

APPENDIX B
Modeling Emission Inventory for the
Ozone State Implementation Plan

**Modeling Emission Inventory for the Ozone State
Implementation Plan
August 2022**



Modeling Emission Inventory

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I. Acronyms

APCD – Air Pollution Control District

AQMD – Air Quality Management District

Caltrans – California Department of Transportation

CalVAD – California Vehicle Activity Database

CARB – California Air Resources Board

CCAQS – Central California Air Quality Studies

CCOS – Central California Ozone Study

CEIDARS – California Emission Inventory Development and Reporting System

CEMS – Continuous emissions monitoring system

CEPAM – California Emission Projection Analysis Model

CMAQ – Community Multi-Scale Air Quality

CRPAQS – California Regional PM10/PM25 Air Quality Study

EIC – Emission Inventory Code

EICSUM – EIC SUMmary category, the first three digits of EIC

ERG – Eastern Research Group

HD – Heavy Duty

I&M – Inspection and Maintenance

MPO – Metropolitan Planning Organization

NLCD – National Land Cover Database

NOx – Oxides of Nitrogen

OGV – Ocean Going Vessel

PM – Particulate Matter

PM10 – Particulate Matter 10 micrometers in diameter and smaller

PM2.5 – Particulate Matter 2.5 micrometers in diameter and smaller

ROG – Reactive Organic Gases

RRF – Relative Response Factor

RTPA – Regional Transportation Planning Agencies

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RWC – Residential Wood Combustion

SAPRC – Statewide Air Pollution Research Center

SCC – Source Classification Code

SIP – State Implementation Plan

SIPIWG – State Implementation Plan Inventory Working Group

SJV – San Joaquin Valley

SMOKE – Sparse Matrix Operator Kernel Emissions

SSS – State SIP Strategy

TOG – Total Organic Gases

II. Development of Ozone Emissions Inventories

Emission inputs for air quality modeling (commonly and interchangeably referred to as “modeling inventories” or “gridded inventories”) have been developed by the California Air Resources Board (CARB) and staff from multiple air districts. These inventories support multiple State Implementation Plans (SIP)s across California to address nonattainment of the federal ozone (O₃) standards. CARB maintains an electronic database of emissions and other useful information to generate aggregate emission estimates at the county, air basin, and district level, [Criteria Pollutant Emission Inventory Data](#). This database is called the California Emission Inventory Development and Reporting System (CEIDARS). CEIDARS provides a foundation for the development of a more refined (hourly, grid cell-specific) set of emission inputs that are required by air quality models. The CEIDARS base year inventory is a primary input to the state’s emission forecasting system, known as the California Emission Projection Analysis Model (CEPAM). CEPAM produces the projected emissions that are then processed to serve as the emission input for air quality models. The following sections of this document describe the methods used to prepare the base and future year emissions inventory estimates.

A. Inventory Coordination

Most of this inventory was developed in direct coordination with staff at the regional Air Pollution Control Districts across the state. In July of 2019 CARB convened the SIP Inventory Working Group (SIPIWG) to provide an opportunity and means for interested parties (CARB, districts, etc.) to discuss issues pertaining to the development and review of base year, future year, planning and gridded inventories to be used in SIP modeling. The group met every four to six weeks since convening into early 2020. Group participants included staff from Bay Area, Butte, Eastern Kern, El Dorado, Feather River, Imperial, Northern Sierra, Placer, Sacramento, San Diego, San Joaquin Valley, San Luis Obispo, South Coast, Ventura, and Yolo-Solano air districts.

Additionally, CARB established the SIPIWG Spatial Surrogate Sub-committee, which focuses on improving input data to spatially disaggregate emissions at a more refined level needed for air quality

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modeling. Local air districts that participate include San Joaquin Valley, San Diego, Bay Area, Imperial, South Coast, Ventura, and Sacramento.

