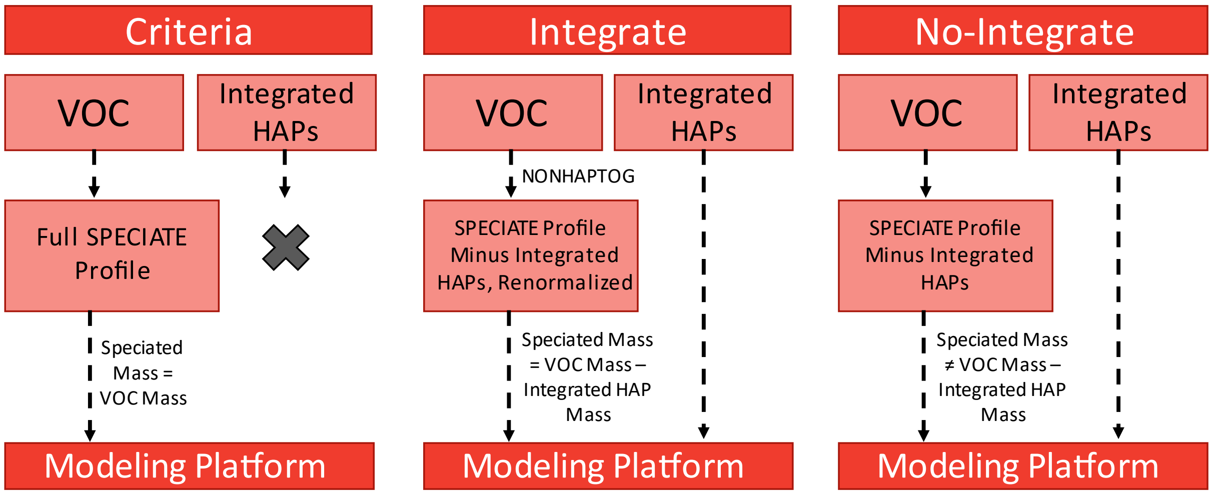


Table 3-5. Integration status for each platform sector

Platform Sector	Approach for Integrating NEI emissions of Naphthalene (N), Benzene (B), Acetaldehyde (A), Formaldehyde (F) and Methanol (M)
afdust	N/A – sector contains no VOC
airports	No integration, use NBAFM in inventory
beis	N/A – sector contains no inventory pollutant "VOC"; but rather specific VOC species
cmv_c1c2	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
cmv_c3	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
fertilizer	N/A – sector contains no VOC
livestock	Full integration (NBAFM)
nonpt	Partial integration (NBAFM)
nonroad	Full integration (internal to MOVES)
np_oilgas	Partial integration (NBAFM)
np_solvents	Partial integration (NBAFM)
openburn	Partial integration (NBAFM)
onroad	Full integration (internal to MOVES)
canada_onroad	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
mexico_onroad	Full integration (internal to MOVES-Mexico); however, MOVES-MEXICO speciation was older CB6, so post-SMOKE emissions were converted to CB6R3AE6
canada_afdust	N/A – sector contains no VOC
canmex_area	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
canmex_point	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
canada_ptdust	N/A – sector contains no VOC
canada_og2D	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
canmex_ag	No integration, no NBAFM in inventory, create NBAFM from VOC speciation
pt_oilgas	No integration, use NBAFM in inventory
ptagfire	Full integration (NBAFM)

Platform Sector	Approach for Integrating NEI emissions of Naphthalene (N), Benzene (B), Acetaldehyde (A), Formaldehyde (F) and Methanol (M)
ptegu	No integration, use NBAFM in inventory
ptfire-rx	Partial integration (NBAFM)
ptfire-wild	Partial integration (NBAFM)
ptfire_othna	Full integration for Canada wildfires (NBAFM), no integration for rest of sector (create NBAFM from VOC speciation)
ptnonipm	No integration, use NBAFM in inventory
ptnonipm_hr	No integration, use NBAFM in inventory
rail	Full integration (NBAFM)
rwc	Full integration (NBAFM)

The HAPs integrated from the base inventory into the modeling platform are sector and chemical mechanism specific. In recent years, CB6R3_AE7 has been the primary chemical mechanism used at the EPA. Within that mechanism, naphthalene (NAPH), benzene (BENZ), acetaldehyde (ALD2), formaldehyde (FORM), and methanol (MEOH) are explicit HAP-VOCs, and these compounds are collectively referred to as NBAFM. Since NBAFM are explicitly modeled in CB6R3_AE7, these species have become the default collection of integrated HAP species at the EPA. MOVES, the EPA's mobile emissions model, features additional species that are explicitly modeled (e.g., ethanol). These species (Table 3-6) are also incorporated directly into modeling platforms. To incorporate these species, additional files from the S2S-Tool are required. For California, speciation of NONHAPTOG is performed on CARB's VOC submissions using the county-specific speciation profile assignments generated by MOVES in California.

Table 3-6. Integrated species from MOVES sources

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

Several sectors require VOC speciation to occur at the county-level and consistent speciation profiles cannot be applied across the nation. To accomplish this, the GSREF is setup to provide profiles that are “blended” at the county/SCC-level using proportions included in the input file. These variable VOC speciation methods are year-specific and applied in the oil and gas sector and for various mobile emissions sources. In both the np_oilgas and pt_oilgas sector, VOC speciation profiles are weighted to reflect region-specific application of controls, differences in gas composition, and variable sources of emissions (e.g., varying proportions of emissions from associated gas, condensate tanks, crude oil tanks, dehydrators, liquids unloading and well completions). The Nonpoint Oil and Gas Emissions Estimation Tool generates an intermediate file that provides SCC and county-specific emissions proportions, which are subsequently incorporated into the modeling platform.

For onroad and nonroad mobile sources, the speciation of total organic gas and particulate matter emissions has historically been performed within MOVES. However, this is now performed outside of MOVES as a post-processing step. This has the advantages of making MOVES simpler, faster to run, and making it easier to change or update chemical mechanisms and speciation profiles used in the emissions modeling process. In should be noted that MOVES still generates emissions for some explicit, “integrated species,” as noted above. In many cases, these integrated species have effects like temperature or fuel effects which are not always well captured by external speciation profiles. For total organic gases, MOVES calculates 16 integrated species, such as methane and benzene, and the remainder is called NONHAPTOG and speciated outside MOVES.

In MOVES, speciation profiles are assigned by emission process, fuel subtype, regulatory class, and model year. Each of these dimensions are available in MOVES output except for fuel subtype, which is aggregated as part of each fuel type. To apply speciation outside of MOVES and make it compatible with the needs of SMOKE, we need to determine the speciation profile mapping by SMOKE process (aggregation of MOVES emission processes) and SMOKE Source Classification Codes (SCC), which are defined by fuel type, source type, and road type. To support use of new ROC-based speciation profiles for mobile sources, during nonroad inventory post-MOVES processing, speciation profile assignments were updated to both NONHAPTOG and PM2.5 in a one-to-one manner. As well, to support use of these new profiles, PM2.5 was split into four parts: PEC and PSO4 (based on the new speciation profiles); total organic matter, or TOM (PNCOM plus PEC); and residual PM is RESID_PM (all other PM species).

For this platform, MOVES runs were performed in inventory mode for each representative county and season (i.e., winter and summer) to compute NONHAPTOG output by emission process, fuel type, regulatory class, and model year. Inventory mode was run rather than rates mode because: 1) MOVES inventory mode is faster than rates mode, 2) there are several dimensions of rates mode output which are not relevant to the assigning of speciation profiles, such as speed bin and temperature profile and 3) weighting speciation profiles by their emissions inventory is both easier and more accurate than by MOVES output activity or emission rates. Emissions were then disaggregated by fuel subtype using the market share of each fuel blend in each county. Then, emissions were normalized and aggregated to calculate the percentage of total NONHAPTOG emissions that should be speciated by each profile for each SMOKE SCC and process. Finally, these percentages were applied in SMOKE-MOVES to all counties based on their representative county. A MOVES post-processing tool was used to generate the speciation cross-references (GSREFs) for SMOKE from the outputs of the inventory mode runs.

To generate onroad emissions and to perform the subsequent speciation, SMOKE-MOVES was first run to estimate emissions and both the MEPROC and INVTABLE files were used to control which pollutants are processed and eventually integrated. From there, the NONHAPTOG emission factor tables produced

by MOVES were speciated within SMOKE using the GSREF files and the NONHAPTOG GSPRO files generated by the S2S-Tool.
In Canada, a GSPRO_COMBO file is used to generate speciated gasoline emissions that account for various ethanol mixes. In Mexico, onroad emissions are pre-speciated from the MOVES-Mexico model, thus eliminating the need for a GSPRO_COMBO file. For both Canada and Mexico, nonroad VOC emissions are not defined by mode (e.g., exhaust versus evaporative), which necessitates the need for a GSPRO_COMBO file that splits total VOC into exhaust and evaporative components. In addition, MOVES-Mexico uses an older version of MOVES that is hardcoded for an older version of the CB6 chemical mechanism ("CB6-CAMx"). This version does not generate the model species XYLMN or SOAALK, so additional post-processing is performed to generate those emissions:

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

3.2.2 PM speciation

Like VOC speciation, $PM_{2.5}$ speciation does feature integrated species from the base inventory for nonroad and onroad emissions, though there are far fewer (only BC and SO_4). The remaining mass is either TOM (total organic matter) or RESID_PM (residual PM = $PM_{2.5}$ – BC – SO_4 – TOM), which is speciated using SPECIATE profiles that were post-processed using the S2S-Tool. Small adjustments to the methods were needed to accommodate the reporting by California. Since California does not provide speciated $PM_{2.5}$ emissions, total $PM_{2.5}$ emissions for onroad and nonroad sources in California were speciated using the profile proportions estimated by MOVES in California. Finally, onroad brake and tire wear $PM_{2.5}$ emissions were speciated in SMOKE-MOVES using the SPECIATE profiles 95462 and 95460, respectively. In the 2022v2 platform, new profiles were applied to specific SCCs in the RWC sector: 2104008031 now uses profile 95873 and 2104008611 and 2104008614 now use profile 8898a.

3.2.2.1 Diesel PM

Diesel PM emissions are explicitly included in the NEI using the pollutant names DIESEL-PM10 and DIESEL-PM25 for select mobile sources whose engines burn diesel or residual oil fuels. This includes sources in onroad, nonroad, point airport ground support equipment, point locomotives, nonpoint locomotives, and all PM from diesel or residual oil fueled nonpoint CMV. These emissions are equal to their primary PM10-PRI and PM25-PRI counterparts, are exclusively from exhaust (i.e., do not include brake/tire wear), and are exclusively used in toxics modeling. Diesel PM is then speciated in SMOKE using the same speciation profiles and methods as primary PM, except that diesel PM is mapped to model species that feature "DIESEL_PM" in their species name.

3.2.3 NO_X speciation

In the NEI, NO_x emissions are inventoried on a NO_2 weighted basis, but must be speciated into NO, NO_2, and HONO for modeling platforms to provide the species used by air quality models. Table 3-7 provides the NO_x speciation profiles used in EPA's modeling platforms. The only difference between the two profiles is the allocation of some NO_2 mass to HONO in the "HONO" profile. HONO emissions from mobile sources have been identified in tunnel studies and its inclusion in emissions inventories is important for urban chemistry. Here, a HONO to NO_x ratio of 0.008 was selected (Sarwar, 2008). In this modeling platform, all non-mobile sources use the "NHONO" profile, all non-onroad mobile sources (including nonroad, cmv, and rail) use the "HONO" profile, and all onroad NO_x speciation occurs within

MOVES. For further details on NO_x speciation within MOVES, please see Table 3-8 and in the associated technical reports (EPA-420-R-22-017, EPA-420-R-23-006).

Table 3-7. NO_X speciation profiles

Profile	Pollutant	Species	Mass 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

Table 3-8. Mobile NOx and HONO fractions

Fuel	Model Years	Process	NO	Nox	HONO
Gasoline	1960-1980	Running Exhaust	0.975	0.017	0.008
Gasoline	1981-1990	Running Exhaust	0.932	0.06	0.008
Gasoline	1991-1995	Running Exhaust	0.954	0.038	0.008
Gasoline	1996-2050	Running Exhaust	0.836	0.156	0.008
Gasoline	1960-1980	Start Exhaust	0.975	0.017	0.008
Gasoline	1981-1990	Start Exhaust	0.961	0.031	0.008
Gasoline	1991-1995	Start Exhaust	0.987	0.005	0.008
Gasoline	1996-2050	Start Exhaust	0.951	0.041	0.008
Diesel	1960-2003	Exhaust	0.9622	0.0298	0.008
Diesel	2004-2006	Exhaust	0.9325	0.0595	0.008
Diesel	2007-2009	Exhaust	0.7529	0.2381	0.008
Diesel	2010-2060	Exhaust	0.8035	0.1885	0.008

3.2.4 Sulfuric Acid Vapor (SULF)

Sulfuric acid vapor (SULF) is added for coal and distillate oil fuel combustion sources to the emissions files using SO_2 emissions from the base inventory. This process utilizes profiles assignments in the GSREF file and the profiles were derived using data from AP-42 (EPA, 1998). The weight fraction of added sulfuric acid vapor is fuel specific, assumes that gaseous sulfate is primarily H_2SO_4, and is calculated as follows:

$$SULF\ emissions\ = SO_2\ emissions\ \times \frac{fraction\ of\ S\ emitted\ as\ sulfate}{fraction\ of\ S\ emitted\ as\ SO_2} \times \frac{MW\ H_2SO_4}{MW\ SO_2}$$

In the above, the molecular weight (*MW*) of sulfate and sulfur dioxide are 98 g/mol and 64 g/mol, respectively. The fractions of sulfur emissions emitted as sulfate and sulfur dioxide, as well as the resulting sulfuric acid vapor split factors, by fuel, are summarized in Table 3-9 and Table 3-10 below.

Table 3-9. Sulfate split factor computation

Fuel	SCCs	Profile Code	Fraction as SO2	Fraction as Sulfate	Split Factor (Mass Fraction)
Bituminous	**1-0X-002-YY** X is 1, 2, or 3 YY is 01-19 **21-0Z-002-000** Z is 2, 3, or 4	95014	0.95	0.014	.014/.95 * 98/64 = 0.0226
Subbituminous	**1-0X-002-YY** X is 1, 2, or 3 YY is 21-38	87514	0.875	0.014	.014/.875 * 98/64 = 0.0245
Lignite	**1-0X-003-YY** X is 1, 2, or 3 YY is 01-18	75014	0.75	0.014	.014/.75 * 98/64 = 0.0286
Residual oil	**1-0X-004-YY** X is 1, 2, or 3 YY is 01-06 **21-0Z-005-000** Z is 2, 3, or 4	99010	0.99	0.01	.01/.99 * 98/64 = 0.0155
Distillate oil	**1-0X-005-YY** X is 1, 2, or 3 YY is 01-06 **21-0Z-004-000** Z is 2, 3, or 4	99010	0.99	0.01	Same as residual oil

Table 3-10. 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

3.2.5 Speciation of Metals and Mercury

Metals and mercury emissions from the base inventory require speciation for use in modeling. Non-mercury metals must be speciated into coarse and fine size ranges for use in CMAQ, and Table 3-11, summarizes the particle size profiles used for each data category.

Table 3-11. Particle size speciation of metals

Source Type	Profile	Pollutant	Fine	Coarse
Onroad	OARS	Arsenic	0.95	0.05

Source Type	Profile	Pollutant	Fine	Coarse
Onroad	ONMN	Manganese	0.4375	0.5625
Onroad	ONNI	Nickel	0.83	0.17
Onroad	CRON	Chromhex	0.86	0.14
Nonroad	NOARS	Arsenic	0.83	0.17
Nonroad	NONMN	Manganese	0.67	0.33
Nonroad	NONNI	Nickel	0.49	0.51
Nonroad	CRNR	Chromhex	0.80	0.20
Stationary	STANI	Nickel	0.59	0.41
Stationary	STACD	Cadmium	0.76	0.24
Stationary	STAMN	Manganese	0.67	0.33
Stationary	STAPB	Lead	0.74	0.26
Stationary	STABE	Beryllium	0.68	0.32
Stationary	CRSTA	Chromhex	0.71	0.29
Stationary	STARS	Arsenic	0.59	0.41

Mercury is speciated into one of the three forms used by CMAQ; elemental, divalent gaseous, and divalent particulate. Table 3-12 provides the mercury speciation profiles used in the modeling platform. All relevant SCCs were mapped to these profiles within the GSREF. A caveat is the onroad and nonroad sectors, where mercury emissions are estimated in MOVES, nonroad emissions from California, which use the appropriate profiles below, and onroad emissions from California, where MOVES-based speciation is applied.

Table 3-12. Mercury speciation profiles

Profile Code	Description	Elemental	Divalent Gas	Particulate
HGCEM	Cement kiln exhaust	0.66	0.34	0
HGCLI	Cement clinker cooler	0	0	1
HBCMB	Fuel combustion	0.5	0.4	0.1
HGCRE	Human cremation	0.8	0.15	0.05
HGELE	Elemental only (used?)	1	0	0
HGGEO	Geothermal power plants	0.87	0.13	0
HGGLD	Gold mining	0.8	0.15	0.05
HGHCL	Chlor-Alkali plants	0.972	0.028	0
HGINC	Waste incineration	0.2	0.6	0.2
HGIND	Industrial average	0.73	0.22	0.05
HGMD	Mobile diesel	0.56	0.29	0.15
HGMG	Mobile gas	0.915	0.082	0.003
HGMET	Metal production	0.8	0.15	0.005
HGMWI	Medical waste incineration	0.2	0.6	0.2
HGPETCOKE	Petroleum coke	0.6	0.3	0.1

3.3 Temporal Allocation

Temporal allocation is the process of distributing aggregated emissions for a specific time period to a finer temporal resolution, such as converting annual emissions to hourly emissions as is required by CMAQ. While the total of the emissions are important, the timing of the occurrence of emissions is also essential for accurately simulating ozone, PM, and other pollutant concentrations in the atmosphere. Many emissions inventories are annual or monthly in nature. Temporal allocation takes these aggregated emissions and distributes the emissions to the hours of each day. This process is typically done by applying temporal profiles to the inventories in this order: monthly, day of the week, and diurnal, with monthly and day-of-week profiles applied only if the inventory is not already at that level of detail.

The temporal factors applied to the inventory were selected using some combination of country, state, county, SCC, and pollutant, as appropriate for the specific sector. Table 3-13 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 3-13. Temporal settings used for the platform sectors in SMOKE

Platform sector short name	Inventory resolutions	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process holidays as separate days
afdust_adj	Annual	Yes	week	all	Yes
airports	Annual	Yes	all	all	No
beis	Hourly		n/a	all	No
cmv_c1c2	Annual & hourly		all	all	No
cmv_c3	Annual & hourly		all	all	No
fertilizer	Monthly		met-based	all	Yes
livestock	Daily	No	all	all	No
nonpt	Annual	Yes	week	week	Yes
nonroad	Monthly		mwdss	mwdss	Yes
np_oilgas	Annual	Yes	aveday	aveday	No
np_solvents	Annual	Yes	aveday	aveday	No
openburn	Annual	Yes	aveday	aveday	No
onroad	Annual & monthly[1]		all	all	Yes
onroad_ca_adj	Annual & monthly[1]		all	all	Yes
pt_oilgas	Annual	Yes	mwdss	mwdss	Yes
ptegu	Annual & hourly	Yes[2]	all	all	No
ptnonipm	Annual	Yes	mwdss	mwdss	Yes
ptnonipm_hr	Hourly		all	all	No
ptagfire	Daily		all	all	No

Platform sector short name	Inventory resolutions	Monthly profiles used?	Daily temporal approach	Merge processing approach	Process holidays as separate days
ptfire-rx	Daily		all	all	No
ptfire-wild	Daily		all	all	No
ptfire_othna	Daily		all	all	No
canada_afdust	Annual	Yes	week	all	No
rail	Annual	Yes	aveday	aveday	No
rwc	Annual	No[3]	met-based[3]	all	No[3]
canmex_area	Annual & monthly	Yes	week	week	No
canada_onroad	Monthly		week	week	No
mexico_onroad	Monthly		week	week	No
canmex_point	Annual & monthly	Yes	mwdss	mwdss	No
canada_ptdust	Monthly		week	all	No
canmex_ag	Annual	Yes	mwdss	mwdss	No
canada_og2D	Annual	Yes	mwdss	mwdss	No

[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 3 SCCs that do not use met-based speciation.

The value "all" in the "Merge processing approach" column means that hourly emissions were computed for every day of the year and that emissions potentially have day-of-year variation. The value "week" means that hourly emissions were 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, temporal processing includes a "spin-up" period of several days prior to January 1, 2022, which is intended to mitigate the effects of initial conditions on simulated air quality pollutant concentrations. Here, the spin-up period was 10 days (December 22-31, 2021). For all anthropogenic sectors, emissions from December 2022 were used to fill in surrogate emissions for the end of December 2021. For biogenic emissions, December 2021 emissions were computed using year meteorology.

3.3.1 Use of FF10 format for finer than annual emissions

The FF10 inventory format for SMOKE provides a consolidated format for monthly, daily, and hourly emissions inventories. With the FF10 format, a single inventory file can contain emissions for all 12 months and the annual emissions in a single record. This helps simplify the management of numerous inventories. Similarly, daily and hourly FF10 inventories contain individual records with data for all days in a month and all hours in a day, respectively.

SMOKE prevents the application of temporal profiles on top of the "native" resolution of the inventory. For example, a monthly inventory should not have annual-to-month temporal allocation applied to it; rather, it should only have month-to-day and diurnal temporal allocation. This becomes particularly important when specific sectors have a mix of annual, monthly, daily, and/or hourly inventories. The flags that control temporal allocation for a mixed set of inventories are discussed in the SMOKE documentation. The modeling platform sectors that make use of monthly values in the FF10 files are nonroad, onroad (for activity data), and all Canada and Mexico inventories except for agriculture. Commercial marine vessels in cmv_c3 and cmv_c1c2 use hourly data in the FF10 files, as well as units in the ptegu sector which are matched to CEMS data.

3.3.2 Temporal allocation for non-EGU sources (ptnonipm, ptnonipm_hr)

New for the 2022v2 platform, select units from the ptnonipm sector were split into a new sector called "ptnonipm_hr", consisting of units for which hourly emissions are available. The ptnonipm_hr sector includes two types of units:

- Taconite facilities in Minnesota, for which hourly emissions were provided by the Minnesota Pollution Control Agency (MPCA); and
- Units from nonEGUs which could be matched to hourly CEMS data.

The ptnonipm_hr sector is processed separately from the remainder of ptnonipm though SMOKE, using hourly emissions inventories to process emissions for each day of the year. The methodology is similar to the ptegu sector as described in Section 3.3.3, except that all sources in the ptnonipm_hr sector are present in the hourly inventory, and no temporal profiles are needed. NO_x and SO_2 emissions are based on MPCA data for Taconite facilities, and CEMS data for other units in the sector. Hourly temporalization for pollutants other than NO_x and SO_2 is scaled to hourly NO_x for Taconite facilities and is based on hourly heat input for units with CEMS data. As in the ptegu sector, CEMS data for nonEGUs in the ptnonipm_hr sector is processed through the CEMCorrect tool.

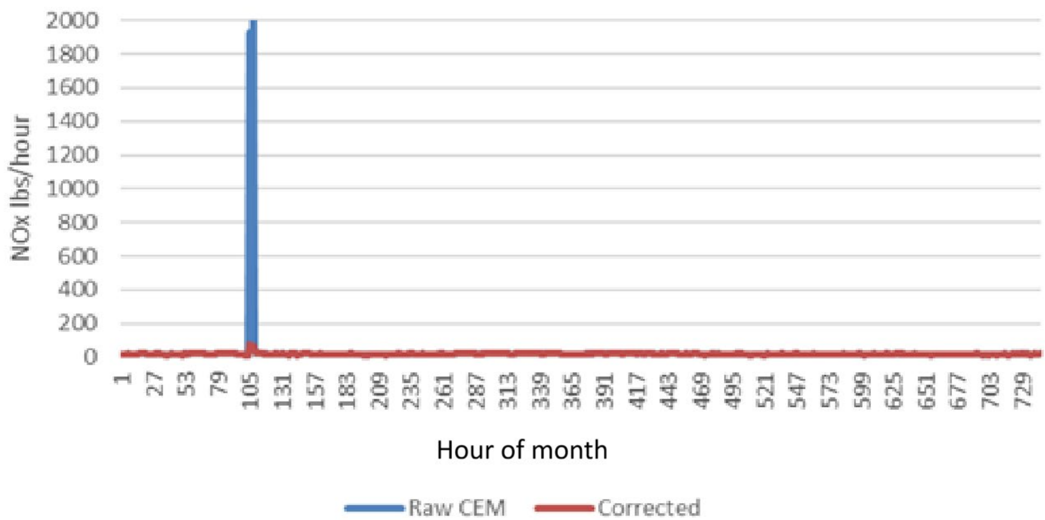
Most temporal profiles for sources remaining in the ptnonipm sector result in constant emissions for each day of the year, although some have lower emissions on Sundays. For the 2022v1 platform, temporal profiles for SCC 40202501 emissions for which are related to surface coating for metals were changed to use hourly profiles number 11 that reflects operations from 7AM to 5PM local time.

3.3.3 Electric Generating Utility temporal allocation (ptegu)

Electric generating unit (EGU) sources matched to ORIS units were temporally allocated to hourly emissions needed for modeling using the hourly CEMS data for units that could be matched to the CEMS emissions. Those hourly data were processed through v2.1 of the CEMCorrect tool to mitigate the impact of unmeasured values in the data.

The temporal allocation procedure for EGUs in the base year is differentiated by whether or not the unit could be directly matched to a unit with CEMS data via its ORIS facility code and boiler ID. Note that for units matched to CEMS data, annual totals of their emissions input to CMAQ may be different than the values in the annual inventory because the CEMS data replace the NO_x and SO_2 annual inventory data for the seasons during 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 were 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



The region, fuel, and type (peaking or non-peaking) must be identified for each EGU with CEMS data so the data can be used to generate profiles. The identification of peaking units was done using summed hourly heat input data from 2022 and the two previous years (2020 and 2021). Equation 1 shows how the annual heat input value is converted from heat units (BTU/year) to power units (MW) using the NEEDS v6 derived unit-level heat rate (BTU/kWh). In equation 2 a capacity factor is calculated by dividing the annual unit MW value by the NEEDS v6 unit capacity value (MW) multiplied by the hours in the year. A peaking unit was defined as any unit that had a maximum capacity factor of less than 0.2 for every year (2020, 2021, and 2022) and a 3-year average capacity factor of less than 0.1.

Equation 1. Annual unit power output

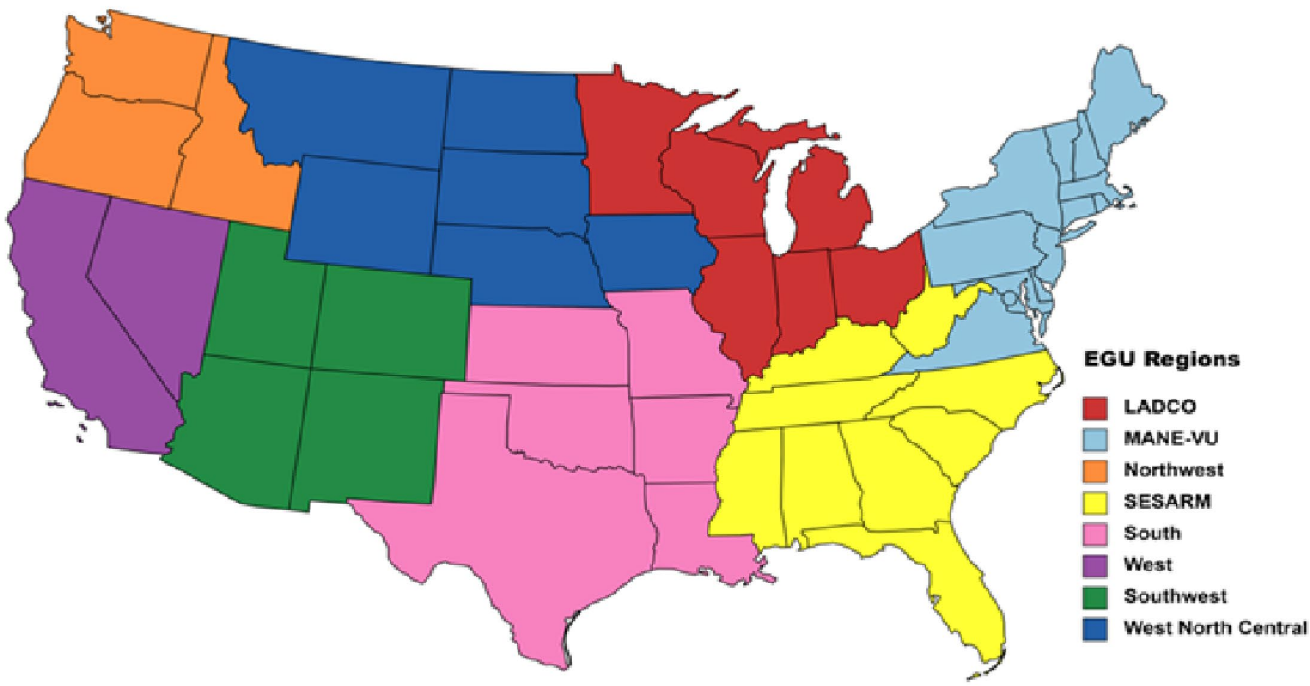
$$Annual\ Unit\ Output\ (MW) = \frac{\sum_{i=0}^{8760} \frac{Hourly\ HI}{(BTU)} * 1000\ (\frac{MW}{kW})}{NEEDS\ Heat\ Rate\ \left(\frac{BTU}{kW\ h}\right)}$$

Equation 2. Unit capacity factor

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

Input regions were determined from one of the eight EGU modeling regions based on MJO and climate regions. Regions were used to group units with similar climate-based load demands. Region assignment is made on a state level, where all units within a state were assigned to the appropriate region. Unit fuel assignments were made using the primary NEEDS v6 fuel. Units fueled by bituminous, subbituminous, or lignite were 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. Figure 3-4 shows the regions used to generate the profiles. Currently there are 64 unique profiles available based on 8 regions, 4 fuels, and 2 for peaking unit status (peaking and non-peaking).

Figure 3-4. Regions used to Compute Temporal non-CEMS EGU Temporal Profiles



The daily and diurnal profiles were calculated for each region, fuel, and peaking type group from the year 2022 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. Separate diurnal factors were created for four seasons: summer (May through September), fall (October and November), winter (December through February), and spring (March and April), 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 input over all hours to get the hour 1 factor. Each grouping contained 12 monthly factors, up to 31 daily factors per month, and four sets of 24 hourly factors. The profiles were weighted by unit size where the units with more heat input have more 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 example peaking and non-peaking daily temporal profiles for the gas fuel type in the LADCO region. Figure 3-6 shows example 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

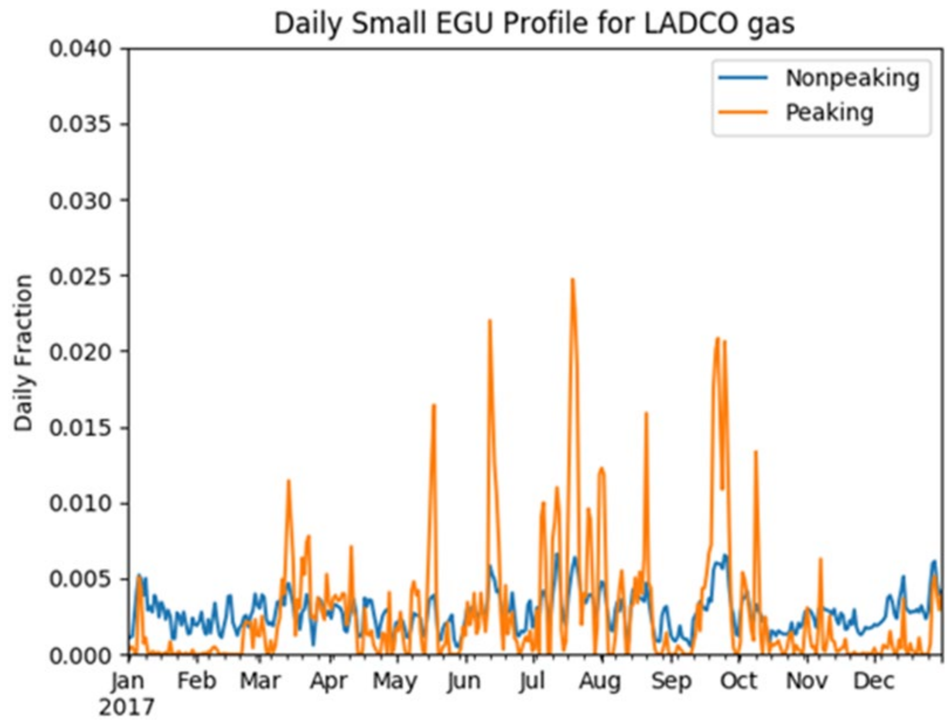
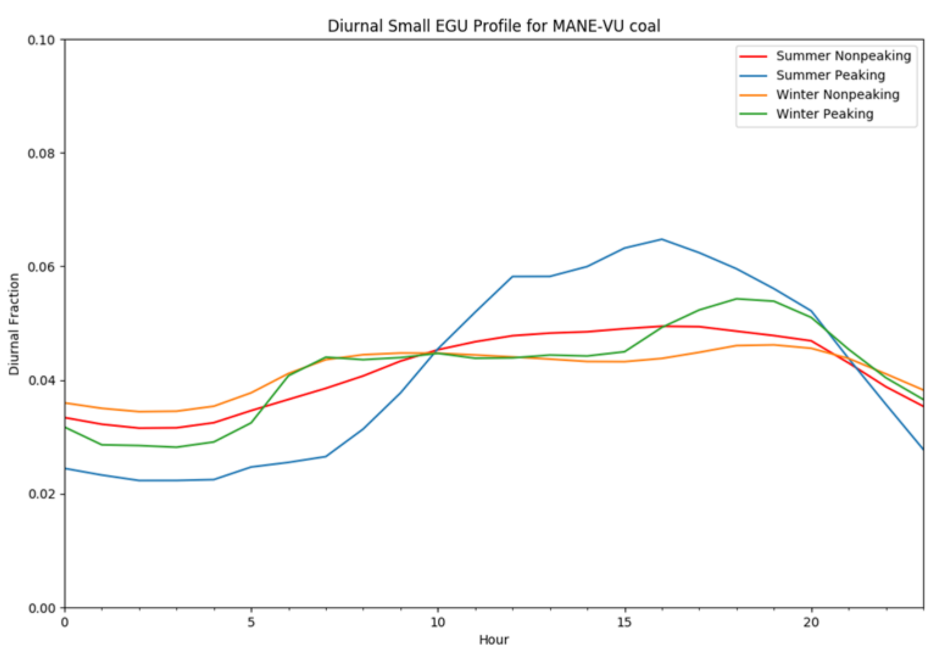


Figure 3-6. Example Diurnal Temporal Profiles for the MANE-VU Region and the Coal Fuel Type



SMOKE uses a cross-reference file to select a monthly, daily, and diurnal profile for each source. For the 2022 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. The region used to select the temporal profile is assigned based on the state from the unit FIPS. The fuel was assigned by SCC to one of the four fuel types: coal, gas, oil, and other. A fuel type unit assignment is made by summing the VOC, NOX, PM2.5, and SO2 for all SCCs in the unit. The SCC that contributed the highest total emissions to the unit for selected pollutants was used to assign the unit fuel type. Peaking units were identified as any unit with an oil, gas, or oil fuel type with a NAICS of 22111 or 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. Municipal waste combustor and cogeneration units were identified using the NEEDS primary fuel type and cogeneration flag, respectively, from the NEEDS database. Assignments for each unit needing a profile were made using the regions shown in Figure 3-4.

3.3.4 Airport Temporal allocation (airports)

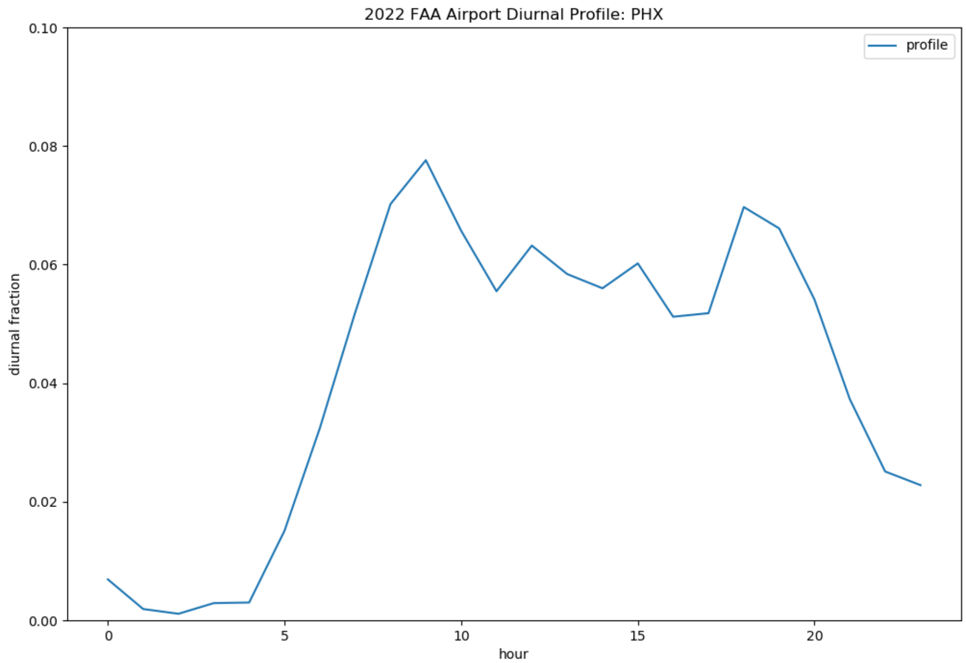
Airport temporal profiles were updated to 2022-specific temporal profiles for all airports other than Alaska seaplanes. Hourly airport operations data were obtained from the Aviation System Performance Metrics (ASPM) Airport Analysis website (https://aspm.faa.gov/apm/sys/AnalysisAP.asp). A report of 2022 hourly Departures and Arrivals for Metric Computation by airport was generated. An overview of the ASPM metrics is at https://aspmhelp.faa.gov/index/Aviation_System_Performance_Metrics_(ASPM).html. Figure 3-7 shows examples of diurnal airport profiles for the Phoenix airport (PHX) and the default profile for Texas.

Month-to-day and Annual-to month temporal profiles were developed based on a separate query of the 2022 ASPM. A report of all airport operations (takeoffs and landings) by day for 2022 was generated. Annual-to-month profiles were derived directly from the daily airport operations report and examples are shown for Wisconsin and Atlanta in Figure 3-8.

For 2022, all airport SCCs (i.e., 2275*, 2265008005, 2267008005, 2268008005 and 2270008005) were assigned to individual commercial airports where a match could be made between the inventory facility and the FAA identifier in the ASPM derived data. State average profiles were calculated as the average of the temporal fractions for all airports within a state. The state average profiles were assigned by state to all airports in the inventory that did not have an airport specific match in the ASPM data. Package processing hubs at the Memphis (MEM), Indianapolis (IND), Louisville (SDF), and Chicago Rockford (RFD) airports produced peaks in the average state profiles at times not typical for activity in smaller commercial airports. These packaging hubs were removed from the state averages. Airports that required state-defaults in states lacking ASPM data use national average profiles calculated from the average of the state temporal profiles.

Alaska seaplanes, which are outside the CONUS domain use the monthly profile in Figure 3-9. These were assigned based on the facility ID.

Figure 3-7. 2022 Airport Diurnal Profiles for PHX and state of Texas



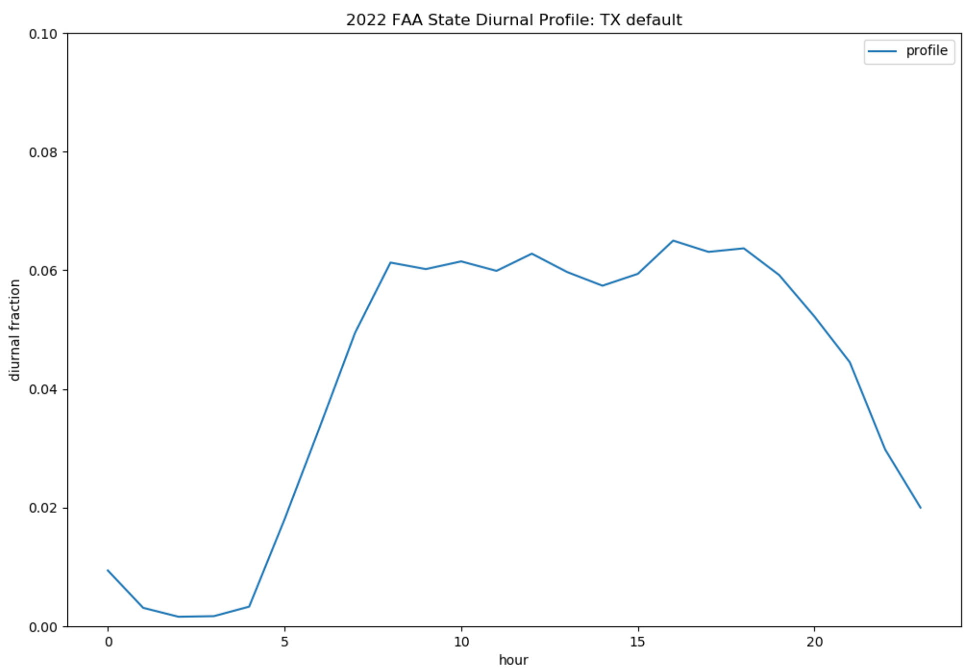
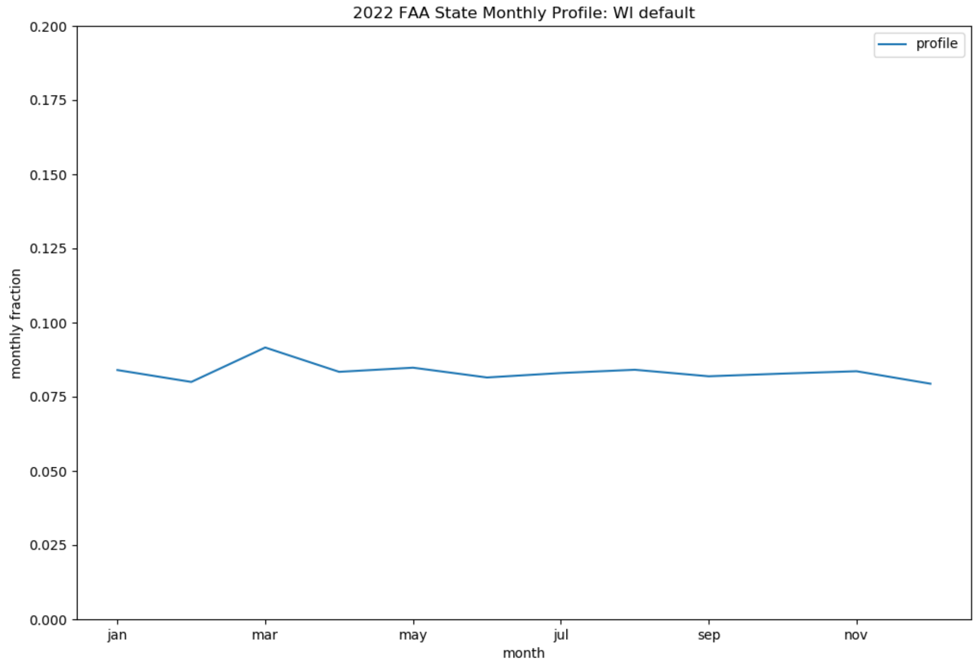


Figure 3-8. 2022 Wisconsin and Atlanta annual-to-month profile for airport emissions



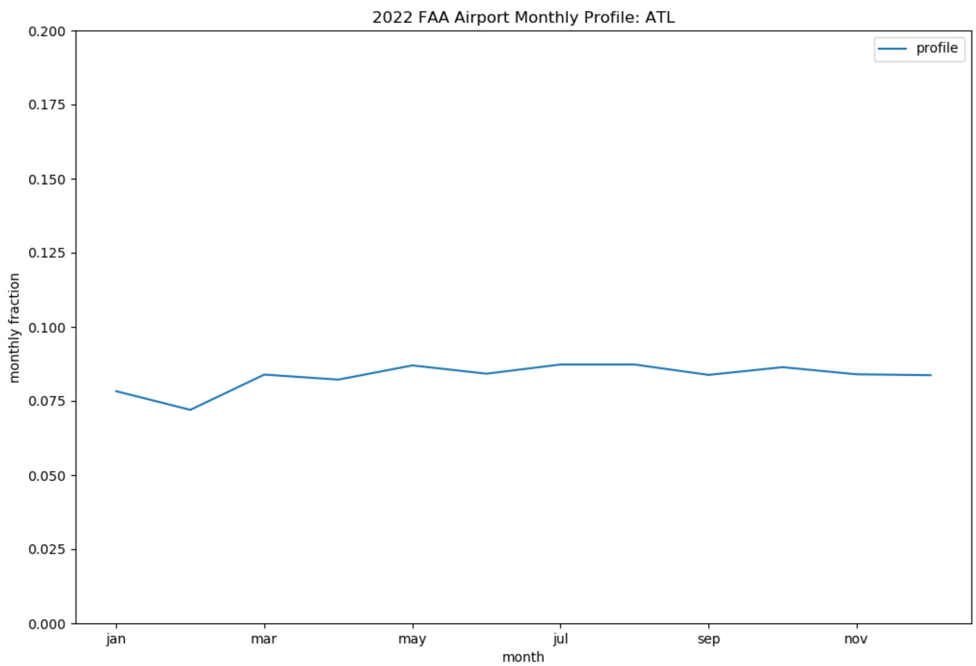
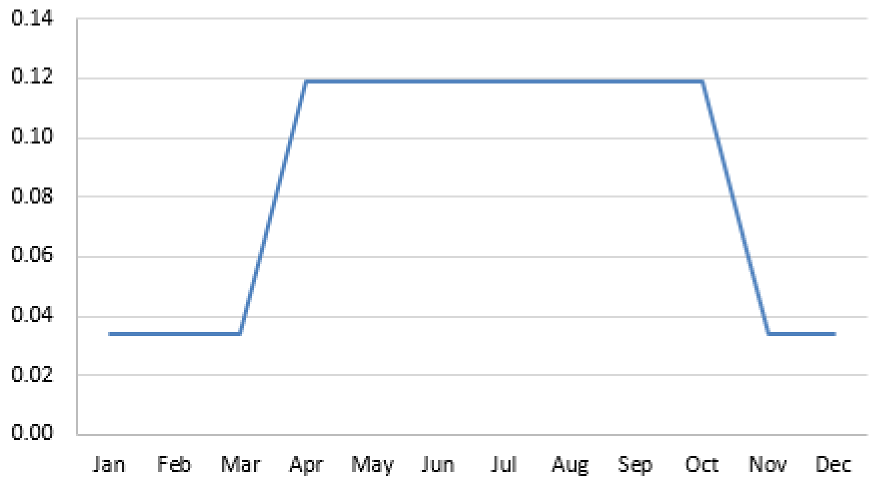


Figure 3-9. Alaska seaplane monthly profile



3.3.5 Residential Wood Combustion Temporal allocation (rwc)

There are many factors that impact the timing of when emissions occur, and for some sectors this includes meteorology. The benefits of utilizing meteorology as a method for temporal allocation can be realized when: (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 the livestock and fertilizer setors.