A great deal of work preceded this modeling effort through the Central California Air Quality Studies (CCAQS). CCAQS consisted of two studies: 1) the Central California Ozone Study (CCOS); and 2) the California Regional PM₁₀ (particulate matter 10 μ m in diameter and smaller) /PM_{2.5} (particulate matter 2.5 μ m in diameter and smaller) Air Quality Study (CRPAQS).

B. Background

California's emission inventory is an estimate of the amounts and types of pollutants emitted from thousands of industrial facilities, millions of motor vehicles, and myriad emission sources such as consumer products and fireplaces. The development and maintenance of the emission inventory involves several agencies. This multi-agency effort includes: CARB, 35 local air pollution control and air quality management districts (Districts), regional transportation planning agencies (RTPAs), and the California Department of Transportation (Caltrans). CARB is responsible for the compilation of the final statewide emission inventory, and for maintaining this information in CEIDARS. In addition to the statewide emission inventory, emissions from northern Mexico and western United States (Nevada, Arizona, Oregon, Idaho, and Utah) are also incorporated in the final emission inventory used for modeling. The final emission inventory reflects the best information available at the time.

The basic principle for estimating county-wide regulatory emissions is to multiply an estimated, per-unit emission factor by an estimate of typical usage or activity. For example, on-road motor vehicle emission factors are estimated for a specific vehicle type and applied to all applicable vehicles. The estimates are based on dynamometer tests of a small sample for a vehicle type. The activity for any given vehicle type is based on an estimate of typical driving patterns, number of vehicle starts, and typical miles driven. Assumptions are also made regarding typical usage: it is assumed that all vehicles of a certain vehicle type are driven under similar conditions in each region of the state.

Developing emission estimates for stationary sources involves the use of per unit emission factors and activity levels. Under ideal conditions, facility-specific emission factors are determined from emission tests for a particular process at a facility. A continuous emission monitoring system (CEMS) can also be used to determine a gas or particulate matter concentration or emission rate (U.S. EPA, 2016). More commonly, a generic emission factor is developed by averaging the results of emission tests from similar processes at several different facilities. This generic factor is then used to estimate emissions from similar types of processes when a facility-specific emission factor is not available. Activity levels from stationary sources can be derived from the amount of product produced, solvent used, or fuel used.

The district-reported and CARB-estimated emissions totals are stored in the CEIDARS database for any given pollutant. Both criteria pollutants and their precursors are stored in this complex database. These are typically annual average emissions for each county, air basin, and district. Modeling inventories for reactive organic gases (ROG) are estimated from total organic gases (TOG). Similarly, the modeling inventories for PM₁₀ and PM_{2.5} are estimated from total particulate matter (PM). Details about chemical and size resolved speciation of emissions for modeling can be found in Section

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III.E. Additional information on CARB emission inventories can be found at [CARB Emission Inventory Activities](#).

C. Inventory Years

The emission inventory scenarios used for air quality modeling must be consistent with U.S. EPA's Modeling Guidance (U.S. EPA, 2014). Since changes in the emissions inventory can affect the calculation of the relative response factors (RRFs) used to project air quality to future years, the terms used in the preparation of the emission inventory scenarios must be clearly defined. In this document, the following inventory definitions will be used.

1. Base Case Modeling Inventory (2018)

Base case modeling is intended to evaluate model performance and demonstrate confidence in the modeling system used for the modeled attainment test. The base case modeling inventory is not used as part of the modeled attainment test itself. Model performance is assessed relative to how well model-simulated concentrations match actual measured concentrations. The modeling inputs are developed to represent (as best as possible) actual, day-specific conditions. Emissions for certain sectors are based on day-specific activities, meteorology, and emission adjustments. Actual district-reported point source emissions were gathered for the year 2017 and forecasted to 2018. The year 2018 was selected to coincide with the year selected for baseline design values (described below). The U.S. EPA modeling guidance states that once the model has been shown to perform adequately, the use of day-specific emissions is no longer needed. In preparation for SIP development, both CARB and the local air districts began a comprehensive review and update of the emission inventory resulting in a comprehensive emissions inventory for 2018.