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 sector, two different algorithms for calculating temporal allocation are used. For most SCCs in the sector, in which wood burning is more prominent on colder days, Gentpro was used to compute annual-to-daily temporal profiles based on the daily minimum temperature. These 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.

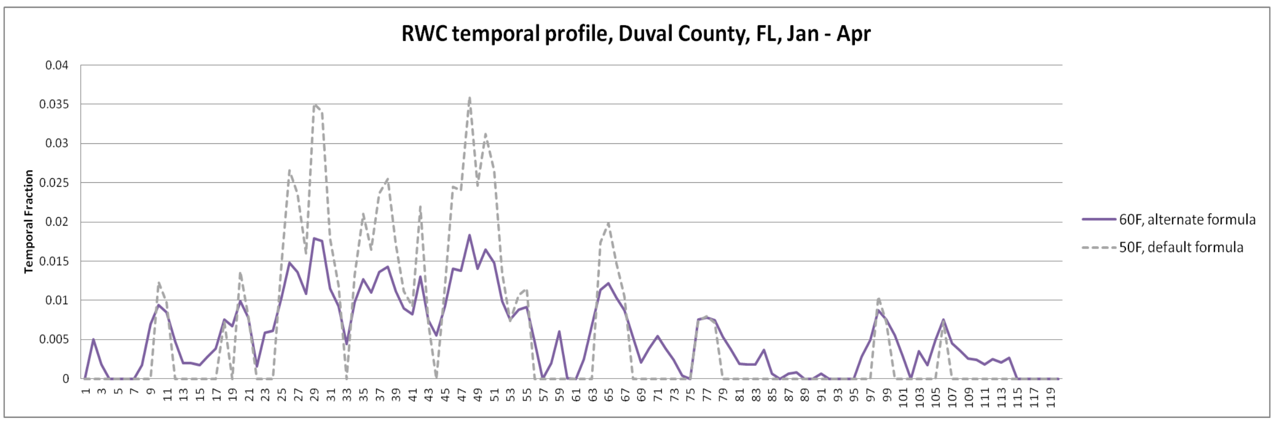
Similar to other temporal allocation profiles, the total annual emissions do not change, only the distribution of the emissions within the year is affected. The temperature threshold for RWC emissions was 50 ˚F for most of the country, and 60 ˚F for the following states: Alabama, Arizona, California, 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 were normalized to sum to 1 to ensure that the total annual emissions are unchanged (or minimally changed) during the temporal allocation process.

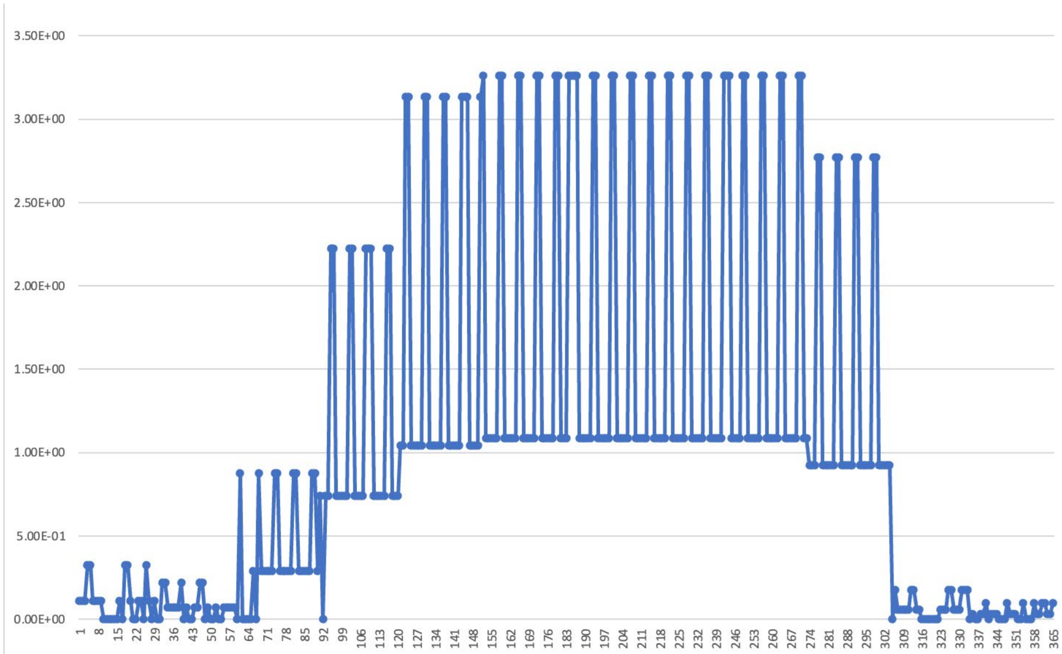
Figure 3-10 illustrates the impact of changing the temperature threshold for a warm climate county. The plot shows the temporal fraction by day for Duval County, Florida, for the first four months of 2007. The default 50 ˚F threshold creates large spikes on a few days, while the 60 ˚F threshold dampens these spikes and distributes a small amount of emissions to the days that have a minimum temperature between 50 and 60 ˚F.

Figure 3-10. Example of RWC temporal allocation using a 50 versus 60 ˚F threshold



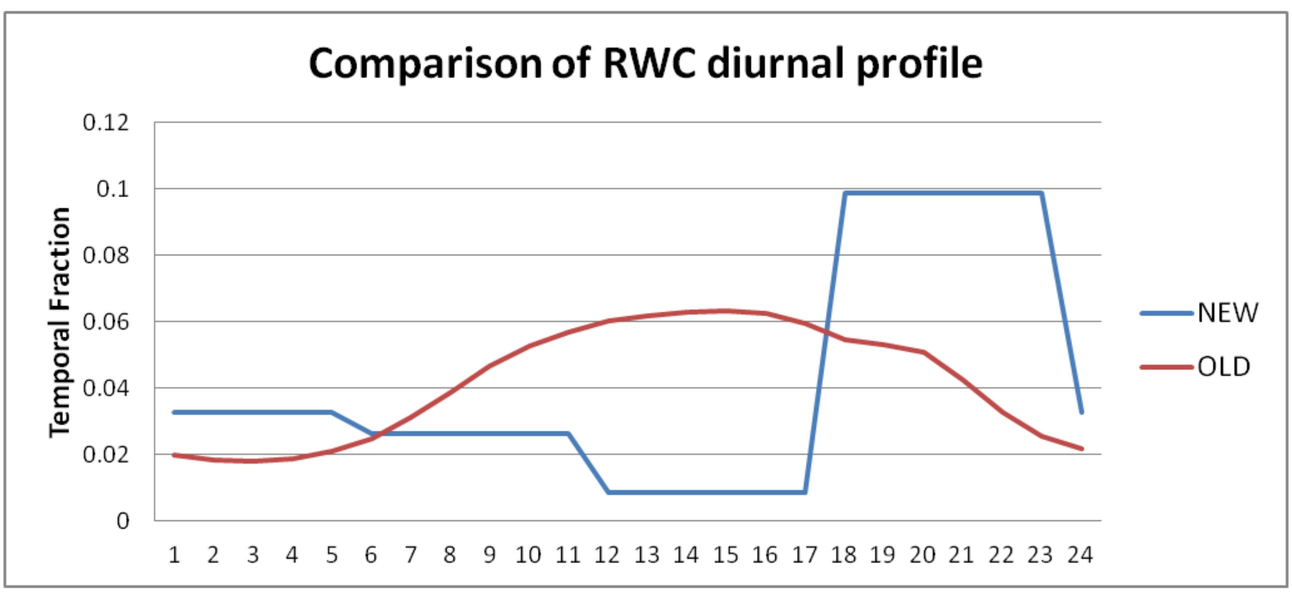
Starting with the 2022 emissions modeling platform, a separate algorithm is used to determine temporal allocation of recreational wood burning, e.g., fire pits (SCC 2104008700) and is applied by Gentpro. Recreational wood burning depends on both minimum and maximum daily temperatures by county and also uses a day-of-week temporal profile (61500) in which emissions are much higher on weekends than on weekdays. According to the recreational wood burning algorithm, the only days with receive emissions are those in which the temperature falls within a range of 50°F and 80°F at some point during the day. On days when the maximum temperature is less than 50°F or the minimum temperature is above 80°F, the daily temporal factor is zero. For all other days, the day-of-week profile 61500 is applied, which has 33% of the emissions on each weekend day and lower emissions on weekdays. An example is shown in Figure 3-11. As a result of applying this algorithm, northern states have more recreational wood burning in summer months while southern states show a flatter pattern with emissions distributed more evenly throughout the year.

Figure 3-11. Example of Annual-to-day temporal pattern of recreational wood burning emissions



The diurnal profile used for most RWC sources (see Figure 3-12) 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 (MANE-VU, 2004). 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 3-12. RWC diurnal temporal profile



The temporal profiles for hydronic heaters" (i.e., SCCs=2104008610 [outdoor], 2104008620 [indoor], and 2104008620 [pellet-fired]) are not based on temperature data, because the meteorologically based temporal allocation used for the rest of the rwc sector did not agree with observations for how these appliances are used.

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

Data used to create the diurnal profile for hydronic heaters, shown in Figure 3-13, are based on a conventional single-stage heat load unit burning red oak in Syracuse, New York.

Annual-to-month temporal allocation for OHH was computed from the MDNR 2008 survey and is illustrated in Figure 3-14. The hydronic heater emissions still exhibit strong seasonal variability, but do not drop to zero because many units operate year-round for water and pool heating.

Figure 3-13. Data used to produce a diurnal profile for hydronic heaters

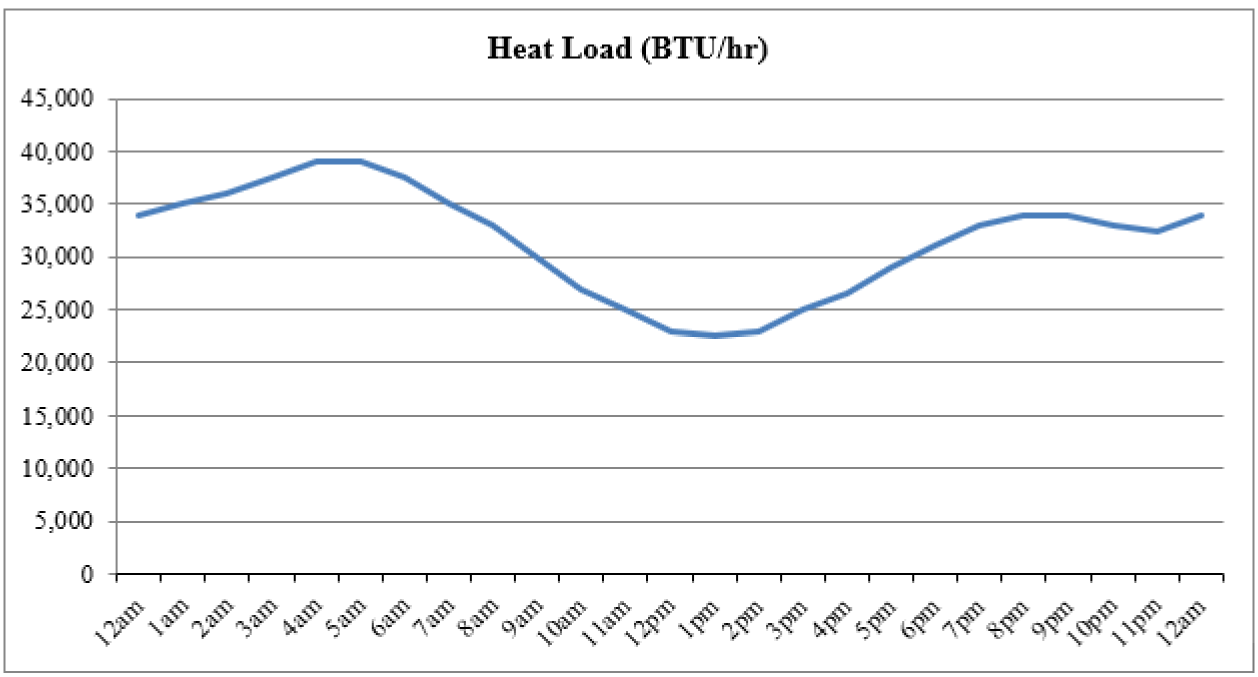
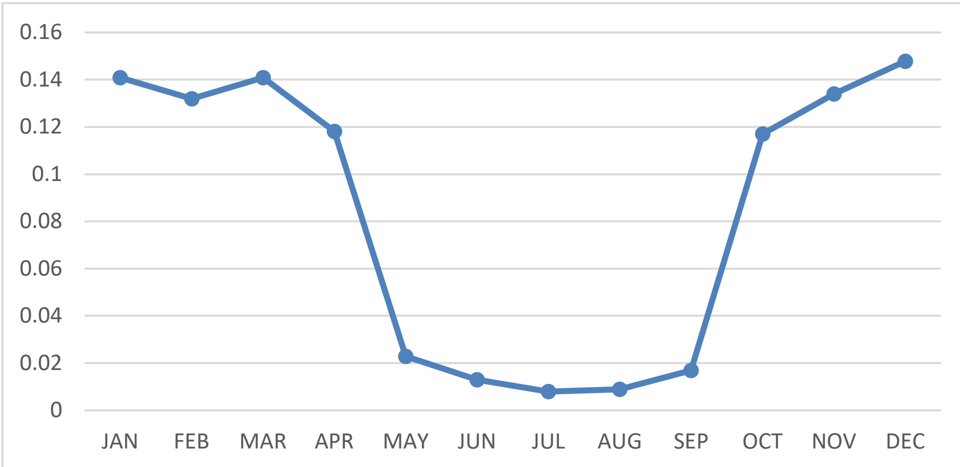


Figure 3-14. Monthly temporal profile for hydronic heaters



3.3.6 Agricultural Ammonia Temporal Profiles (livestock)

For the livestock sector, day-specific emissions are based on the output from the livestock waste emissions model (FEM). Agricultural GenTPRO temporal allocation was applied to livestock emissions and to all pollutants within the sector and was used to temporally allocate the FEM-computed daily emissions to the hourly level. FEM day specific emissions were used directly for broilers, layers, beef cows, dairy cows, and swine. For temporal allocation purposes, turkeys follow the FEM daily temporal distributions for broilers, while horses, sheep, and goats follow the FEM daily temporal distributions for dairy cows. Figure 3-15 shows some example plots of daily emissions by animal type in different parts of the country, as computed by the FEM model.

To develop day-to-hour temporal profiles of livestock emissions, GenTPRO was run using the "BASH_NH3" profile method to create for these sources The GenTPRO algorithm is based on an equation derived based on the Zhu, Henze, et al. (2014) empirical equation. Figure 3-16 shows hourly distributions of emissions for a typical summer day, as computed by Gentpro, for the same counties and animal types as Figure 3-15. A general non-Gentpro hourly profile (profile 26) is also included in Figure 3-16 for comparison.

Figure 3-15. Examples of 2022v2 livestock daily emissions profiles

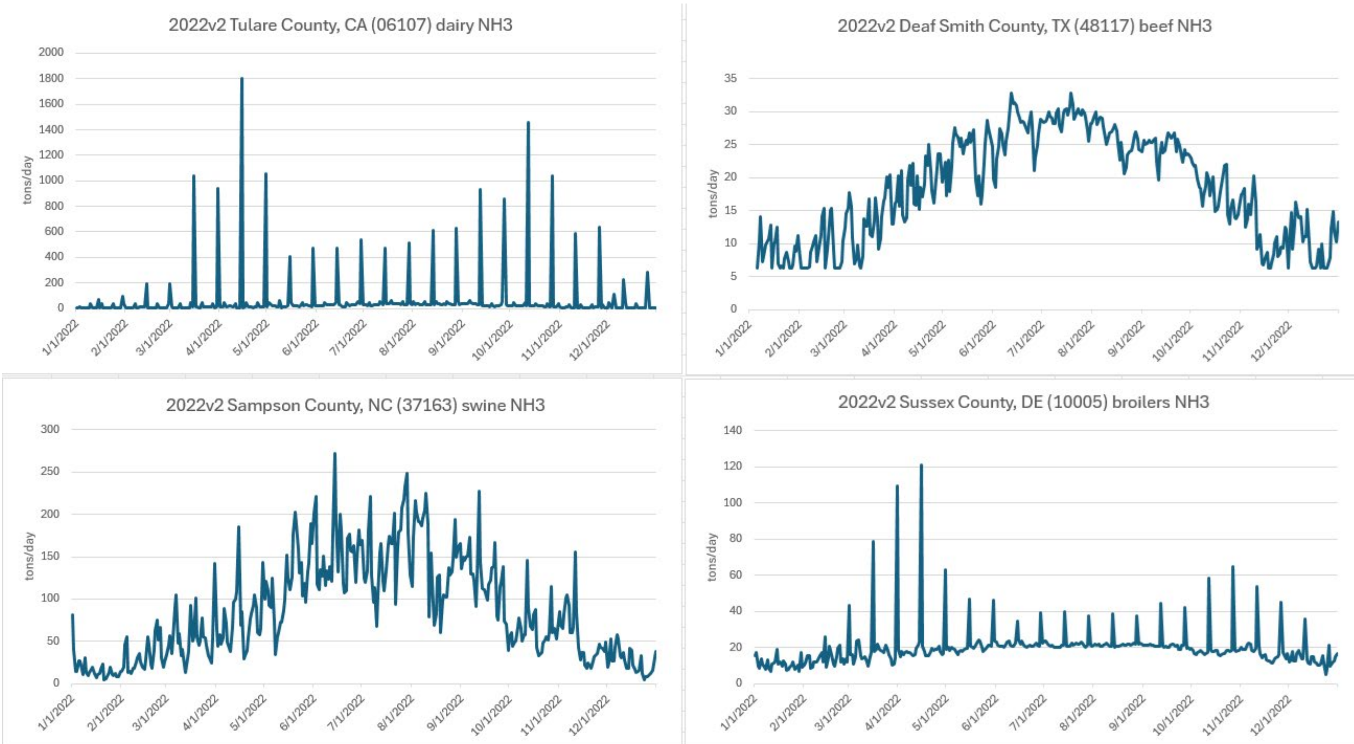
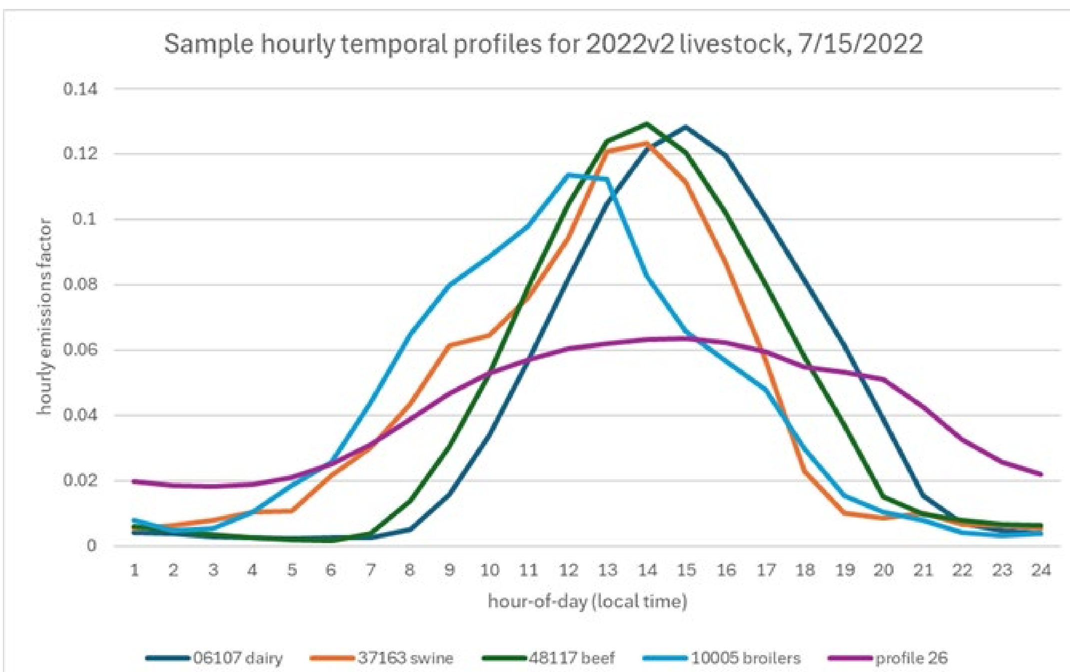


Figure 3-16. Sample animal NH_3 hourly temporal profiles



3.3.7 Oil and gas temporal allocation (np_oilgas)

Monthly temporalization of np_oilgas emissions is based primarily on year-specific monthly factors from the Oil and Gas Tool (OGT) for 2022v2. Factors were specific to each county and SCC. For use in SMOKE, each unique set of factors was assigned a label (starting from OG22M_0001 and counting upward), and then a SMOKE-formatted ATPRO_MONTHLY and an ATREF were developed. This dataset of monthly temporal factors included profiles for all counties and SCCs in the Oil and Gas Tool inventory. Because we are using non-tool datasets in some states, this monthly temporalization dataset did not cover all counties and SCCs in the entire inventory used for this study. To fill in the gaps in those states, state average monthly profiles for oil, natural gas, and combination sources were calculated from Energy Information Administration (EIA) data and assigned to each county/SCC combination not already covered by the OGT monthly temporal profile dataset. Coal bed methane (CBM) and natural gas liquid sources were assigned flat monthly profiles where there was not already a profile assignment in the dataset.

3.3.8 Onroad mobile temporal allocation (onroad)

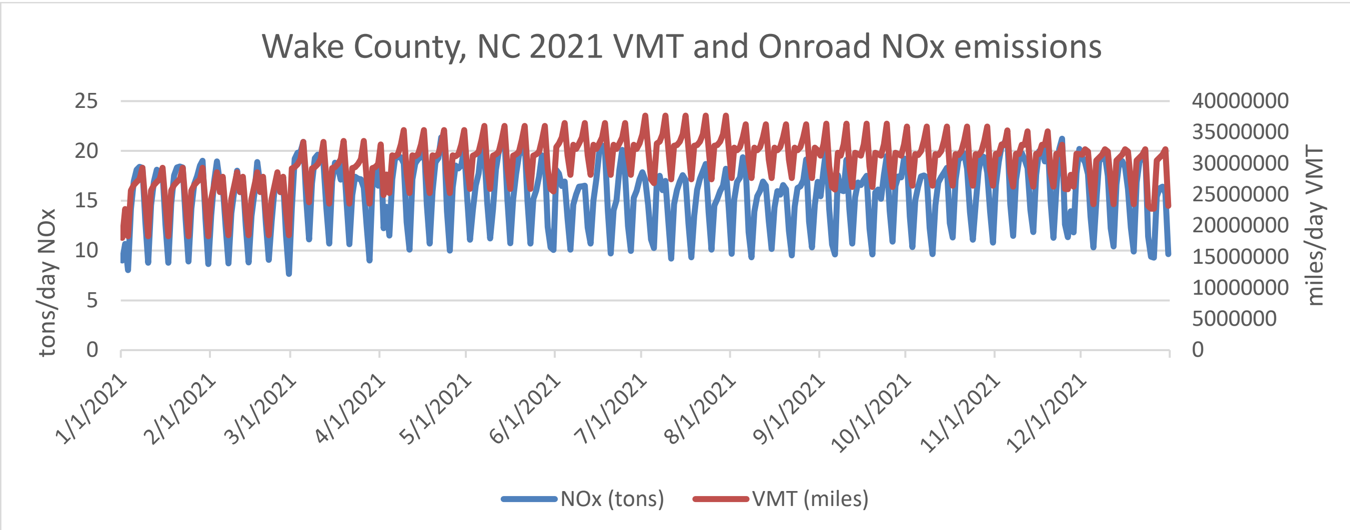
For the onroad sector, the temporal distribution of emissions is a combination of traditional temporal profiles and the influence of meteorology. For the 2022v2 platform, EPA utilized both the FHWA's Travel Monitoring and Analysis System (TMAS) and telematics vehicle activity data for all months of 2022 and months January through May of 2023 from StreetLight. Information from these datasets was converted into MOVES and SMOKE model inputs. Data from the years 2022 and 2023 were used to generate daily and hourly temporal profiles, as well as average speed distributions by county, weekday/weekend, hour of day, and SCC.

The "inventories" referred to in Table 3-13 consist of activity data for the onroad sector, not emissions. VMT is the activity data used for on-network rate-per-distance (RPD) processes. The off-network emissions from the rate-per-profile (RPP) and rate-per-vehicle (RPV) processes use the VPOP activity data, which are annual and do 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 RPD processes, the VMT activity data are annual for some sources and monthly for other sources, depending on the source of the data. Sources without monthly VMT were temporalized from annual to month through temporal profiles. VMT was also temporalized from month-to-day of the week, and then to hourly through temporal profiles. The RPD processes also use hourly speed distributions (SPDIST) as discussed in Section 2.3.

For onroad, the temporal profiles and SPDIST will impact not only the distribution of emissions through time but also the total emissions. SMOKE-MOVES calculates emissions for RPD processed based on the VMT, speed and meteorology. Thus, if the VMT or speed data were shifted 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 3-17 (an example taken from 2021) 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, the meteorologically varying emission factors add variation on top of the temporal allocation of the activity data.

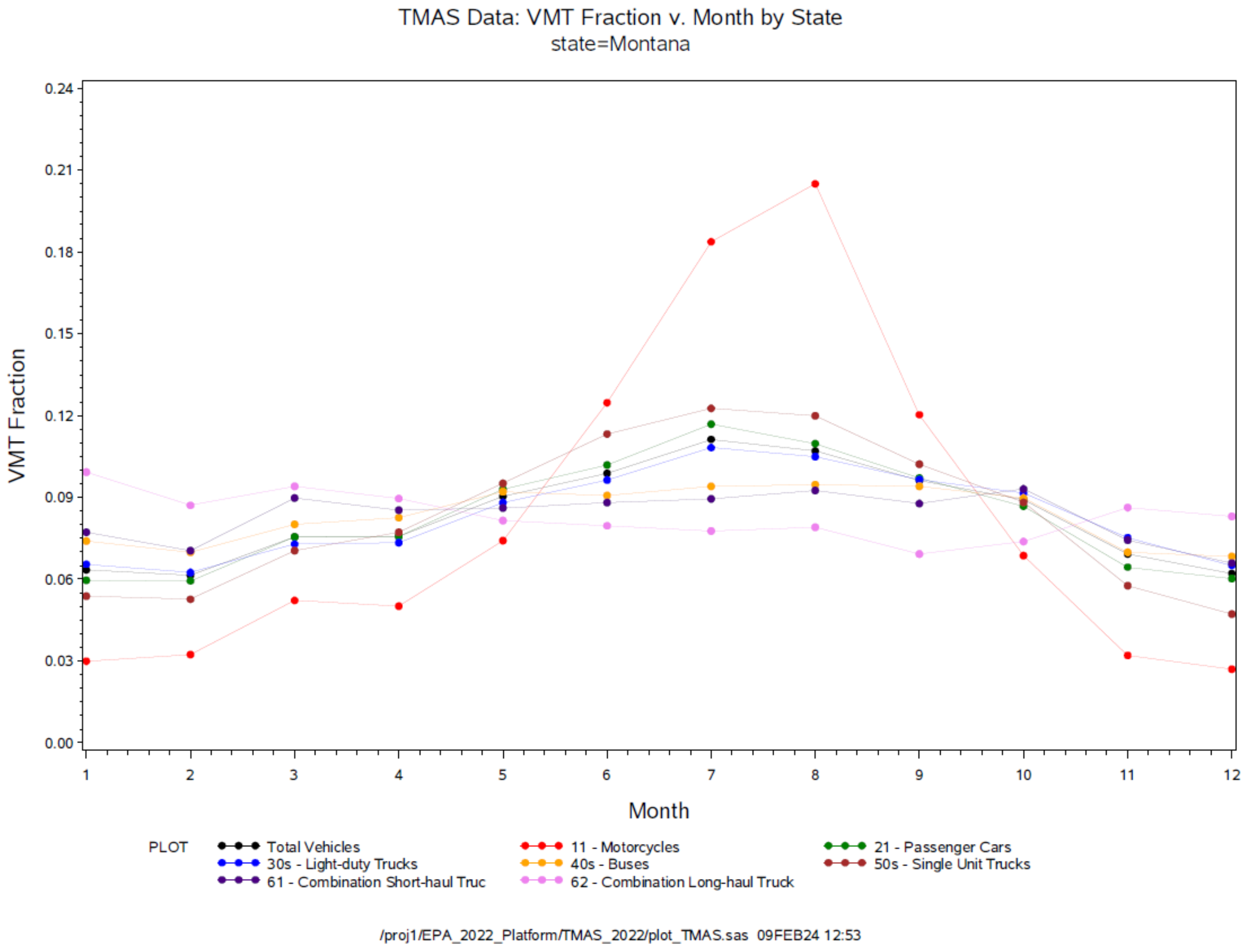
Figure 3-17. Example temporal variability of VMT compared to onroad NO_X emissions



Meteorology is not used in the development of the temporal profiles, but rather it impacts the calculation of the hourly emissions through the program Movesmrg. The result is that the emissions vary at the hourly level by grid cell. More specifically, the on-network (RPD) and the off-network parked and stationary vehicle (RPV, RPH, RPHO, RPS, and RPP) processes use the gridded meteorology (MCIP) either directly or indirectly. For RPD, RPV, RPH, RPHO, and RPS, Movesmrg determines the temperature for each hour and grid cell and uses that information to select the appropriate emission factor for the specified SCC/pollutant/mode combination. For RPP, instead of reading gridded hourly meteorology, Movesmrg reads gridded daily minimum and maximum temperatures. The total of the emissions from the combination of these six processes (RPD, RPV, RPH, RPHO, RPS, and RPP) comprise the onroad sector emissions. In summary, the temporal patterns of emissions in the onroad sector are influenced by meteorology.

Month-of-year temporal profiles for VMT were developed from FHWA's Travel Monitoring and Analysis System (TMAS) and are unchanged from 2022v1 platform. This system measures monthly traffic volume, by class and weight. TMAS data was processed for each state, month, and vehicle class. Data were provided for motorcycles (11), passenger vehicles (21), light duty trucks (30s), buses (40s), single unit trucks (50s), and combination short-haul trucks (61), and combination long-haul trucks (62). The dataset includes temporal profiles for individual states. utilized the Figure 3-18 shows an annual, by month plot of TMAS data for Montana. Note that there is an increase in passenger cars and light duty trucks during the month of July. This may be due to an increase in tourism during the warmer months.

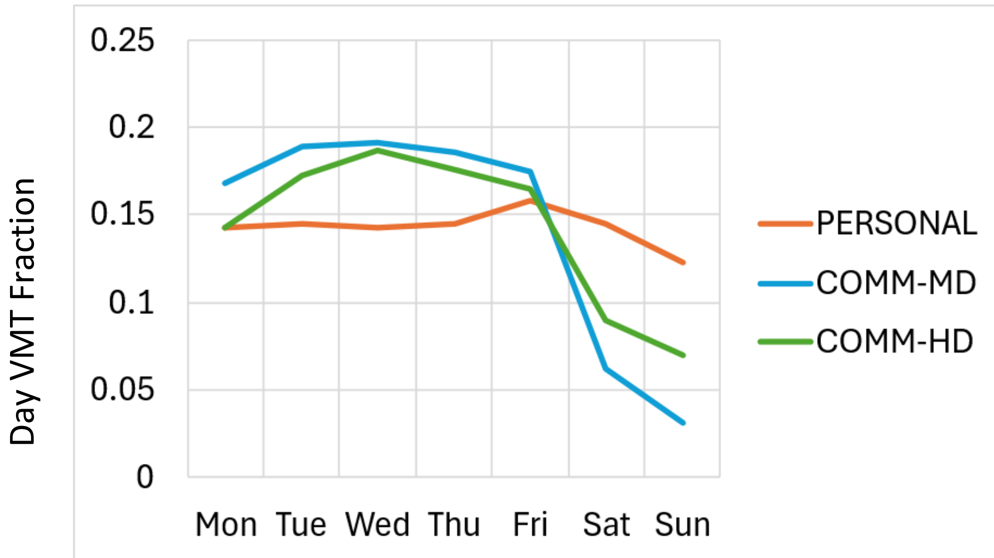
Figure 3-18 TMAS Data: VMT Fraction by Month for Montana by Vehicle Type



Day-of-week and hour-of-day temporal profiles and speed data for the 2022v2 platform are derived from StreetLight data. Day-of-week profiles vary by county, road type, month, and for three vehicle classes (i.e., light-duty, commercial medium-duty, and commercial heavy-duty), while hour-of-day profiles vary by county, road type, day of week, and the sa0me three vehicle classes. No submitted temporal profiles were carried forward from the 2020 NEI. 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. Figure 3-19 shows example day-of-week fractions for VMT on urban freeways and non-freeways. The non-freeways show a steeper drop off on weekends than the freeways for all vehicle classes. Figure 3-20 shows national average StreetLight VMT fraction by vehicle class for urban non-freeways. The first plot shows hour of the day for a weekday in local time. Note that you can see the rush hour in the morning and the evening. The second plot shows hour of day for a weekend day. Figure 3-21 shows example vehicle speeds on urban freeways and non-freeways in local time. The freeways show higher speeds and a more pronounced dip in speeds during rush hours than the non-freeways.

Figure 3-19. Example Day of Week Fractions for VMT on Urban Freeways and non-Freeways

Urban Freeways



Urban non-freeways

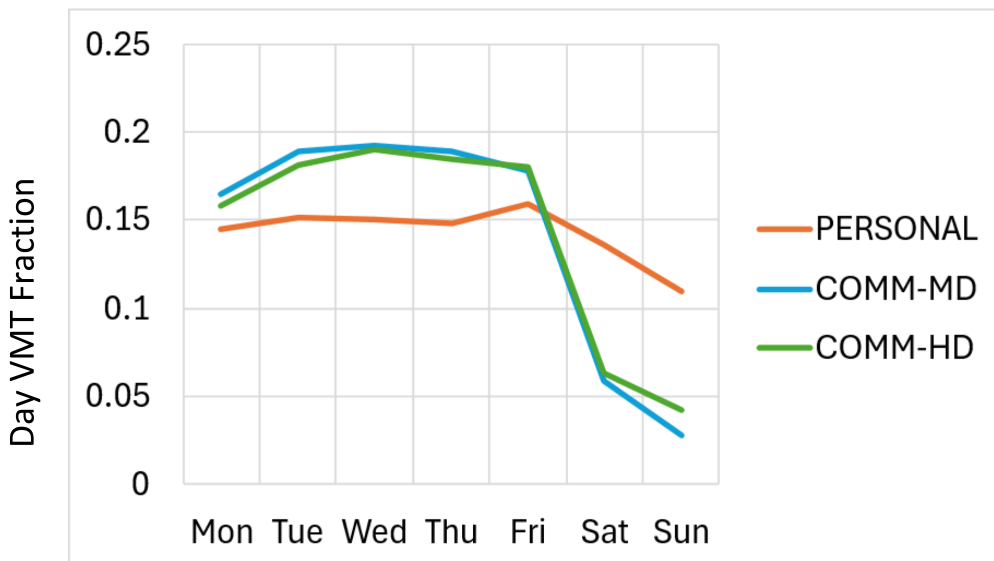
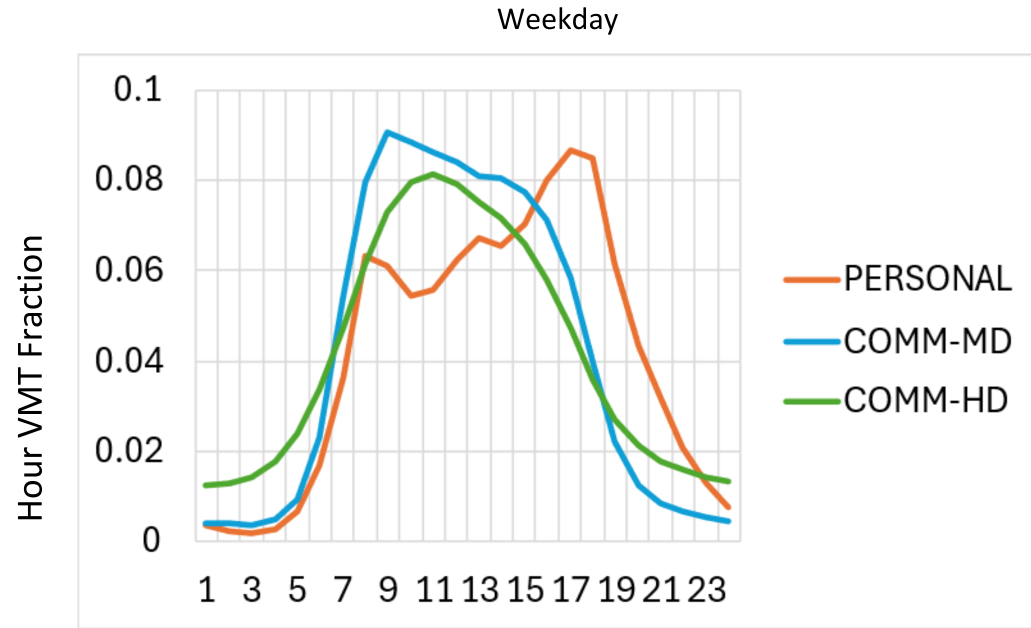


Figure 3-20. National Average VMT Fraction by Hour of Day (weekday and weekend)



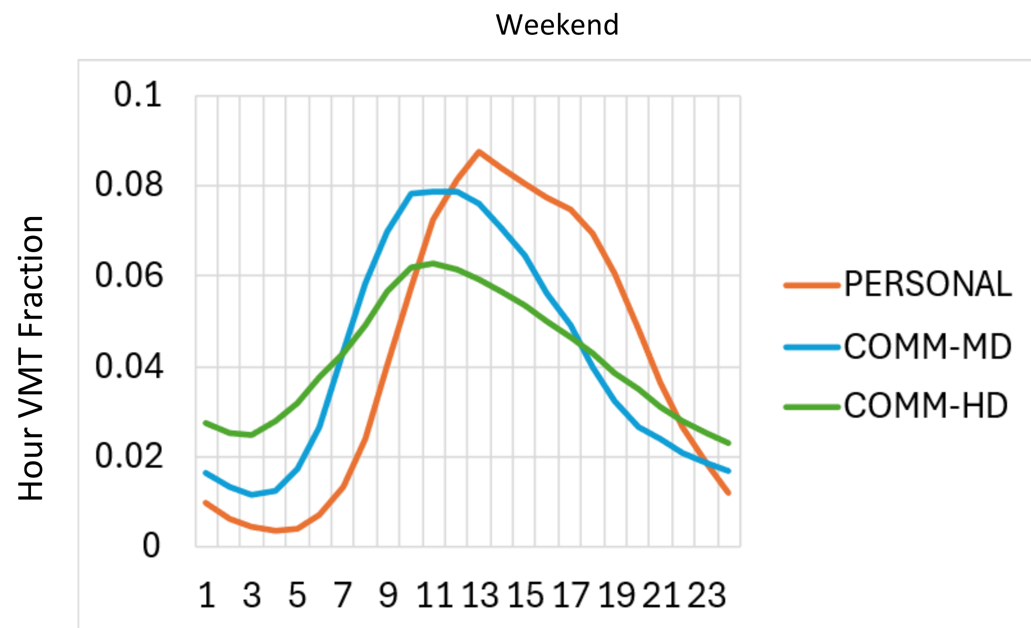
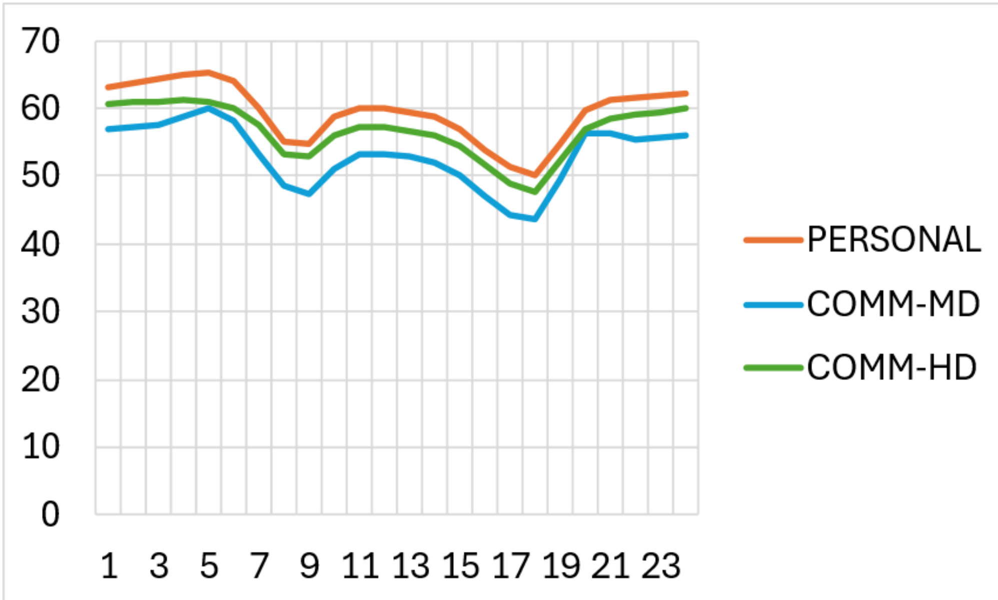
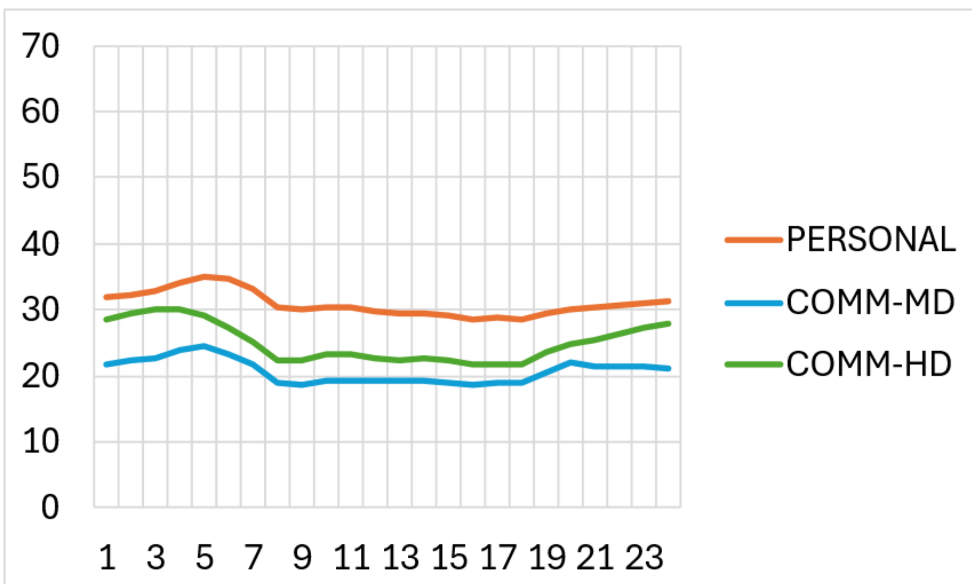


Figure 3-21. Example Vehicle Speeds for Weekdays by hour Urban Freeways and non-Freeways

Urban Freeways



Urban non-freeways



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 the same day-of-week profiles as on-network processes in RPD, but uses a separate set of diurnal temporal profiles specifically for starts activity. For starts, there are two hour-of-day temporal profiles for each source type, one for weekdays and one for weekends. The starts diurnal temporal profiles are applied nationally and are based on the default starts-hour-fraction tables from MOVES.