2. Reference Year Modeling Inventory (2018)

The reference year inventory is intended to be a representation of emission patterns occurring through the baseline design value period and the emission patterns expected in the future year. U.S. EPA modeling guidance describes the reference year modeling inventory as "a common starting point" that represents average or "typical" conditions that are consistent with the baseline design value period. U.S. EPA guidance also states "using a 'typical' or average reference year inventory provides an appropriate platform for comparisons between baseline and future years." The 2018 reference year inventory represents typical average conditions and emission patterns through the 2018 design value period. This reference emissions inventory is not developed to capture all day-specific emission characteristics; however, this reference inventory does include meteorological effects for 2018 (e.g., temperature, relative humidity, and solar insolation), as well as certain day-specific emission activities, such as agricultural and prescribed burning.

3. Future Year Modeling Inventory (2026 and 2032)

Future year modeling inventories, along with the reference year modeling inventory, are used in the model-derived RRF calculation. Projected inventory year 2026 was chosen to address the modeled attainment year for the 8-hour 2008 ozone standard of 75 ppb. Projected inventory year 2032 was chosen to address the modeled attainment year for the 8 hour 2015 ozone standard of 70 ppb.

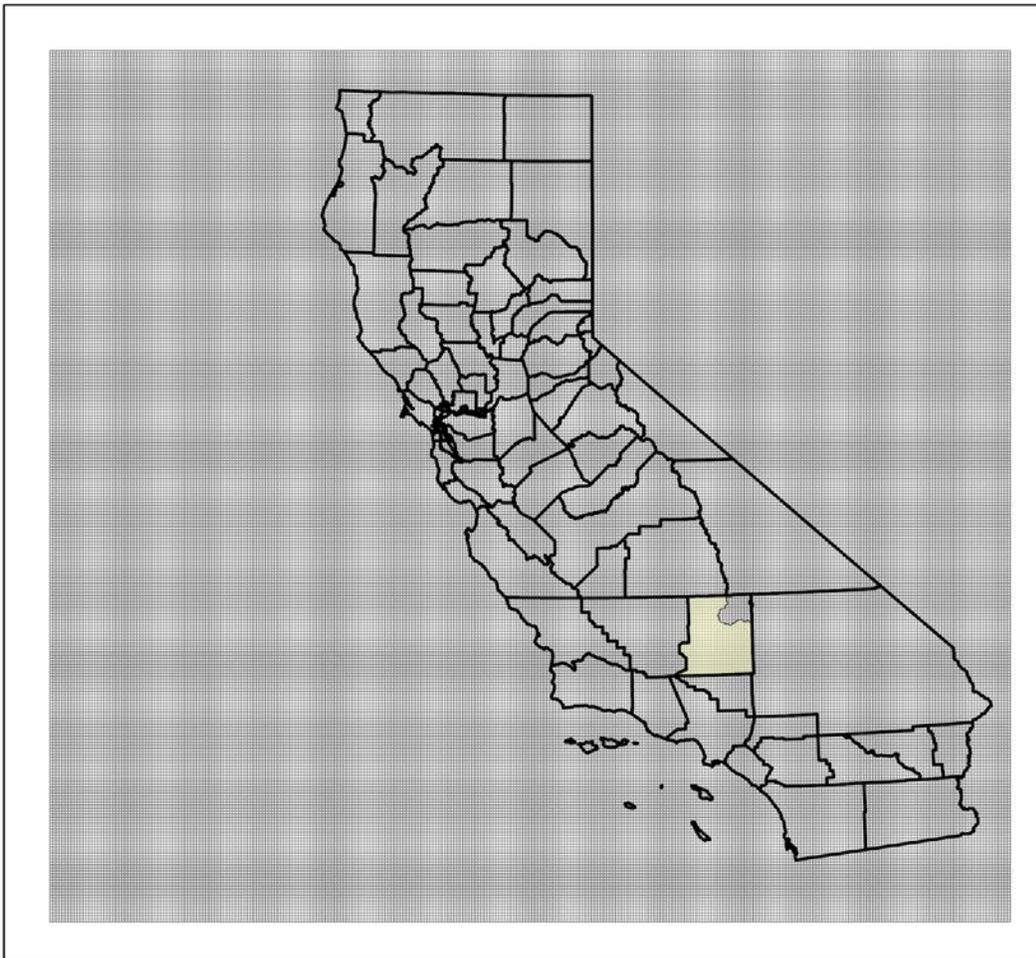
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These inventories maintain the “typical,” average patterns of the 2018 reference year modeling inventory. Some sectors of the 2026 and 2032 inventories include temporal variations that were driven by temperature, relative humidity, and solar insolation effects from reference year (2018) meteorology. Future year point and area source emissions are projected from the 2017 baseline emissions. Future year on-road emission inventories are used as projected by EMFAC.