3.3.9 Nonroad mobile temporal allocation (nonroad)

For nonroad mobile sources, temporal allocation is performed differently for different SCCs. Beginning with the final 2011 platform, improvements to temporal allocation of nonroad mobile sources were made to make the temporal profiles more realistically reflect real-world practices. The specific updates were made for agricultural sources (e.g., tractors), construction, and commercial residential lawn and garden sources. In the 2022v1 platform, temporal profiles for residential and commercial snowblowers were changed to be flat for each day of the week since snowfall is not influenced by the day of the week.

Figure 3-22 shows two previously existing temporal profiles (9 and 18) and a newer temporal profile (19) which has lower emissions on weekends. In this platform, construction and commercial lawn and garden sources use the new profile 19 which has lower emissions on weekends. Residental lawn and garden sources continue to use profile 9 and agricultural sources continue to use profile 19.

Figure 3-22. Example Nonroad Day-of-week Temporal Profiles

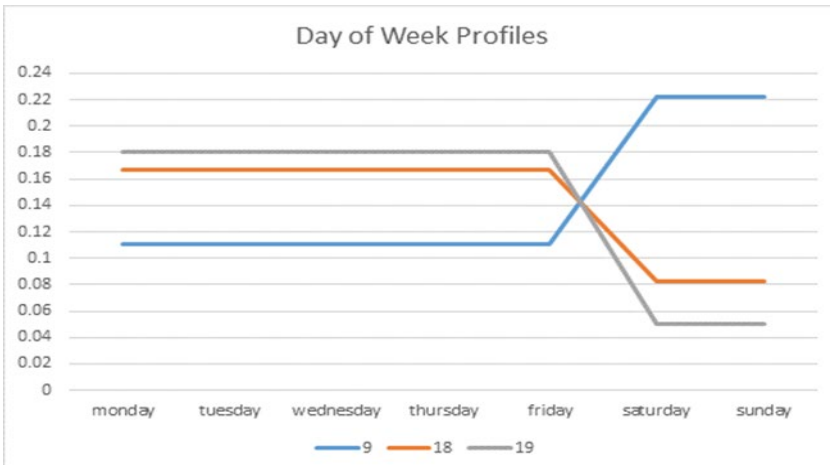
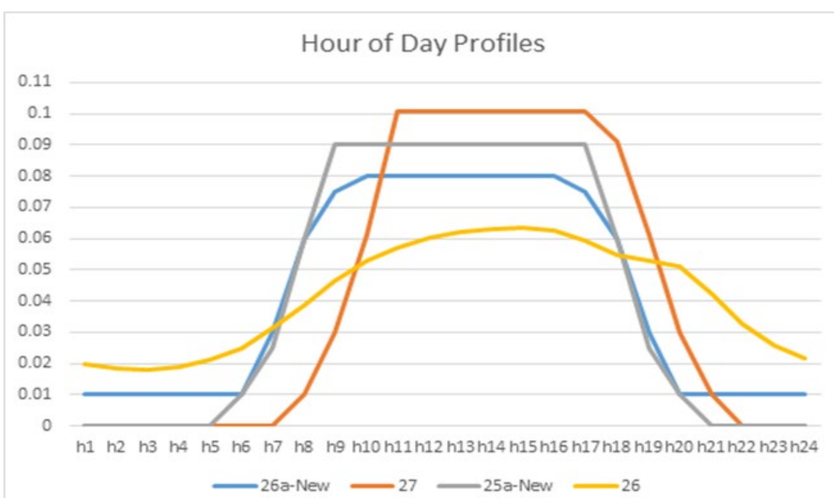


Figure 3-23 shows the previously existing temporal profiles 26 and 27 along with newer temporal profiles (25a and 26a) which have lower emissions overnight. In this platform, construction sources use profile 26a. Commercial lawn and garden and agriculture sources use the profiles 26a and 25a, respectively. Residental lawn and garden sources use profile 27.

Figure 3-23. Example Nonroad Diurnal Temporal Profiles



For the nonroad sector, 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.

3.3.10 Fugitive dust temporal profiles (afdust)

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 ("met adjusted"). The land use data used to reduce the NEI emissions explain 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, slightly different emissions will result from different grid resolutions.

Starting with the 2022v1 platform, some changes were made to temporal profiles in the afdust sector:

- New temporal profiles (monthly, weekly, hourly) were created for paved and unpaved road dust. The monthly profile is based on monthly emissions from the 2022hc onroad PM2.5 brake and tire wear, since that has less temperature dependence than other pollutants and process. Weekly and hourly profiles are based on averages of the TMAS profiles used in SMOKE-MOVES. Unpaved road dust profiles use averages of passenger trucks only; paved road dust profiles use weighted averages of 3/4 light-duty vehicle emissions excluding motorcycles, and 1/4 heavy duty emissions excluding buses. There are separate hourly profiles for weekdays vs weekends.
- For agricultural tilling, flat day-of-week profiles are now being used along with new monthly profiles mostly based on nonroad ag emissions. The monthly nonroad ag profiles are based on LADCO-provided MOVES data and more accurately reflect tilling activities, peaking in spring and fall.
- For dust from livestock, the monthly profiles for 2805100010 and 2805100050 (beef cattle and swine) were updated to the 2022 data from https://u.osu.edu/beef/2023/10/25/more-heifers-supporting-feedlot-inventory/. Profiles for other livestock dust are not changed from the 2020 platform.

3.3.11 Additional sector specific details (beis, cmv, rail, nonpt, np_solvents, ptfire-rx, ptfire-wild)

Starting with the 2022v1 platform, some changes were made to temporal profiles in the nonpt sector:

- Evaporative SCCs starting with 250105 and 250106 were updated to use monthly temporal profiles based on monthly total VOC emissions computed from the 2022hc onroad evaporative off-network processes in the RPP and RPV subsectors contained in the final 2022 onroad emissions.

- Residential natural gas (SCC 2104006000) monthly temporal profiles were derived for each state based on Energy Information Administration (EIA) data for 2022.

Starting with the 2022v1 platform, some changes were made to temporal profiles in the np_solvents sector:

- All asphalt SCCs (paving and roofing) are using new EIA-based monthly profiles for "asphalt and road oil" by PADD region. The data source is https://www.eia.gov/dnav/pet/PET_CONS_PSUP_A_EPPA_VPP_MBBL_A.htm.

- Architectural coating (2401001000): created a new monthly profile PAINT22 based on 2022 data from https://fred.stlouisfed.org/series/MRTSSM44412USN/.

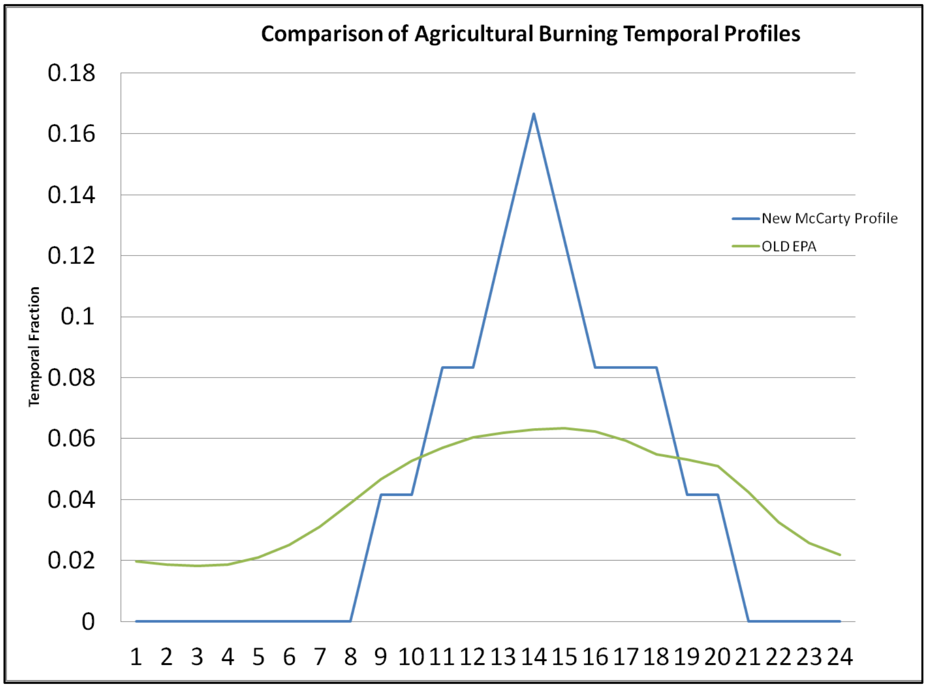
- Pesticides (SCCs 2461850000, 2461800001, and 2460800000): monthly profiles were changed as follows: AZ/CA/FL/HI/TX (the warmest states) are flat annual. Other moderately warm southeast states from North Carolina south and west to Oklahoma are flat from March through October, and zero in other months. All other states are flat from April through September and zero in other months.

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

For the cmv sectors, most areas use hourly emission inventories derived from the 5-minute AIS data. For the rail sector, monthly profiles from the 2016 platform were used. 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 but it is not known how closely rail emissions track with passenger activity since passenger trains run on a fixed schedule regardless of how many passengers are aboard, and so a flat profile is chosen for passenger trains. Rail emissions are allocated with flat day of week profiles, and most emissions are allocated with flat hourly profiles.

For the ptagfire sector, the inventories are in the daily point fire format FF10 PTDAY. The diurnal temporal profile for ag fires reflects the fact that burning occurs during the daylight hours - see Figure 3-24 (McCarty et al., 2009). This profile puts most of the emissions during the work-day and suppresses the emissions during the middle of the night.

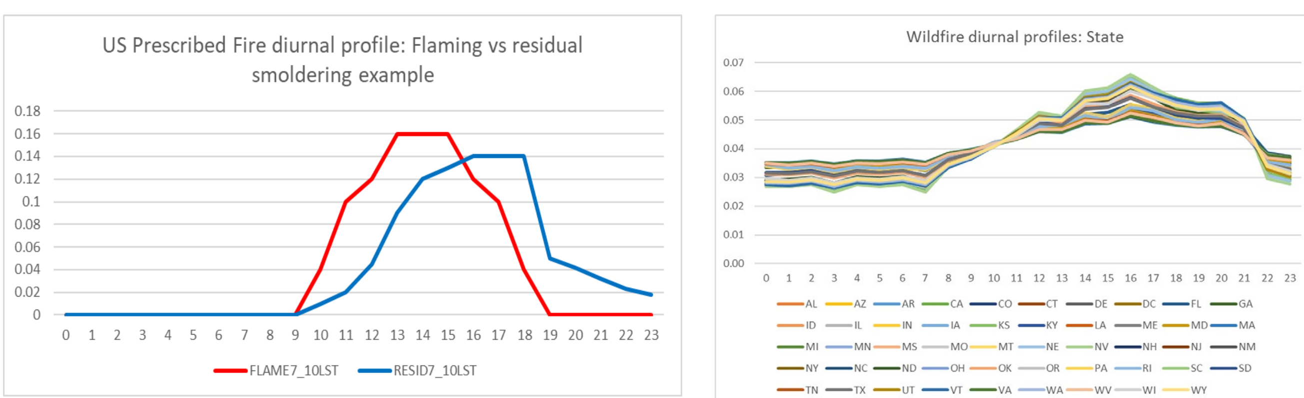
Figure 3-24. Agricultural burning diurnal temporal profile



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 typically shut down on Sundays use profiles that reflect Sunday shutdowns.

For the ptfire sectors, the inventories are in the daily point fire format FF10 PTDAY, so temporal profiles are only used to go from day-specific to hourly emissions. Separate hourly profiles for prescribed and wildfires were used. For ptfire, state-specific hourly profiles were used, with distinct profiles for prescribed fires and wildfires. Figure 3-25 below shows the profiles used for each state for the platform. The wildfire diurnal profiles are similar but vary according to the average meteorological conditions in each state. For all agricultural burning, the diurnal temporal profile used reflects the fact that burning occurs during the daylight. This puts most of the emissions during the workday and suppresses the emissions during the middle of the night. This diurnal profile was used for each day of the week for all agricultural burning emissions in all states.

Figure 3-25. Prescribed and Wildfire diurnal temporal profiles



3.4 Spatial Allocation

For the modeling platform, spatial factors are typically applied by county and SCC. Spatial allocation was performed for the 12US1 grid shown in Section 3.1. To accomplish this, SMOKE used national 12-km spatial surrogates and a SMOKE area-to-point data file. For the U.S., the surrogates mostly utilize circa 2020 geographic data. The U.S., Mexican, and Canadian spatial surrogates cover the entire CONUS domain 12US1 shown in Figure 3-1. While highlights of information are provided below, the file *Surrogate_specifications_2022v2_platform_US_Can_Mex.xlsx* documents the complete configuration for generating the surrogates and can be referenced for more details.

3.4.1 Spatial Surrogates for U.S. emissions

There are more than 90 spatial surrogates available for spatially allocating U.S. county-level emissions to the grid cells used by the air quality model. As described in Section 3.4.2, an area-to-point approach overrides the use of surrogates for airport refueling sources and off-road diesel trucks at mines in St. Louis County, Minnesota.

The surrogates for the platform are based on a variety of geospatial data sources, including the American Community Survey (ACS) for census-related data and the National Land Cover Database (NLCD). Onroad surrogates are based on average annual daily traffic counts (AADT) from the highway monitoring performance system (HPMS). New for the 2022v2 platform, Federal Emergency Management Agency (FEMA) structure data, were used to spatially allocate emissions from residential wood combustion.

When developing modeling platforms, EPA routinely updates surrogates to utilize updated versions of the underlying surrogate databases or to use a different source of data when it is deemed more representative for a particular source category. Spatial surrogates for the U.S. for this platform were developed as follows:

- County boundaries for all surrogates are from the 2020 Topologically Integrated Geographic Encoding and Referencing (TIGER) boundaries.
- Oil and gas activity data for other than abandoned wells were from the year 2022 and were slightly updated from those used for the 2022v1 platform by using the latest available data for 2022v2.
- The 5-year 2020 ACS data were used to derive surrogates for population, housing, and residential heating.
- The NLCD 2019 data were used to derive surrogates for land, water, agriculture, and various levels of development.
- Animal specific livestock waste surrogates were derived from National Pollutant Discharge Elimination System (NPDES) 2020 animal operation water permits and Food and Agriculture Organization (FAO) 2010 gridded livestock count data.
- Surrogates for fuel stations, asphalt surfaces, and unpaved roads are based on data extracted from the OpenStreetMap database in 2024.
- Gravel and lead mines use separate surrogates based on the more general United States Geological Survey (USGS) mining surrogate circa 2024.

- Residential wood combustion surrogates are based on a combination of 2020 ACS population and FEMA residential structure data circa 2025.
- Roadway locations, miles, and AADT for 2022 from the Federal Highway Administration (FHWA) HPMS. This was an update from the 2022v1 platform, which used HPMS data for 2017.

The 2022v2 platform uses the following spatial surrogates for RWC emissions sources: "All Residential Structures" (111), "Single Family + Manufactured + small Multi-family Residential Structures" (112), and "Single Family Residential Structures" (113). Surrogate 111 is used for fireplaces (SCC 2104008100) and fire logs (SCC 2104009000), surrogate 113 is used for hydronic heaters (SCCs 21040086*), and 112 is used for all other RWC SCCs. For the 2022v2 platform EPA examined surrogates for RWC emissions based on housing data from the ACS. The particular attributes previously used were: single family detached, single family attached, dual family and mobile home and combinations of these, depending on the particular RWC specific source category. However, evaluation of the ACS block group-level RWC surrogates against satellite basemaps showed that emissions were allocated to locations without residential structures, such as forests and industrial areas.

To further constrain emissions to locations with residential wood combustion activity the RWC spatial surrogates in the 2022v2 platform incorporated FEMA structure data (https://gis-fema.hub.arcgis.com/pages/usa-structures). For each census block group, FEMA polygons were subset to residential polygons. If structures identified as residential were not available in the Census block group other structure types were used to gap-fill the dataset. The ACS housing data are considered more complete and accurate than the FEMA structure data in terms of unit count and structure classification, therefore each FEMA structure was assigned a weighting factor based on the total ACS units by type (e.g. detached, attached, multi-family, etc.) divided by total FEMA structures by type in each block group. An improvement resulting from including structures is that emissions are allocated only to residential areas with structures instead of being uniformly distributed over the entire area of the censes block group and therefore the approach including structure data was used. A comparison of the 2022v2 RWC emissions of $PM_{2.5}$ gridded with each of these approaches is shown in Figure 3-26 and Figure 3-27.

Figure 3-26. 2022v2 Residential Wood Combustion Emissions using ACS-based Surrogate

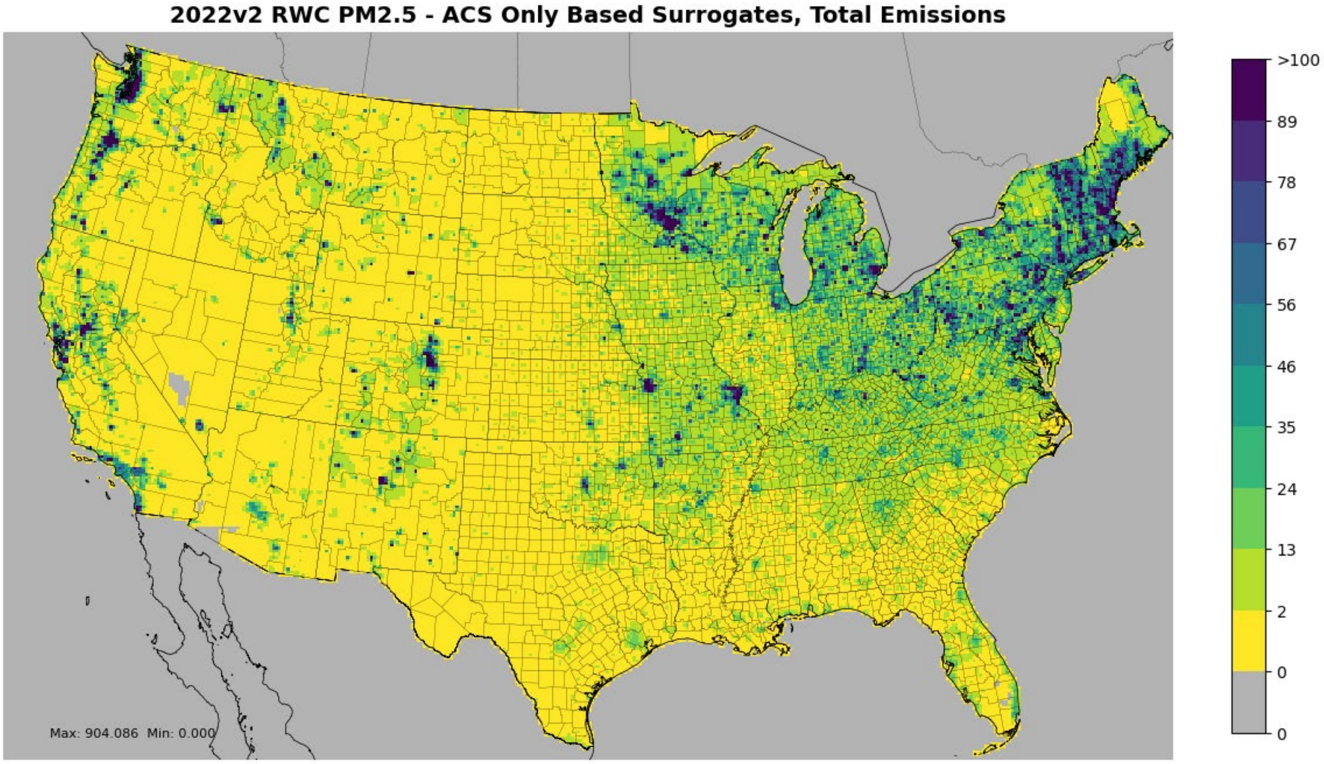
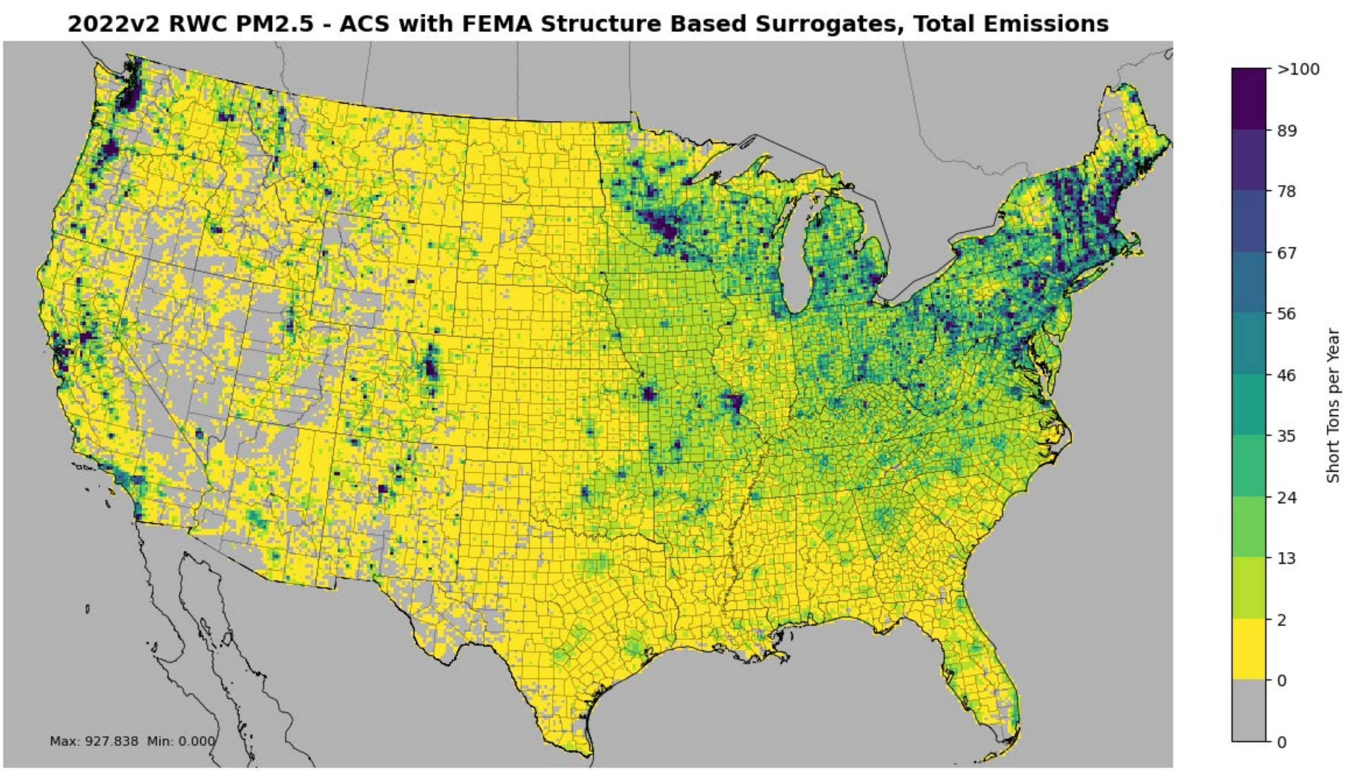


Figure 3-27. 2022v2 Residential Wood Combustion Emissions using ACS and FEMA structure-based Surrogate



Surrogates for the U.S. were generated using the Surrogate Tools DB with the Java-based Surrogate tools used to perform gap filling and normalization where needed. The tool and documentation for the original Surrogate Tool are available at https://www.cmascenter.org/sa-tools/documentation/4.2/SurrogateToolUserGuide_4_2.pdf, and the tool and documentation for the Surrogate Tools DB is available from https://www.cmascenter.org/surrogate_tools_db/. Table 3-14 lists the codes and descriptions of the surrogates. Surrogate names and codes listed in *italics* are not directly assigned to any sources in the platform, but they are sometimes used to gap fill other surrogates. When the source data for a surrogate have no values for a particular county, gapfilling is used to provide values for the spatial surrogate in those counties to ensure that no emissions are dropped when the spatial surrogates are applied to the emission inventories. The Shapefiles used to develop the US surrogates along with the attributes and filters used are shown in Table 3-15.

Table 3-14. U.S. surrogates available for the 2022v2 modeling platform

Code	Surrogate Description	Code	Surrogate Description
N/A	Area-to-point approach (see 3.6.2)	508	Public Schools
100	Population	650	Refineries and Tank Farms
110	Housing	*669*	All Abandoned Wells
111	All Residential Structures	*6691*	All Abandoned Oil Wells
112	Single Family + Manufactured + small Multi-family Residential Structures	*6692*	All Abandoned Gas Wells
113	Single Family Residential Structures	6694	All Abandoned Oil Wells - Plugged
135	Detached Housing	6695	All Abandoned Gas Wells - Plugged
136	Single and Dual Unit Housing	6697	All Abandoned Oil Wells - Unplugged
150	Residential Heating - Natural Gas	6698	All Abandoned Gas Wells - Unplugged
170	Residential Heating - Distillate Oil	670	Spud Count - CBM Wells
180	Residential Heating - Coal	671	Spud Count - Gas Wells
190	Residential Heating - LP Gas	*672*	Gas Production at Oil Wells
205	Extended Idle Locations	674	Unconventional Well Completion Counts
239	Total Road AADT	*676*	Well Count - All Producing
240	Total Road Miles	*677*	Well Count - All Exploratory
242	All Restricted AADT	678	Completions at Gas Wells
244	All Unrestricted AADT	679	Completions at CBM Wells
258	*Intercity Bus Terminals*	681	Spud Count - Oil Wells
259	Transit Bus Terminals	683	Produced Water at All Wells
261	NTAD Total Railroad Density	6831	Produced Water at CBM Wells
271	NTAD Class 1 2 3 Railroad Density	6832	Produced Water at Gas Wells
300	NLCD Low Intensity Development	6833	Produced Water at Oil Wells
304	NLCD Open + Low	685	Completions at Oil Wells
305	NLCD Low + Med	*686*	*Completions at All Wells*
306	NLCD Med + High	687	Feet Drilled at All Wells
307	NLCD All Development	689	Gas Produced – Total
308	NLCD Low + Med + High	691	Well Counts - CBM Wells
309	NLCD Open + Low + Med	692	Spud Count - All Wells

Code	Surrogate Description	Code	Surrogate Description
310	NLCD Total Agriculture	*693*	*Well Count - All Wells*
319	NLCD Crop Land	694	Oil Production at Oil Wells
320	NLCD Forest Land	695	Well Count - Oil Wells
321	NLCD Recreational Land	696	Gas Production at Gas Wells
340	*NLCD Land*	*697*	*Oil Production at Gas Wells*
350	NLCD Water	698	Well Count - Gas Wells
401	*FAO 2010 Cattle*	699	Gas Production at CBM Wells
4011	FAO 2010 Large Cattle Operations	711	Airport Areas
4012	NPDES 2020 Beef Cattle	801	Port Areas
4013	NPDES 2020 Dairy Cattle	850	Golf Courses
402	*FAO 2010 Pig*	860	Mines
4021	NPDES 2020 Swine	861	Sand and Gravel Mines
403	*FAO 2010 Chicken*	*862*	*Lead Mines*
4031	NPDES 2020 Chicken	863	Crushed Stone Mines
404	*FAO 2010 Goat*	900	OSM Fuel
4041	NPDES 2020 Goat	901	OSM Asphalt Surfaces
405	FAO 2010 Horse	902	OSM Unpaved Roads
406	FAO 2010 Sheep		
4071	NPDES 2020 Turkey		

Table 3-15. Shapefiles used to develop U.S. Surrogates

Code	Surrogate	Weight Shapefile	Weight Attribute	Filter Function
100	Population	ACS_2020_5YR_BG_pop_hu	POP2020	
110	Housing	ACS_2020_5YR_BG_pop_hu	HU2020	
111	All Residential Structures	structure_population_rwc_2022		occ_label IN ('single_family','manufactured','multi_family_2_4','multi_family_5+')
112	Single Family + Manufactured + small Multi-family Residential Structures	structure_population_rwc_2022		occ_label IN ('single_family','manufactured','multi_family_2_4')
113	Single Family Residential Structures	structure_population_rwc_2022		occ_label = 'single_family'
135	Detached Housing	ACS_2020_5YR_BG_pop_hu	detachedh	
136	Single and Dual Unit Housing	ACS_2020_5YR_BG_pop_hu	lttriunit	
150	Residential Heating - Natural Gas	ACS_2020_5YR_BG_pop_hu	UTIL_GAS	
170	Residential Heating - Distillate Oil	ACS_2020_5YR_BG_pop_hu	FUEL_OIL	

Code	Surrogate	Weight Shapefile	Weight Attribute	Filter Function
180	Residential Heating - Coal	ACS_2020_5YR_BG_pop_hu	COAL	
190	Residential Heating - LP Gas	ACS_2020_5YR_BG_pop_hu	LP_GAS	
205	Extended Idle Locations	pil_2019_06_24	rev_truck	rev_truck>0
239	Total Road AADT	hpms_roadways_2022_us_moves5	aadt	moves5type IN ('2', '3', '4', '5')
240	Total Road Miles	hpms_roadways_2022_us_moves5	NONE	moves5type IN ('2', '3', '4', '5')
242	All Restricted AADT	hpms_roadways_2022_us_moves5	aadt	moves5type IN ('2', '4')
244	All Unrestricted AADT	hpms_roadways_2022_us_moves5	aadt	moves5type IN ('3', '5')
259	Transit Bus Terminals	ntad_2016_ipcd	NONE	bus_t=1
260	Total Railroad Miles	tiger_2014_rail	NONE	
261	NTAD Total Railroad Density	ntad_2014_rail_fixed	dens	RAILTYPE IN (1,2,3)
271	NTAD Class 1 2 3 Railroad Density	ntad_2014_rail_fixed	dens	RAILTYPE=1
300	NLCD Low Intensity Development	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE=22
304	NLCD Open + Low	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (21,22)
305	NLCD Low + Med	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (22,23)
306	NLCD Med + High	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (23,24)
307	NLCD All Development	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (21,22,23,24)
308	NLCD Low + Med + High	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (22,23,24)
309	NLCD Open + Low + Med	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (21,22,23)
310	NLCD Total Agriculture	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (81,82)
318	NLCD Pasture Land	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE=81
319	NLCD Crop Land	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE=82
320	NLCD Forest Land	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (41,42,43)
321	NLCD Recreational Land	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE IN (21,31,41,42,43,52,71)
340	NLCD Land	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE != 11

Code	Surrogate	Weight Shapefile	Weight Attribute	Filter Function
350	NLCD Water	nlcd_2019_land_cover_l48_20210604_500m_ll	NONE	GRIDCODE=11
401	FAO 2010 Cattle	fao_Cattle_2010_Da_nlcdproj_masked	DN	
4011	FAO 2010 Large Cattle Operations	fao_LargeCattle_2010_Da_nlcdproj_masked	DN	
4012	NPDES 2020 Beef Cattle	livestock_npdes_state_permits_subset	Population	Animal = 'Beef'
4013	NPDES 2020 Dairy Cattle	livestock_npdes_state_permits_subset	Population	Animal = 'Dairy'
402	FAO 2010 Pig	fao_Pig_2010_Da_nlcdproj_masked	DN	
4021	NPDES 2020 Swine	livestock_npdes_state_permits_subset	Population	Animal = 'Swine'
403	FAO 2010 Chicken	fao_Chicken_2010_Da_nlcdproj_masked	DN	
4031	NPDES 2020 Chicken	livestock_npdes_state_permits_subset	Population	Animal = 'Chicken'
404	FAO 2010 Goat	fao_Goat_2010_Da_nlcdproj_masked	DN	
4041	NPDES 2020 Goat	livestock_npdes_state_permits_subset	Population	Animal = 'Goat'
405	FAO 2010 Horse	fao_Horse_2010_Da_nlcdproj_masked	DN	
406	FAO 2010 Sheep	fao_Sheep_2010_Da_nlcdproj_masked	DN	
4071	NPDES 2020 Turkey	livestock_npdes_state_permits_subset	Population	Animal = 'Turkey'
508	Public Schools	public_schools_2018_2019	TOTAL	
650	Refineries and Tank Farms	eia_2015_us_oil	NONE	
669	All Abandoned Wells	AW_ALL_COUNTS_669_2022	ACTIVITY	
6695	All Abandoned Gas Wells - Plugged	AW_GAS_PLUGGED_6695_2022	ACTIVITY	
6692	All Abandoned Gas Wells	AW_GAS_PLUGGED_UNPLUGGED_6692_2022	ACTIVITY	
6698	All Abandoned Gas Wells - Unplugged	AW_GAS_UNPLUGGED_6698_2022	ACTIVITY	
6694	All Abandoned Oil Wells - Plugged	AW_OIL_PLUGGED_6694_2022	ACTIVITY	
6691	All Abandoned Oil Wells	AW_OIL_PLUGGED_UNPLUGGED_6691_2022	ACTIVITY	
6697	All Abandoned Oil Wells - Unplugged	AW_OIL_UNPLUGGED_6697_2022	ACTIVITY	
670	Spud Count - CBM Wells	SPUD_CBM_670_2022v2	ACTIVITY	
671	Spud Count - Gas Wells	SPUD_GAS_671_2022v2	ACTIVITY	
672	Gas Production at Oil Wells	ASSOCIATED_GAS_PRODUCTION_672_2022v2	ACTIVITY	
673	Oil Production at CBM Wells	CONDENSATE_CBM_PRODUCTION_673_2022v2	ACTIVITY	
674	Unconventional Well Completion Counts	COMPLETIONS_UNCONVENTIONAL_674_2022v2	ACTIVITY	
676	Well Count - All Producing	TOTAL_PROD_WELL_676_2022v2	ACTIVITY	
677	Well Count - All Exploratory	TOTAL_EXPL_WELL_677_2022v2	ACTIVITY	
678	Completions at Gas Wells	COMPLETIONS_GAS_678_2022v2	ACTIVITY	

Code	Surrogate	Weight Shapefile	Weight Attribute	Filter Function
679	Completions at CBM Wells	COMPLETIONS_CBM_679_2022v2	ACTIVITY	
681	Spud Count - Oil Wells	SPUD_OIL_681_2022v2	ACTIVITY	
683	Produced Water at All Wells	PRODUCED_WATER_ALL_683_2022v2	ACTIVITY	
6831	Produced Water at CBM Wells	PRODUCED_WATER_CBM_6831_2022v2	ACTIVITY	
6832	Produced Water at Gas Wells	PRODUCED_WATER_GAS_6832_2022v2	ACTIVITY	
6833	Produced Water at Oil Wells	PRODUCED_WATER_OIL_6833_2022v2	ACTIVITY	
685	Completions at Oil Wells	COMPLETIONS_OIL_685_2022v2	ACTIVITY	
686	Completions at All Wells	COMPLETIONS_ALL_686_2022v2	ACTIVITY	
687	Feet Drilled at All Wells	FEET_DRILLED_687_2022v2	ACTIVITY	
689	Gas Produced - Total	TOTAL_GAS_PRODUCTION_689_2022v2	ACTIVITY	
691	Well Counts - CBM Wells	CBM_WELLS_691_2022v2	ACTIVITY	
692	Spud Count - All Wells	SPUD_ALL_692_2022v2	ACTIVITY	
693	Well Count - All Wells	TOTAL_WELL_693_2022v2	ACTIVITY	
694	Oil Production at Oil Wells	OIL_PRODUCTION_694_2022v2	ACTIVITY	
695	Well Count - Oil Wells	OIL_WELLS_695_2022v2	ACTIVITY	
696	Gas Production at Gas Wells	GAS_PRODUCTION_696_2022v2	ACTIVITY	
697	Oil Production at Gas Wells	CONDENSATE_GAS_PRODUCTION_697_2022v2	ACTIVITY	
698	Well Count - Gas Wells	GAS_WELLS_698_2022v2	ACTIVITY	
699	Gas Production at CBM Wells	CBM_PRODUCTION_699_2022v2	ACTIVITY	
711	Airport Areas	airport_area	area	
801	Port Areas	Ports_2014NEI	area_sqmi	
850	Golf Courses	usa_golf_courses_2019_10	NONE	
860	Mines	usgs_mrds_active_mines	NONE	
861	Sand and Gravel Mines	usgs_mrds_active_mines	NONE	CAT='Gravel'
862	Lead Mines	usgs_mrds_active_mines	NONE	CAT='Lead'
863	Crushed Stone Mines	usgs_mrds_active_mines	NONE	CAT='Stone'
900	OSM Fuel	osm_fuel_points_us_mar2023	NONE	
901	OSM Asphalt Surfaces	osm_asphalt_surfaces_us_mar2023	NONE	
902	OSM Unpaved Roads	osm_unpaved_roads_us_mar2023	NONE	

The 'Data Shapefile' used for all of the U.S. surrogates except for those based on HPMS data is cb_2020_us_county_500k, while the HPMS-based surrogates use hpms_roadways_2022_us_moves5. Similarly, all surrogates use the GEOID. The gapfilling configuration for the surrogates is shown in Table 3-16. If there are no entries for a county for the primary surrogate, the values for the county from the secondary surrogate are used. If there are also no entries for the secondary surrogate, the values for the tertiary surrogate are used, with the quarternary surrogate being the final fallback. Typically, only surrogates that should have values for all counties are selected as the quarternary surrogate. This process is used to limit any emissions that could be dropped if there are emissions in the inventory in a county for which the primary surrogate does not have values. It is important to note that once gapfilling is performed, SMOKE does not know that emissions for that county were from a secondary, tertiary or quarternary surrogate and any reports will assign the emissions in gapfilled counties to the primary surrogate.

Table 3-16. Surrogates used to gapfill U.S. surrogates for CONUS grids

SURROGATE CODE	SURROGATE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
100	Population			
110	Housing	Population		
111	All Residential Structures			
112	Single Family + Manufactured + small Multi-family Residential Structures			
113	Single Family Residential Structures			
135	Detached Housing	NLCD Low Intensity Development		
136	Single and Dual Unit Housing	NLCD Low Intensity Development		
150	Residential Heating - Natural Gas	Population		
170	Residential Heating - Distillate Oil	Housing		
180	Residential Heating – Coal	Housing		
190	Residential Heating - LP Gas	Housing		
205	Extended Idle Locations	Total Road Miles		
239	Total Road AADT	Total Road Miles		
240	Total Road Miles			
242	All Restricted AADT	Total Road Miles		
244	All Unrestricted AADT	Total Road Miles		
259	Transit Bus Terminals	Population	NLCD Land	
260	Total Railroad Miles	Total Road Miles	Population	
261	NTAD Total Railroad Density	Total Railroad Miles	Total Road Miles	Population
271	NTAD Class 1 2 3 Railroad Density	NTAD Total Railroad Density	Total Railroad Miles	Total Road Miles
300	NLCD Low Intensity Development	Housing	Population	NLCD Land
304	NLCD Open + Low	Housing	Population	NLCD Land
305	NLCD Low + Med	Housing	Population	NLCD Land
306	NLCD Med + High	Housing	Population	NLCD Land
307	NLCD All Development	Housing	Population	NLCD Land
308	NLCD Low + Med + High	Housing	Population	NLCD Land
309	NLCD Open + Low + Med	Housing	Population	NLCD Land
310	NLCD Total Agriculture	NLCD Open + Low	NLCD Land	
318	NLCD Pasture Land	Housing	NLCD Land	
319	NLCD Crop Land	Housing	NLCD Land	
320	NLCD Forest Land	Housing	NLCD Land	
321	NLCD Recreational Land	Housing	NLCD Land	

SURROGATE CODE	SURROGATE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
340	NLCD Land			
350	NLCD Water			
401	FAO 2010 Cattle	NLCD Total Agriculture	NLCD Open + Low	
4011	FAO 2010 Large Cattle Operations	FAO 2010 Cattle	NLCD Total Agriculture	NLCD Open + Low
4012	NPDES 2020 Beef Cattle	FAO 2010 Cattle	NLCD Total Agriculture	NLCD Open + Low
4013	NPDES 2020 Dairy Cattle	FAO 2010 Large Cattle Operations	NLCD Total Agriculture	NLCD Open + Low
402	FAO 2010 Pig	NLCD Total Agriculture	NLCD Open + Low	
4021	NPDES 2020 Swine	FAO 2010 Pig	NLCD Total Agriculture	NLCD Open + Low
403	FAO 2010 Chicken	NLCD Total Agriculture	NLCD Open + Low	
4031	NPDES 2020 Chicken	FAO 2010 Chicken	NLCD Total Agriculture	NLCD Open + Low
404	FAO 2010 Goat	NLCD Total Agriculture	NLCD Open + Low	
4041	NPDES 2020 Goat	FAO 2010 Goat	NLCD Total Agriculture	NLCD Open + Low
405	FAO 2010 Horse	NLCD Total Agriculture	NLCD Open + Low	
406	FAO 2010 Sheep	NLCD Total Agriculture	NLCD Open + Low	
4071	NPDES 2020 Turkey	NLCD Total Agriculture	NLCD Open + Low	
508	Public Schools	Population	NLCD Land	
650	Refineries and Tank Farms	NLCD Low + Med	Population	NLCD Land
669	All Abandoned Wells	Well Count - All Wells	NLCD Open + Low	
6695	All Abandoned Gas Wells - Plugged	All Abandoned Gas Wells	Well Count - All Wells	NLCD Open + Low
6692	All Abandoned Gas Wells	Well Count - All Wells	NLCD Open + Low	
6698	All Abandoned Gas Wells - Unplugged	All Abandoned Gas Wells	Well Count - All Wells	NLCD Open + Low
6694	All Abandoned Oil Wells - Plugged	All Abandoned Oil Wells	Well Count - All Wells	NLCD Open + Low
6691	All Abandoned Oil Wells	Well Count - All Wells	NLCD Open + Low	
6697	All Abandoned Oil Wells - Unplugged	All Abandoned Oil Wells	Well Count - All Wells	NLCD Open + Low
670	Spud Count - CBM Wells	Spud Count - All Wells	Well Count - All Wells	
671	Spud Count - Gas Wells	Well Count - Gas Wells	Well Count - All Wells	
672	Gas Production at Oil Wells	NLCD Open + Low	Well Count - Oil Wells	Well Count - All Wells
673	Oil Production at CBM Wells	Well Count - CBM Wells	Well Count - All Wells	NLCD Open + Low
674	Unconventional Well Completion Counts	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
676	Well Count - All Producing	Well Count - All Wells	NLCD Open + Low	
677	Well Count - All Exploratory	Well Count - All Wells	NLCD Open + Low	
678	Completions at Gas Wells	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low

SURROGATE CODE	SURROGATE	SECONDARY SURROGATE	TERTIARY SURROGATE	QUARTERNARY SURROGATE
679	Completions at CBM Wells	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low
681	Spud Count - Oil Wells	Well Count - Oil Wells	Well Count - All Wells	NLCD Open + Low
683	Produced Water at All Wells	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
6831	Produced Water at CBM Wells	Well Counts - CBM Wells	Well Count - All Wells	NLCD Open + Low
6832	Produced Water at Gas Wells	Well Count - Gas Wells	Well Count - All Wells	NLCD Open + Low
6833	Produced Water at Oil Wells	Well Count - Oil Wells	Well Count - All Wells	NLCD Open + Low
685	Completions at Oil Wells	Spud Count - All Wells	Well Count - All Wells	NLCD Open + Low
686	Completions at All Wells	Well Count - All Exploratory	Well Count - All Wells	NLCD Open + Low
687	Feet Drilled at All Wells	Well Count - All Exploratory	Well Count - All Wells	NLCD Open + Low
689	Gas Produced - Total	Well Count - All Wells	NLCD Open + Low	
691	Well Counts - CBM Wells	Completions at CBM Wells	Well Count - All Wells	NLCD Open + Low
692	Spud Count - All Wells	Completions at All Wells	Well Count - All Wells	NLCD Open + Low
693	Well Count - All Wells	NLCD Open + Low		
694	Oil Production at Oil Wells	Completions at Oil Wells	Well Count - All Wells	NLCD Open + Low
695	Well Count - Oil Wells	Completions at Oil Wells	Well Count - All Wells	NLCD Open + Low
696	Gas Production at Gas Wells	Completions at Gas Wells	Well Count - All Wells	NLCD Open + Low
697	Oil Production at Gas Wells	Well Count - Gas Wells	Well Count - All Wells	NLCD Open + Low
698	Well Count - Gas Wells	Completions at Gas Wells	Well Count - All Wells	NLCD Open + Low
699	Gas Production at CBM Wells	Well Counts - CBM Wells	Well Count - All Wells	NLCD Open + Low
711	Airport Areas	Population	NLCD Land	
801	Port Areas	NLCD Water		
850	Golf Courses	Housing	Population	NLCD Land
860	Mines	NLCD Open + Low	NLCD Land	
861	Sand and Gravel Mines	Mines	NLCD Open + Low	NLCD Land
862	Lead Mines	Mines	NLCD Open + Low	NLCD Land
863	Crushed Stone Mines	Mines	NLCD Open + Low	NLCD Land
900	OSM Fuel	Total Road AADT	Total Road Miles	
901	OSM Asphalt Surfaces	NLCD All Development		
902	OSM Unpaved Roads	NLCD Open + Low		

For the onroad sector, the on-network (RPD) emissions were spatially allocated differently from other off-network processes (i.e., RPV, RPP, RPHO, RPS, RPH). 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 3-17. 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 roadway surrogates were updated from 2017 based Highway Performance Monitoring System data to 2022 based data to better account for road network changes.