D. Spatial Extent of Emission Inventories

The emissions model-ready files that are prepared for use as an input for the air quality model conform to the definition and extent of the grids shown in Figure 1. Figure 2 illustrates an enlarged image of the Eastern Kern Nonattainment area in Central California (highlighted in yellow) in the statewide 4 km modeling grid.

Figure 1. Spatial coverage of emissions grid with nonattainment area highlighted in yellow



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Figure 2: Eastern Kern Nonattainment area highlighted in Central California with statewide 4 km grid overlaid



The domain uses a Lambert projection and assumes a spherical Earth. The emissions inventory grid uses a Lambert Conical Projection with two parallels. The parallels are at 30° and 60° N latitude, with a central meridian at 120.5° W longitude. The coordinate system origin is offset to 37° N latitude. The emissions inventory is developed for the gridded statewide domain on a spatial resolution of 4 km x 4 km. The state modeling domain extends entirely over California and 100 nautical miles west over the Pacific Ocean. The specifications for the statewide modeling domain are summarized in Table 1.

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Table 1: Modeling domain parameters

| Parameter | Statewide domain |
|-------------------------------|-----------------------------|
| Map Projection | Lambert Conformal Conic |
| Datum | None (Clarke 1866 spheroid) |
| 1st Standard Parallel | 30.0° N |
| 2nd Standard Parallel | 60.0° N |
| Central Meridian | -120.5° W |
| Latitude of projection origin | 37.0° N |
| Coordinate system Units | Meters |
| Semi-major axis | 6370 km |
| Semi-minor axis | 6370 km |
| Grid size | 4 km x 4 km |
| Number of cells | 291 x 321 cells |
| Lambert origin | (-684,000 m, -564,000 m) |
| Geographic center | -120.5° Lat and 37.0° Lon |

III. Estimation of Base Year Modeling Inventory

As mentioned in Section I.C.1, base case modeling is intended to demonstrate confidence in the modeling system used for the modeled attainment test. The following sections describe the temporal and spatial distribution of emissions and how each of the sectors within the modeling inventories are prepared.

A. Terminology

The terms “point sources” and “area sources” are often confused. Traditionally, these terms have had different meanings to the developers of planning emissions inventories and the developers of modeling emissions inventories. Table 2 summarizes the difference in the terms as both sets of terms are used in this document. In modeling terminology, “point sources” traditionally refer to elevated emission sources that exit from a stack and have an associated plume rise. The current inventory

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includes emissions sources reported by the Air Pollution Control District (APCD). Those sources associated with a facility are treated as either elevated sources or non-elevated. The emissions processor calculates plume rise for elevated sources; non-elevated sources are treated as ground-level sources. Examples of non-elevated emissions sources include landfills and composting facilities. “Area sources” refers collectively to area-wide sources, stationary-aggregated sources, and other mobile sources (including aircraft, trains, ships, and all off-road vehicles and equipment). That is, “area sources” are low-level sources from a modeling perspective.