Table 3-17. 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 3-18 using 2022 data consistent with what was used to develop the nonpoint oil and gas emissions. The exploration and production of oil and gas have generally increased in terms of quantities and locations over recent years, primarily due to the use of new technologies, such as hydraulic fracturing. Census-tract, 2-km, and 4-km sub-county Shapefiles were developed, from which the 2020 oil and gas surrogates were generated. All spatial surrogates for np_oilgas are developed based on known locations of oil and gas activity for year 2022. The oil and gas-related spatial surrogates in the 2022v2 platform were updated based on Shapefiles consistent with the 2022v2 oil and gas emissions, other than the coal-bed methane abandoned well spatial surrogates that are based on data from the 2021 platform and the remaining abandoned well surrogates that are based on data from the 2022v1 platform. All surrogate changes for oil and gas in 2022v2 were minor changes.

The primary activity data source used for the development of the oil and gas spatial surrogates was data from ENVERUS [formerly Drilling Info (DI) Desktop's HPDI] database (ENVERUS, 2023). This database contains well-level location, production, and exploration statistics at the monthly level. Due to a proprietary agreement with ENVERUS, 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, Pennsylvania, and 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) were downloaded and used. Under that methodology, both completion date and date of first production from HPDI were used to identify wells completed during 2022. The spatial surrogates were gapfilled using fallback surrogates as shown in Table 3-16. All gapfilling was performed with the Surrogate Tool.

Table 3-18. Spatial surrogates used for oil and gas Sources

Surrogate Code	Surrogate Description
669	*All Abandoned Wells*
6691	*All Abandoned Oil Wells*
6692	*All Abandoned Gas Wells*
6694	All Abandoned Oil Wells – Plugged
6695	All Abandoned Gas Wells – Plugged
6697	All Abandoned Oil Wells – Unplugged
6698	All Abandoned Gas Wells – Unplugged
670	Spud Count - CBM Wells
671	Spud Count - Gas Wells
672	Gas Production at Oil Wells
673	Oil Production at CBM Wells
674	Unconventional Well Completion Counts
676	Well Count - All Producing
677	Well Count - All Exploratory
678	Completions at Gas Wells
679	Completions at CBM Wells
681	Spud Count - Oil Wells
683	Produced Water at All Wells
685	Completions at Oil Wells
686	Completions at All Wells
687	Feet Drilled at All Wells
689	Gas Produced – Total
691	Well Counts - CBM Wells
692	Spud Count - All Wells
693	Well Count - All Wells
694	Oil Production at Oil Wells
695	Well Count - Oil Wells
696	Gas Production at Gas Wells
697	Oil Production at Gas Wells
698	Well Count - Gas Wells
699	Gas Production at CBM Wells
6831	Produced water at CBM wells
6832	Produced water at gas wells
6833	Produced water at oil wells

Table 3-19 shows the CAP emissions (i.e., NH_3, NOx, $PM_{2.5}$, SO_2, and VOC) by sector assigned to each spatial surrogate.

Table 3-19. Selected 2022v2 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	305,537	0	0
afdust	306	NLCD Med + High	0	0	41,167	0	0
afdust	308	NLCD Low + Med + High	0	0	122,726	0	0
afdust	310	NLCD Total Agriculture	0	0	502,702	0	0
afdust	861	Sand and Gravel Mines	0	0	271	0	0
afdust	863	Crushed Stone Mines	0	0	291	0	0
afdust	902	OSM Unpaved Roads	0	0	823,325	0	0
afdust	4012	NPDES 2020 Beef Cattle	0	0	185,956	0	0
afdust	4013	NPDES 2020 Dairy Cattle	0	0	12,408	0	0
afdust	4021	NPDES 2020 Swine	0	0	630	0	0
afdust	4031	NPDES 2020 Chicken	0	0	4,948	0	0
afdust	4071	NPDES 2020 Turkey	0	0	1,948	0	0
fertilizer	310	NLCD Total Agriculture	1,671,402	0	0	0	0
livestock	405	FAO 2010 Horse	31,973	0	0	0	2,560
livestock	406	FAO 2010 Sheep	18,425	0	0	0	1,474
livestock	4012	NPDES 2020 Beef Cattle	775,290	0	0	0	61,885
livestock	4013	NPDES 2020 Dairy Cattle	350,829	0	0	0	28,168
livestock	4021	NPDES 2020 Swine	839,869	0	0	0	67,190
livestock	4031	NPDES 2020 Chicken	473,844	0	0	0	37,908
livestock	4041	NPDES 2020 Goat	17,609	0	0	0	1,409
livestock	4071	NPDES 2020 Turkey	82,538	0	0	0	6,603
nonpt	0	Area-to-point spatial allocation	0	126	4	12	26,843
nonpt	100	Population	454	0	0	0	36
nonpt	150	Residential Heating - Natural Gas	47,317	228,596	2,638	1,522	13,491
nonpt	170	Residential Heating - Distillate Oil	1,718	29,360	3,626	738	1,246
nonpt	180	Residential Heating - Coal	0	2	1	7	2
nonpt	190	Residential Heating - LP Gas	136	39,187	156	175	1,539
nonpt	239	Total Road AADT	0	0	0	0	6,536
nonpt	244	All Unrestricted AADT	0	0	0	0	98,151
nonpt	271	NTAD Class 1 2 3 Railroad Density	0	0	0	0	2,074
nonpt	300	NLCD Low Intensity Development	155	2,315	12,856	180	21,920
nonpt	306	NLCD Med + High	17,326	232,474	346,115	65,183	130,101
nonpt	307	NLCD All Development	0	0	0	0	19
nonpt	308	NLCD Low + Med + High	1,065	176,160	18,615	5,173	10,906
nonpt	310	NLCD Total Agriculture	517	311	504	31	440
nonpt	319	NLCD Crop Land	0	0	95	70	292
nonpt	320	NLCD Forest Land	0	0	3	0	3
nonpt	650	Refineries and Tank Farms	0	0	0	0	98,366
nonpt	711	Airport Areas	0	0	0	0	414
nonpt	801	Port Areas	0	0	0	0	2,351
nonpt	900	OSM Fuel	0	0	0	0	221,575
nonpt	4011	FAO 2010 Large Cattle Operations	0	0	0	0	295,993

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
nonroad	0	Area-to-point spatial allocation	3	1,383	23	1	32
nonroad	136	Single and Dual Unit Housing	100	14,573	2,944	54	91,727
nonroad	261	NTAD Total Railroad Density	3	1,484	146	1	315
nonroad	304	NLCD Open + Low	6	1,583	140	4	5,597
nonroad	305	NLCD Low + Med	5	867	1,027	3	21,964
nonroad	306	NLCD Med + High	387	155,576	8,687	279	100,475
nonroad	307	NLCD All Development	113	28,655	16,188	59	185,682
nonroad	308	NLCD Low + Med + High	597	202,042	16,433	235	41,447
nonroad	309	NLCD Open + Low + Med	134	21,884	1,309	74	51,247
nonroad	310	NLCD Total Agriculture	355	214,915	14,943	159	23,336
nonroad	320	NLCD Forest Land	15	1,614	378	7	3,427
nonroad	321	NLCD Recreational Land	81	13,823	5,085	40	184,608
nonroad	350	NLCD Water	203	111,414	3,862	111	221,945
nonroad	850	Golf Courses	14	2,144	124	7	6,091
nonroad	860	Mines	2	2,316	210	1	423
np_oilgas	670	Spud Count - CBM Wells	0	0	0	0	43
np_oilgas	671	Spud Count - Gas Wells	0	0	0	0	2,273
np_oilgas	674	Unconventional Well Completion Counts	13	14,496	190	5	875
np_oilgas	678	Completions at Gas Wells	0	6,076	130	1,743	14,312
np_oilgas	679	Completions at CBM Wells	0	5	0	226	694
np_oilgas	681	Spud Count - Oil Wells	0	1	0	0	28,932
np_oilgas	683	Produced Water at All Wells	0	434	0	0	2,585
np_oilgas	685	Completions at Oil Wells	0	368	0	2,218	33,258
np_oilgas	687	Feet Drilled at All Wells	0	24,786	656	13	1,014
np_oilgas	689	Gas Produced - Total	0	276	26	2	53,069
np_oilgas	691	Well Counts - CBM Wells	0	19,717	321	7	15,442
np_oilgas	692	Spud Count - All Wells	0	15	1	1	1
np_oilgas	694	Oil Production at Oil Wells	0	3,428	0	31,091	801,359
np_oilgas	695	Well Count - Oil Wells	0	170,235	4,244	243,871	668,732
np_oilgas	696	Gas Production at Gas Wells	0	2,689	2	0	396,590
np_oilgas	698	Well Count - Gas Wells	0	349,563	5,007	155	459,387
np_oilgas	699	Gas Production at CBM Wells	0	33	4	0	3,829
np_oilgas	6694	All Abandoned Oil Wells - Plugged	0	0	0	0	115
np_oilgas	6695	All Abandoned Gas Wells - Plugged	0	0	0	0	64
np_oilgas	6697	All Abandoned Oil Wells - Unplugged	0	0	0	0	166,197
np_oilgas	6698	All Abandoned Gas Wells - Unplugged	0	0	0	0	14,255
np_oilgas	6831	Produced water at CBM wells	0	0	0	0	1,025
np_oilgas	6832	Produced water at gas wells	0	3	0	0	10,257
np_oilgas	6833	Produced water at oil wells	0	0	0	0	40,687
np_solvents	100	Population	0	0	0	0	1,376,197
np_solvents	240	Total Road Miles	0	0	0	0	43,466
np_solvents	306	NLCD Med + High	0	0	0	0	391,245
np_solvents	307	NLCD All Development	0	0	0	0	235,011

Sector	ID	Description	NH3	NOX	PM2_5	SO2	VOC
np_solvents	308	NLCD Low + Med + High	0	0	0	0	31,056
np_solvents	310	NLCD Total Agriculture	0	0	0	0	173,739
np_solvents	901	OSM Asphalt Surfaces	0	0	0	0	339,732
openburn	135	Detached Housing	0	16,203	80,344	2,698	18,784
openburn	300	NLCD Low Intensity Development	2,704	1,113	4,159	226	4,514
openburn	307	NLCD All Development	76,463	28,172	126,918	10,917	81,324
onroad	205	Extended Idle Locations	7	28,995	202	15	2,453
onroad	242	All Restricted AADT	71,490	874,793	28,295	4,371	197,694
onroad	244	All Unrestricted AADT	109,981	1,056,368	46,549	6,439	303,918
onroad	259	Transit Bus Terminals	7	2,263	37	1	231
onroad	304	NLCD Open + Low		467	13	0	2,466
onroad	306	NLCD Med + High	1,255	106,083	2,248	83	24,305
onroad	307	NLCD All Development	6,042	163,308	7,255	636	587,182
onroad	308	NLCD Low + Med + High	271	15,888	486	37	27,628
onroad	508	Public Schools	16	1,624	48	1	323
rail	261	NTAD Total Railroad Density	16	26,427	763	18	1,249
rail	271	NTAD Class 1 2 3 Railroad Density	287	430,178	10,685	324	17,539
rwc	111	All Residential Structures	3,321	7,677	55,925	847	49,969
rwc	112	Single Family + Manufactured + small Multi-family Residential Structures	15,603	26,108	273,568	7,478	397,651
rwc	113	Single Family Residential Structures	2,999	2,442	109,712	3,579	116,538

3.4.2 Area-to-point spatial allocation (nonpt, nonroad)

The NEI contains numerous airport-related emission sources, such as aircraft, airport ground support equipment, and jet refueling. The modeling platform includes the aircraft and airport ground support equipment emissions in the airports sector as point sources. Some airport-related emissions are included in the nonpt sector as area sources, specifically, SCCs 2501080050 and 2501080100 (petroleum storage at airports), and 2810040000 (aircraft/rocket engine firing and testing). For the modeling platform, the EPA used the SMOKE "area-to-point" approach for these nonpt sector SCCs. The ARTOPNT file that lists the nonpoint sources to locate using point data was unchanged from the 2005-based platform.

In the nonroad sector, 2022v2 platform contains emissions representing emissions from offroad diesel trucks at mines in St. Louis County, Minnesota, as SCC 2270002051. These emissions were spatially allocated using an ARTOPNT file containing the locations of mines throughout St. Louis County.

3.4.3 Surrogates for Canada and Mexico emission inventories

The surrogates for Canada to spatially allocate the Canadian emissions are based on the 2020 Canadian inventories and associated data. The spatial surrogate data came from ECCC, along with cross references. The shapefiles they provided were used in the Surrogate Tool (previously referenced) to create spatial surrogates. The Canadian surrogates used for this platform are listed in Table 3-20. The Canadian surrogates were the same for the 2022v1 and 2022v2 platforms. The Shapefiles used to compute these surrogates and some configuration information are shown in Table 3-21. Note that the name of most Data Shapefiles have been abbreviated to shorten the table. The complete names and additional details on surrogate computation for Canada and Mexico are available in the file *Surrogate_specifications_2022v2_platform_US_Can_Mex.xlsx* that is posted in the reports folder for this platform.

Mexico surrogates were updated for the 2021 EMP. The data source for the Mexico population surrogate is the INEGI National Geostatistical Framework's Censo de Población y Vivienda 2020 based on the 2020 GPW v4 (see https://en.www.inegi.org.mx/app/biblioteca/ficha.html?upc=889463807469). Other data sources used are Sistema Nacional de Informacion Estadistic y Geografica (SNIEG), US Department of Transportation's (DOT) North American Rail Network Lines, and US DOT's Bureau of Transportation Statistics Border Crossing Data. The Shapefiles and some configuration information used to develop the Mexico surrogates are shown in Table 3-22. The Data Shapefile for all Mexico surrogates is areas_geoestadisticas_municipales_II and the Data Attribute is FIPS. Most of the CAP emissions allocated to the Mexico and Canada surrogates are shown in Table 3-23.

During the development of 2022v2 EMP it was discovered that there was a surrogate data duplication issue that affected 2022v1 EMP. The error resulted in Mexico surrogate "MEX Commercial plus Industrial Land" using the same dataset as "MEX Total Agriculture" resulting in identical surrogates. The duplication issue was resolved by updating the commercial land surrogate with the appropriate dataset.

Table 3-20. Canadian spatial surrogates

Code	Canadian Surrogate Description	Code	Description
100	Population	925	Manufacturing and Assembly
101	total dwelling	926	Distribution and Retail (no petroleum)
102	*urban dwelling*	927	Commercial Services
103	*rural dwelling*	933	Rail-Passenger
104	capped total dwelling	934	Rail-Freight
105	*capped meat cooking dwelling*	935	Rail-Yard
106	ALL_INDUST	940	PAVED ROADS NEW
113	Forestry and logging	*945*	*Commercial Marine Vessels*
116	*Total Resources*	946	Construction and mining
200	Urban Primary Road Miles	*948*	*Forest*
210	Rural Primary Road Miles	*949*	*Combination of Dwelling*
211	*Oil and Gas Extraction*	951	Wood Consumption Percentage
212	Mining except oil and gas	*952*	*Residential Fuel Wood Combustion (PIRD)*
220	Urban Secondary Road Miles	955	UNPAVED_ROADS_AND_TRAILS
221	Total Mining	*960*	*TOTBEEF*
222	Utilities	961	80110_Broilers
230	Rural Secondary Road Miles	962	80111_Cattle_dairy_and_Heifer
233	*Total Land Development*	963	80112_Cattle_non-Dairy
240	capped population	964	80113_Laying_hens_and_Pullets
308	Food manufacturing	965	80114_Horses
321	Wood product manufacturing	966	80115_Sheep_and_Lamb
323	Printing and related support activities	967	80116_Swine
324	Petroleum and coal products manufacturing	968	80117_Turkeys

Code	Canadian Surrogate Description	Code	Description
326	Plastics and rubber products manufacturing	969	80118_Goat
327	Non-metallic mineral product manufacturing	*970*	*TOTPOUL*
331	Primary Metal Manufacturing	971	80119_Buffalo
340	*Construction - Oil and Gas*	972	80120_Llama_and_Alpacas
350	*Water*	973	80121_Deer
412	Petroleum product wholesaler-distributors	974	80122_Elk
448	clothing and clothing accessories stores	975	80123_Wild boars
562	Waste management and remediation services	976	80124_Rabbit
601	SCL:12003 Petroleum Liquids Transportation (PIRD)	977	80125_Mink
602	SCL:12007 Oil Sands In-Situ Extraction and Processing (PIRD)	978	80126_Fox
603	SCL:12010 Light Medium Crude Oil Production (PIRD)	*980*	*TOTSWIN*
604	SCL:12011 Well Drilling (PIRD)	981	Harvest_Annual
605	SCL:12012 Well Servicing (PIRD)	*982*	*Harvest_Perennial*
606	SCL:12013 Well Testing (PIRD)	983	Synthfert_Annual
607	SCL:12014 Natural Gas Production (PIRD)	*984*	*Synthfert_Perennial*
608	SCL:12015 Natural Gas Processing (PIRD)	985	Tillage_Annual
609	*SCL:12016 Heavy Crude Oil Cold Production (PIRD)*	*990*	*TOTFERT*
610	*SCL:12018 Disposal and Waste Treatment (PIRD)*	996	urban_area
611	SCL:12019 Accidents and Equipment Failures (PIRD)	1251	OFFR_TOTFERT
612	SCL:12020 Natural Gas Transmission and Storage (PIRD)	1252	OFFR_MINES
651	*MEIT C1C2 Anchored*	1253	OFFR Other Construction not Urban
652	*MEIT C1C2 Underway*	1254	OFFR Commercial Services
653	*MEIT C1C2 Berthed*	1255	OFFR Oil Sands Mines
661	*MEIT C3 Anchored*	1256	OFFR Wood industries CANVEC
662	*MEIT C3 Underway*	1257	OFFR UNPAVED ROADS RURAL
663	*MEIT C3 Berthed*	1258	OFFR_Utilities
901	AIRPORT	1259	OFFR total dwelling
902	*Military LTO*	1260	OFFR_water
903	*Commercial LTO*	1261	OFFR_ALL_INDUST
904	*General Aviation LTO*	1262	OFFR Oil and Gas Extraction
905	*Air Taxi LTO*	1263	OFFR_ALLROADS
921	Commercial Fuel Combustion	*1264*	*OFFR_AIRPORT*
923	TOTAL INSTITUTIONAL AND GOVERNEMNT	1265	OFFR_RAILWAY
924	Primary Industry		

Table 3-21. Shapefiles and attributes used to compute Canadian spatial surrogates

Code	Surrogate	Data Shapefile	Data Attribute	Weight Shapefile	Weight Attribute
100	Population	gpr_gda	pruid	da_popdwell_100m_nolakes_1nov17	Pop
101	total dwelling	gpr_gda	pruid	da_popdwell_100m_nolakes_1nov17	Urdwell
102	urban dwelling	gpr_gda	pruid	da_popdwell_100m_nolakes_1nov17	Uadwell
103	rural dwelling	gpr_gda	pruid	da_popdwell_100m_nolakes_1nov17	Radwell
104	capped total dwelling	gpr_gda	pruid	da_popdwell_100m_nolakes_1nov17	CAP_URDWEL
105	capped meat cooking dwelling	gpr	pruid	da_SimP_100m_pop_dwell_jul2014	Cap_Dwell
106	ALL_INDUST	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	ALL_INDUST
111	Farms	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	FARMS
113	Forestry and logging	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	FORLOG
116	Total Resources	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	TOTRESOURC
1251	OFFR_TOTFERT	gcd	CDID	naesi_fert	TOTFERT
1252	OFFR_MINES	gcd	CDID	mine	MINES
1253	OFFR Other Construction not Urban	gcd	CDID	construction_other	TOTAL
1254	OFFR Commercial Services	gcd	CDID	da2006_pop_labour_SimP_MaxOff_100m_noLake	COMSER
1255	OFFR Oil Sands Mines	gcd	CDID	OS_MinePit_D_v2	
1256	OFFR Wood industries CANVEC	gcd	CDID	wood_industries	WOOD
1257	OFFR UNPAVED ROADS RURAL	gcd	CDID	unpaved_ur	
1258	OFFR_Utilities	gcd	CDID	da2006_pop_labour_SimP_MaxOff_100m_noLake	UTILITIES
1259	OFFR total dwelling	gcd	CDID	da2006_pop_labour_SimP_MaxOff_100m_noLake	DATDWELL20
1260	OFFR_water	gcd	CDID	lu100_valid	
1261	OFFR_ALL_INDUST	gcd	CDID	da2006_pop_labour_SimP_MaxOff_100m_noLake	ALL_INDUST
1262	OFFR Oil and Gas Extraction	gcd	CDID	da2006_pop_labour_SimP_MaxOff_100m_noLake	OILGASEXTR
1263	OFFR_ALLROADS	gcd	CDID	allroads	
1264	OFFR_AIRPORT	gcd	CDID	offroad_osm_airport_locs_spring2017	Movements
1265	OFFR_RAILWAY	gcd	CDID	shp_railway_canvec_jul17_v2	LENGTH
200	Urban Primary Road Miles	gcd_ON4	CDID	NRN_CA_Simp2_16Apr2016_sphere	Class1
210	Rural Primary Road Miles	gcd_ON4	CDID	NRN_CA_Simp2_16Apr2016_sphere	Class2
211	Oil and Gas Extraction	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	OILGASEXTR
212	Mining except oil and gas	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	MINING2
215	Oil Sands Mines	prov2006	pruid	OS_MinePit_D_v2	
216	Oil Sands Tailing Ponds	prov2006	pruid	OS_WetTailing_D_2015	
217	Oil Sands Plants	prov2006	Pruid	OS_PlantSite_D_2015	
220	Urban Secondary Road Miles	gcd_ON4	CDID	NRN_CA_Simp2_16Apr2016_sphere	Class3

Code	Surrogate	Data Shapefile	Data Attribute	Weight Shapefile	Weight Attribute
221	Total Mining	prov2006	Pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	TOTALMI3
222	Utilities	prov2006	Pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	UTILITIES
230	Rural Secondary Road Miles	gcd_ON4	CDID	NRN_CA_Simp2_16Apr2016_sphere	Class4
233	Total Land Development	prov2006	Pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	TOTLND
240	capped population	gcd_ON4	CDID	da_popdwell_100m_nolakes_1nov17	CAPURPOP
308	Food manufacturing	prov2006	Pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	FOODMANU
321	Wood product manufacturing	prov2006	Pruid	da2006_SimplifyP_250m_sphere_treesa_Clip	WOODMANU
323	Printing and related support activities	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	PRINTSUPRT
324	Petroleum and coal products manufacturing	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	PETCOLMANU
326	Plastics and rubber products manufacturing	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	PLASTCMANU
327	Non-metallic mineral product manufacturing	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	MINERLMANU
331	Primary Metal Manufacturing	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	METALMANU
340	Construction - Oil and Gas	gpr_gda	pruid	loc_land_UOG2015_CO_v3_Que_NB_NS	
350	Water	coast	pruid	CONT42_pop_water_Clip_b	Pop
412	Petroleum product wholesaler-distributors	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	PETPRWSL
416	Building material and supplies wholesaler-distributors	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	BUILDPRWSL
447	Gasoline stations	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	GASSTOR
448	clothing and clothing accessories stores	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	CLOTHSTOR
482	Rail transportation	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	RAILTRANS
562	Waste management and remediation services	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	WASTEMGMT
901	AIRPORT	gcd	CDID	offroad_osm_airport_locs_spring2017	Movements
902	Military LTO	surg_2017	FAKEFIPS	aviation_runways_spring2017	Military
903	Commercial LTO	surg_2017	FAKEFIPS	aviation_runways_spring2017	Commercial
904	General Aviation LTO	surg_2017	FAKEFIPS	aviation_runways_spring2017	General_Av
905	Air Taxi LTO	prov2006	pruid	Airport_movements_2006_MultiRingBuffer	SCC2275060
921	Commercial Fuel Combustion	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	COMFUEL
923	TOTAL INSTITUTIONAL AND GOVERNEMNT	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	TOTINSTGOV
924	Primary Industry	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	PRIM1

Code	Surrogate	Data Shapefile	Data Attribute	Weight Shapefile	Weight Attribute
925	Manufacturing and Assembly	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	MANASSEM
926	Distribution and Retail (no petroleum)	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	DISRET
927	Commercial Services	prov2006	pruid	da2006_pop_labour_SimP_MaxOff_100m_noLake	COMSER
933	Rail-Passenger	gpr_gda	pruid	shp_railway_canvec_jul17_v2	Passenger
934	Rail-Freight	gpr_gda	pruid	shp_railway_canvec_jul17_v2	Fret
935	Rail-Yard	gpr_gda	pruid	shp_railway_canvec_jul17_v2	Yard
940	PAVED ROADS NEW	gpr	fips	NRN_CA_Simp2_16Apr2016_sphere	PAVEDRD
942	UNPAVED ROADS	prov2006	pruid	unpaved4	
945	Commercial Marine Vessels	lowmedjet_ll	CLASS	marine	SO2
946	Construction and mining			MERGE: 0.5*Mining except oil and gas+0.5*Total Land Development	
947	Agriculture Construction and mining			MERGE 0.34*Total Resources + 0.66 * Construction and mining	
948	Forest	prov2006	pruid	treesa_valid	
949	Combination of Dwelling			MERGE: 0.20*urban dwelling+0.80* rural dwelling	
951	Wood Consumption Percentage	gpr	fips	da2006_SimP_100m_WoodCon_1Aug14	WoodComp
955	UNPAVED_ROADS_AND_TRAILS	prov2006	pruid	unpaved5	
960	TOTBEEF	prov2006	pruid	naesi_livestk	TOTBEEF
970	TOTPOUL	prov2006	pruid	naesi_livestk	TOTPOULT
980	TOTSWIN	prov2006	pruid	naesi_livestk	TOTSWINE
990	TOTFERT	prov2006	pruid	naesi_fert	TOTFERT
996	urban_area	prov2006	pruid	ua2001	
961	80110_Broilers	gpr_gda	pruid	animal_nh3_to_agri_slc_80110_valid	QUANTITY
962	80111_Cattle_dairy_and_Heifer	gpr_gda	pruid	animal_nh3_to_agri_slc_80111_valid	QUANTITY
963	80112_Cattle_non-Dairy	gpr_gda	pruid	animal_nh3_to_agri_slc_80112_valid	QUANTITY
964	80113_Laying_hens_and_Pullets	gpr_gda	pruid	animal_nh3_to_agri_slc_80113_valid	QUANTITY
965	80114_Horses	gpr_gda	pruid	animal_nh3_to_agri_slc_80114_valid	QUANTITY
966	80115_Sheep_and_Lamb	gpr_gda	pruid	animal_nh3_to_agri_slc_80115_valid	QUANTITY
967	80116_Swine	gpr_gda	pruid	animal_nh3_to_agri_slc_80116_valid	QUANTITY
968	80117_Turkeys	gpr_gda	pruid	animal_nh3_to_agri_slc_80117_valid	QUANTITY
969	80118_Goat	gpr_gda	pruid	animal_nh3_to_agri_slc_80118_valid	QUANTITY
971	80119_Buffalo	gpr_gda	pruid	animal_nh3_to_agri_slc_80119_valid	QUANTITY
972	80120_Llama_and_Alpacas	gpr_gda	pruid	animal_nh3_to_agri_slc_80120_valid	QUANTITY
973	80121_Deer	gpr_gda	pruid	animal_nh3_to_agri_slc_80121_valid	QUANTITY
974	80122_Elk	gpr_gda	pruid	animal_nh3_to_agri_slc_80122_valid	QUANTITY
975	80123_Wild boars	gpr_gda	pruid	animal_nh3_to_agri_slc_80123_valid	QUANTITY
976	80124_Rabbit	gpr_gda	pruid	animal_nh3_to_agri_slc_80124_valid	QUANTITY

Code	Surrogate	Data Shapefile	Data Attribute	Weight Shapefile	Weight Attribute
977	80125_Mink	gpr_gda	pruid	animal_nh3_to_agri_slc_80125_valid	QUANTITY
978	80126_Fox	gpr_gda	pruid	animal_nh3_to_agri_slc_80126_valid	QUANTITY
979	80127_Mules_and_Asses	gpr_gda	pruid	animal_nh3_to_agri_slc_80127_valid	QUANTITY
981	Harvest_Annual	gpr_gda	pruid	harvest_pm10_Annual_to_agri_slc_valid	QUANTITY
982	Harvest_Perennial	gpr_gda	pruid	harvest_pm10_Perennial_to_agri_slc_valid	QUANTITY
983	Synthfert_Annual	gpr_gda	pruid	synth_fert_nh3_Annual_to_agri_slc_valid	QUANTITY
984	Synthfert_Perennial	gpr_gda	pruid	synth_fert_nh3_Perennial_to_agri_slc_valid	QUANTITY
985	Tillage_Annual	gpr_gda	pruid	tillage_pm10_Annual_to_agri_slc_valid	QUANTITY
601	SCL:12003 Petroleum Liquids Transportation (PIRD)	gpr_gda	pruid	scl12003_valid	
602	SCL:12007 Oil Sands In-Situ Extraction and Processing (PIRD)	gpr_gda	pruid	scl12007_valid	NONE
603	SCL:12010 Light Medium Crude Oil Production (PIRD)	gpr_gda	pruid	scl12010_valid	NONE
604	SCL:12011 Well Drilling (PIRD)	gpr_gda	pruid	scl12011_valid	NONE
605	SCL:12012 Well Servicing (PIRD)	gpr_gda	pruid	scl12012_valid	NONE
606	SCL:12013 Well Testing (PIRD)	gpr_gda	pruid	scl12013_valid	NONE
607	SCL:12014 Natural Gas Production (PIRD)	gpr_gda	pruid	scl12014_valid	NONE
608	SCL:12015 Natural Gas Processing (PIRD)	gpr_gda	pruid	scl12015_valid	NONE
609	SCL:12016 Heavy Crude Oil Cold Production (PIRD)	gpr_gda	pruid	scl12016_valid	NONE
610	SCL:12018 Disposal and Waste Treatment (PIRD)	gpr_gda	pruid	scl12018_valid	NONE
611	SCL:12019 Accidents and Equipment Failures (PIRD)	gpr_gda	pruid	scl12019_valid	NONE
612	SCL:12020 Natural Gas Transmission and Storage (PIRD)	gpr_gda	pruid	scl12020	NONE
952	Residential Fuel Wood Combustion (PIRD)	gpr_gda	pruid	scl20401_valid	NONE
651	MEIT C1C2 Anchored	lowmedjet_ll	CLASS	MEIT_2280002101_2018	Fuel
652	MEIT C1C2 Underway	lowmedjet_ll	CLASS	MEIT_2280002202_2018	Fuel
653	MEIT C1C2 Berthed	lowmedjet_ll	CLASS	MEIT_2280002301_2018	Fuel
661	MEIT C3 Anchored	lowmedjet_ll	CLASS	MEIT_2280003101_2018	Fuel
662	MEIT C3 Underway	lowmedjet_ll	CLASS	MEIT_2280003200_2018	Fuel
663	MEIT C3 Berthed	lowmedjet_ll	CLASS	MEIT_2280003301_2018	Fuel

Table 3-22. Shapefiles and attributes used to compute Mexican spatial surrogates

Code	SURROGATE	WEIGHT SHAPEFILE	WEIGHT ATTRIBUTE
11	MEX Population	mex_population_2020	gridcode_Y
22	MEX Total Road Miles	mex_roadways	NONE
24	MEX Total Railroads Miles	mex_railroads	NONE
26	MEX Total Agriculture	mex_agriculture	NONE
36	MEX Commercial plus Industrial Land	mex_com_ind_land	NONE
44	MEX Airports Area	mex_airports_area	NONE
45	MEX Airports Point	mex_airports_point	NONE
48	MEX Brick Kilns	mex_brick_kilns	NONE
50	MEX Border Crossings	mex_border_crossings	SUM_Value

Table 3-23. 2022v2 CAP emissions allocated to Mexican and Canadian spatial surrogates for 12US1 (short tons)

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	$PM_{2.5}$	SO_2	VOC
11	MEX Population	31,796	64,550	8,670	14,350	141,272
22	MEX Total Road Miles	3,154	519,098	26,957	3,640	234,111
24	MEX Total Railroads Miles	0	22,953	513	200	929
26	MEX Total Agriculture	154,058	10,264	13,732	31,306	2,234
36	MEX Commercial plus Industrial Land	37	24,223	2,577	37	302,503
44	MEX Airports Area	0	2,751	58	318	1,729
48	MEX Brick Kilns	0	215	3,115	26	206
50	MEX Border Crossings	4	86	3	0	65
100	CAN Population	710	57	225	17	4,025
101	CAN total dwelling	0	0	0	0	109,016
104	CAN capped total dwelling	305	31,578	2,383	1,928	1,620
106	CAN ALL_INDUST	0	0	596	0	0
113	CAN Forestry and logging	83	627	2,934	15	2,717
200	CAN Urban Primary Road Miles	1,590	75,668	2,697	209	7,406
210	CAN Rural Primary Road Miles	608	40,578	1,422	89	2,995
212	CAN Mining except oil and gas	0	0	1,785	0	0
220	CAN Urban Secondary Road Miles	2,985	120,376	5,476	406	19,742
221	CAN Total Mining	0	0	13,564	0	0
222	CAN Utilities	0	1,998	2,751	32	89
230	CAN Rural Secondary Road Miles	1,613	75,161	2,728	211	7,997
240	CAN capped population	345	45,969	1,175	41	82,324
308	CAN Food manufacturing	0	0	17,199	0	5,233
321	CAN Wood product manufacturing	513	1,677	591	213	8,464
323	CAN Printing and related support activities	0	0	0	0	20,852
324	CAN Petroleum and coal products manufacturing	0	1,056	1,481	439	6,751

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	$PM_{2.5}$	SO_2	VOC
326	CAN Plastics and rubber products manufacturing	0	0	0	0	21,858
327	CAN Non-metallic mineral product manufacturing	0	0	7,206	0	0
331	CAN Primary Metal Manufacturing	0	148	5,247	28	62
412	CAN Petroleum product wholesaler-distributors	0	0	0	0	37,775
448	CAN clothing and clothing accessories stores	0	0	0	0	178
562	CAN Waste management and remediation services	2,707	1,230	2,300	2,159	16,100
601	CAN SCL:12003 Petroleum Liquids Transportation (PIRD)	0	0	12	154	6,042
602	CAN SCL:12007 Oil Sands In-Situ Extraction and Processing (PIRD)	0	0	0	0	110
603	CAN SCL:12010 Light Medium Crude Oil Production (PIRD)	0	0	0	0	2
604	CAN SCL:12011 Well Drilling (PIRD)	0	0	0	607	658
605	CAN SCL:12012 Well Servicing (PIRD)	0	0	0	68	73
606	CAN SCL:12013 Well Testing (PIRD)	0	0	0	0	0
607	CAN SCL:12014 Natural Gas Production (PIRD)	0	28	1	0	191
608	CAN SCL:12015 Natural Gas Processing (PIRD)	0	0	0	0	0
611	CAN SCL:12019 Accidents and Equipment Failures (PIRD)	0	0	0	0	90,229
612	CAN SCL:12020 Natural Gas Transmission and Storage (PIRD)	1	671	54	11	396
901	CAN AIRPORT	0	98	9	0	11
921	CAN Commercial Fuel Combustion	190	21,587	2,373	435	940
923	CAN TOTAL INSTITUTIONAL AND GOVERNEMNT	0	0	0	0	14,522
924	CAN Primary Industry	0	0	0	0	33,308
925	CAN Manufacturing and Assembly	0	0	0	0	70,606
926	CAN Distribution and Retail (no petroleum)	0	0	0	0	6,666
927	CAN Commercial Services	0	0	0	0	30,828
933	CAN Rail-Passenger	1	3,089	63	1	115
934	CAN Rail-Freight	48	76,567	1,530	43	3,389
935	CAN Rail-Yard	1	4,536	95	1	276
940	CAN PAVED ROADS NEW	0	0	26,017	0	0
946	CAN Construction and mining	44	2,842	163	281	41
951	CAN Wood Consumption Percentage	1,061	11,794	71,798	1,685	100,154
955	CAN UNPAVED_ROADS_AND_TRAILS	0	0	433,847	0	0
961	CAN 80110_Broilers	13,453	0	115	0	12,782
962	CAN 80111_Cattle_dairy_and_Heifer	61,989	0	276	0	40,501
963	CAN 80112_Cattle_non-Dairy	177,740	0	884	0	42,860

Code	Mexican or Canadian Surrogate Description	NH_3	NO_X	$PM_{2.5}$	SO_2	VOC
964	CAN 80113_Laying_hens_and_Pullets	10,085	0	40	0	10,592
965	CAN 80114_Horses	3,155	0	19	0	1,320
966	CAN 80115_Sheep_and_Lamb	2,278	0	6	0	170
967	CAN 80116_Swine	64,225	0	824	0	9,945
968	CAN 80117_Turkeys	5,215	0	41	0	4,507
969	CAN 80118_Goat	1,806	0	2	0	135
971	CAN 80119_Buffalo	2,258	0	6	0	517
972	CAN 80120_Llama_and_Alpacas	118	0	0	0	0
973	CAN 80121_Deer	20	0	0	0	0
974	CAN 80122_Elk	19	0	0	0	0
975	CAN 80123_Wild boars	37	0	0	0	0
976	CAN 80124_Rabbit	78	0	0	0	1
977	CAN 80125_Mink	287	0	0	0	951
978	CAN 80126_Fox	4	0	0	0	3
981	CAN Harvest_Annual	0	0	24,824	0	0
983	CAN Synthfert_Annual	164,425	3,513	2,111	5,807	127
985	CAN Tillage_Annual	0	0	106,806	0	0
996	CAN urban_area	0	0	3,716	0	0
1251	CAN OFFR_TOTFERT	84	59,946	4,056	57	6,120
1252	CAN OFFR_MINES	1	573	40	1	81
1253	CAN OFFR Other Construction not Urban	68	37,617	4,378	46	10,431
1254	CAN OFFR Commercial Services	47	16,663	2,499	40	38,507
1255	CAN OFFR Oil Sands Mines	0	0	0	0	0
1256	CAN OFFR Wood industries CANVEC	9	3,245	257	7	944
1257	CAN OFFR UNPAVED ROADS RURAL	24	10,275	642	21	27,343
1258	CAN OFFR_Utilities	8	4,339	223	6	897
1259	CAN OFFR total dwelling	18	6,288	601	15	12,539
1260	CAN OFFR_water	17	4,785	371	26	24,782
1261	CAN OFFR_ALL_INDUST	4	5,218	183	2	918
1262	CAN OFFR Oil and Gas Extraction	1	378	31	0	123
1263	CAN OFFR_ALLROADS	3	1,753	169	2	463
1265	CAN OFFR_RAILWAY	0	64	6	0	12

4 Emission Summaries

Table 4-1 and Table 4-2 summarize base year emissions by sector for CAPs and key HAPs for the year 2022 in this platform. These summaries are provided at the national level by sector for the contiguous U.S. and for the portions of Canada and Mexico inside the larger 12km domain (12US1) discussed in Section 3.1. Note that totals for the 12US2 domain are not available here, but the sum of the U.S. sectors would be essentially the same and only the Canadian and Mexican emissions would change according to the extent of the grids to the north and south of the continental United States. The afdust sector emissions here represent the emissions *after* application of both the land use (transport fraction) and meteorological adjustments; therefore, this sector is called “afdust_adj” in these summaries. The onroad sector totals are post-SMOKE-MOVES totals, representing air quality model-ready emission totals, and include CARB emissions for California. The cmv sectors include U.S. emissions within state waters only within the 12US1 grid; 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. Canadian CMV emissions are included in the other sector. 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 2022 platform (https://gaftp.epa.gov/Air/emismod/2022/v1).

Table 4-1. National by-sector CAP emissions for the 2022v2 platform, year 2022, 12US1 grid (tons/yr)

Sector	CO	NH3	NOX	PM10	PM2_5	SO2	VOC
afdust_adj				6,081,020	848,604		
airports	370,488	0	116,833	9,085	8,065	11,982	43,814
cmv_c1c2	20,296	70	137,145	3,748	3,632	626	5,265
cmv_c3	10,207	32	84,352	1,833	1,686	4,141	4,676
fertilizer		1,671,402					
livestock		2,590,376					207,196
nonpt	766,248	68,690	708,532	447,173	384,613	73,091	932,300
nonroad	11,159,560	2,018	774,273	76,278	71,523	1,035	938,317
np_oilgas	692,990	13	592,126	10,643	10,580	279,331	2,714,995
np_solvents	0	0	0	0	0	0	2,590,447
onroad	15,274,967	189,098	2,250,203	174,154	85,148	11,583	1,146,496
openburn	1,392,576	79,167	45,489	231,096	211,421	13,841	104,621
ptegu	466,000	17,974	858,786	107,049	91,872	879,962	26,333
ptagfire	908,682	10,438	39,154	127,019	81,900	12,710	140,086
ptfire-rx	7,435,936	64,195	124,213	1,216,451	1,083,296	74,592	1,501,455
ptfire-wild	6,424,718	66,228	65,762	1,349,584	878,415	63,745	1,757,219
ptnonipm	1,200,410	60,747	746,130	342,134	221,433	419,249	730,056
ptnonipm_hr	4,998	259	26,180	2,260	2,086	15,291	366
pt_oilgas	180,631	9,324	327,205	13,434	12,765	32,087	208,830
rail	96,147	303	456,604	11,803	11,448	341	18,789
rwc	2,673,623	21,924	36,227	440,558	439,205	11,904	564,158
beis	3,376,155		964,950				30,694,065
CONUS w/beis	**52,454,632**	**4,852,258**	**8,354,165**	**10,645,323**	**4,447,692**	**1,905,513**	**44,329,483**
Canada ag		506,067		6,564	1,875		124,234
Canada oil and gas 2D		8					293,600
Canada afdust				975,005	183,021		
Canada ptdust				3,980	510		
Canada area	2,061,247	5,978	312,938	184,538	133,031	14,092	712,989
Canada onroad	1,715,237	7,135	357,211	25,404	13,469	955	120,229
Canada point	1,034,599	19,020	521,418	113,269	43,293	440,207	150,300
Canada fires	2,629,627	24,664	30,565	586,235	329,838	13,818	629,981
Canada cmv_c1c2	3,193	10	20,631	545	529	66	726
Canada cmv_c3	8,394	22	66,152	1,255	1,155	2,625	4,082
Mexico ag		154,055		49,130	10,481		0
Mexico area	90,001	31,840	58,056	49,183	23,626	46,201	389,436
Mexico onroad	2,492,380	3,154	585,916	32,570	21,503	3,671	293,471
Mexico point	160,373	948	214,134	92,310	55,240	365,114	32,702
Mexico fires	295,838	4,842	13,179	43,405	34,413	2,562	62,292
Mexico cmv_c1c2	199	1	1,296	35	34	7	50
Mexico cmv_c3	9,626	95	95,412	5,362	4,933	14,099	4,777
Offshore cmv_c1c2	4,864	15	31,122	822	797	123	1,148
Offshore cmv_c3	52,623	313	470,598	17,673	16,259	44,675	25,782
Offshore pt_oilgas	28,548	4	34,658	422	416	299	30,905

Table 4-2. National by-sector VOC HAP emissions for the 2022v2 platform, year 2022, 12US1 grid (tons/yr)

Sector	Acetaldehyde	Benzene	Formaldehyde	Methanol	Naphthalene	Acrolein	1,3-Butadiene
airports	1,629	726	4,714	682	724	927	660
cmv_c1c2	28	14	123	0	90	5	3
cmv_c3	25	12	109	0	80	5	3
livestock	1,479	473		13,699	0		
nonpt	9,218	2,406	5,116	14,564	427	31	326
nonroad	8,102	25,860	19,928	1,170	1,434	1,185	4,374
np_oilgas	3,001	32,853	53,390	2,504	94	2,440	520
np_solvents	73	336	7	13,782	7,807		
openburn	2,124	4,583	2,199	0	56	132	695
onroad	9,798	19,021	11,981	1,517	1,500	843	2,493
ptegu	268	294	2,151	96	29	204	2
ptagfire	11,522	2,125	8,668	0	0		1,050
ptfire-rx	60,166	19,851	119,616	87,162	17,696	24,998	15,540
ptfire-wild	50,045	14,589	90,570	92,239	17,284	15,292	7,773
ptnonipm	5,186	2,801	5,843	46,421	768	889	653
ptnonipm_hr	0	9	1	0	0	8	
pt_oilgas	2,919	2,117	12,407	1,910	82	1,911	261
rail	1,471	423	4,190	0	51	301	35
rwc	65,071	16,553	45,413	0	8,792	2,463	4,573
beis	374,228		513,183	2,110,685			
CONUS w/beis	**606,352**	**145,045**	**899,609**	**2,386,431**	**56,913**	**51,634**	**38,960**
Can. ag	1,398	159	0	32,657	0		
Can. oil & gas 2D	0	877	0	0	0		
Can. Area	15,252	12,725	12,871	4,082	2,589		
Can. Onroad	2,170	5,247	2,997	0	40		
Can. Point	1,543	1,986	5,262	10,627	26		
Can. Fires	22,007	5,953	44,136	49,594	7,291	6,703	3,548
Can. cmv_c1c2	4	2	17	0	12	1	0
Can. cmv_c3	22	11	95	0	70	4	2
Mex. Area	3,228	1,061	2,675	2,772	489		
Mex. Onroad	7,463	7,239	21,941	895	1,869	1,132	549
Mex. Point	63	1,214	2,460	476	10		
Mex. Fires	3,401	889	3,761	1,378	167	0	0
Mex. cmv_c1c2	0	0	1	0	1	0	0
Mex. cmv_c3	26	12	111	0	82	5	3
Off. cmv_c1c2	6	3	27	0	20	1	1
Off. cmv_c3	138	67	602	0	441	26	14
Off. pt_oilgas	248	41	595	0	0	0	0

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