Table 2: Inventory terms for emission source types

| Modeling Term | Emission Inventory Term | Examples |
|------------------------|-------------------------------|---|
| Point | Stationary – Point Facilities | Stacks at Individual Facilities |
| Area | Off-road Mobile | Construction Equipment, Farm Equipment, Trains, Recreational Boats |
| Area | Area-wide | Residential Fuel Combustion, Livestock Waste, Consumer Products, Architectural Coatings |
| Area | Stationary - Aggregated | Industrial Fuel Use |
| On-road Motor Vehicles | On-road Mobile | Cars and Trucks |
| Biogenic | Biogenic | Trees |

The following sections describe in more detail the temporal, spatial, and chemical disaggregation of the emissions inventory for point sources and area sources.

B. Emissions Inventory

Modeling emissions are based on the CEPAM inventories for the base year and future year. Since the modeling inventory was processed in parallel to the application of updates to CEPAM the modeling inventory was patched from CEPAM 2019 v1.03 for the following source sectors:

- Off-Road SORE rule as adopted by the Board December 2021
- Cargo Handling Equipment (CHE)
- Construction “In Use” Equipment
- Large Spark Ignition (LSI) Forklifts
- Forestry Equipment
- Industrial/Military Rail
- Additional adjustments for GSE in South Coast

The resulting modeling inventory matches totals from CEPAM 2019 v1.04.

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C. Temporal Distribution of Emissions

The emissions are temporally resolved by month, week, day, and hour to more accurately gauge model performance and ultimately better assess the influence of control measures on attainment. This section covers the temporal distributions of the point, area, and off-road mobile sources. The temporal distribution of the emissions from on-road, biogenic, and ocean-going vessel (OGV) sources are discussed in Sections IV.B, IV.C, and IV.E. The temporal distribution of residential wood combustion (RWC) and agricultural ammonia sectors are described in Section IV.F.4 and Section IV.F.5, respectively.

Temporal data are stored in CARB’s emission inventory database. Each local air district assigns temporal data for all processes at each facility in their district to represent when emissions at each process occur. For example, emissions from degreasing may operate differently than a boiler. CARB or district staff also assign temporal data for each area source category by county/air basin/district.

1. Monthly Variation

Emissions are adjusted temporally to represent variations by month. Some emission sources operate the same throughout a year. For example, a process heater at a refinery or a line-haul locomotive likely operates the same month-to-month. Other emission categories, such as a tomato processing plant or use of recreational boats, vary significantly by season. CARB’s emission inventory database stores the relative monthly fractional activity for each process, the sum of which is 100. Using an example of emission sources that typically operate the same over each season, emissions from refinery heaters and line-haul locomotives would have a monthly fraction (throughput) of 8.33 for each month (calculated as $100/12 = 8.33$). This is considered a flat monthly profile. To apply monthly variations to create a gridded inventory, the annual average day’s emissions (yearly emissions divided by 365) is multiplied by the typical monthly throughput. For example, a typical monthly throughput of 15 in July for recreational boats results in emissions about 1.8 times higher ($15 / 8.33 = 1.8$) than a day in a month with a flat monthly profile.

2. Weekly Variation

Emissions are adjusted temporally to represent variations by day of the week. Some operations are the same over a week, such as a utility boiler or a landfill. Many businesses operate only 5 days per week. Other emissions sources are similar on weekdays, but may operate differently on weekend days, such as architectural coatings or off-road motorcycles. To accommodate variations in days of the week, each process or emission category is assigned a days-per-week code or DPWK. Table 3 shows the current DPWK codes.

Table 3: Day of week variation factors

| Code | WEEKLY CYCLE CODE DESCRIPTION | M | T | W | TH | F | S | S |
|------|-------------------------------|---|---|---|----|---|---|---|
| 1 | One day per week | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 2 | Two days per week | 1 | 1 | 1 | 1 | 1 | 0 | 0 |

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| Code | WEEKLY CYCLE CODE DESCRIPTION | M | T | W | TH | F | S | S |
|------|---|----|----|----|----|----|----|----|
| 3 | Three days per week | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 4 | Four days per week | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 5 | Five days per week - Uniform activity on weekdays, none on Saturday and Sunday | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 6 | Six days per week - Uniform activity on weekdays, none on Saturday and Sunday | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 7 | Seven days per week – Uniform activity every day of the week | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 20 | Uniform activity on Saturday and Sunday, no activity the remainder of the week | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| 21 | Uniform activity on Saturday and Sunday, half as much activity on weekdays | 5 | 5 | 5 | 5 | 5 | 10 | 10 |
| 22 | Uniform activity on weekdays, reduced activity on weekends | 10 | 10 | 10 | 10 | 10 | 7 | 4 |
| 23 | Uniform activity on weekdays, reduced activity on weekends | 10 | 10 | 10 | 10 | 10 | 8 | 8 |
| 24 | Uniform activity on weekdays; half as much activity on Saturday. Little activity on Sunday | 10 | 10 | 10 | 10 | 10 | 5 | 1 |
| 25 | Uniform activity on weekdays, one third as much on Saturday, little on Sunday | 10 | 10 | 10 | 10 | 10 | 3 | 1 |
| 26 | Uniform activity on weekdays, little activity on Saturday, no activity on Sunday | 10 | 10 | 10 | 10 | 10 | 3 | 0 |
| 27 | Uniform activity on weekdays, half as much activity on weekends | 10 | 10 | 10 | 10 | 10 | 5 | 5 |
| 28 | Uniform activity on weekdays, five times as much activity on weekends | 2 | 2 | 2 | 2 | 2 | 10 | 10 |
| 29 | Uniform activity on Monday through Thursday, increased activity on Friday, Saturday, and Sunday | 8 | 8 | 8 | 8 | 10 | 10 | 10 |

3. Daily Variation

Emissions are adjusted temporally to represent variations by hour of day. Many emission sources occur 24 hours per day, such as livestock waste or a sewage treatment plant whereas many businesses

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operate 8 hours per day. Other emissions sources vary significantly over a day, such as residential space heating or pesticide application. Each process or emission category is assigned an hours-per-day (HPDY) code. Table 4 displays the daily variation factors or current HPDY codes. Code 33 is no longer used for residential fuel combustion in favor of day specific adjustments see Section IV.F.4. Additional temporal profiles are shown in Section IX.

Table 4: Daily variation factors

| Code | CODE DESCRIPTION | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|------|---|---|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 1 | 1 HOUR PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 2 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 3 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 4 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 5 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 6 | 6 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 7 | 7 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 8 HOURS PER DAY - UNIFORM ACTIVITY FROM 8 A.M. TO 4 P.M. (NORMAL WORKING SHIFT) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | 9 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 10 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | 11 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 12 | 12 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 13 | 13 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 14 | 14 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 15 | 15 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |

| Code | CODE DESCRIPTION | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|------|--|----|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 16 | 16 HOURS PER DAY - UNIFORM ACTIVITY FROM 8 A.M. TO MIDNIGHT (2 WORKING SHIFTS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 17 | 17 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 18 | 18 HOURS PER DAY | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 19 | 19 HOURS PER DAY | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| 20 | 20 HOURS PER DAY | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 21 | 21 HOURS PER DAY | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 22 | 22 HOURS PER DAY | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 |
| 23 | 23 HOURS PER DAY | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 24 | 24 HOURS PER DAY - UNIFORM ACTIVITY DURING THE DAY | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 31 | MAJOR ACTIVITY 5-9 P.M., AVERAGE DURING DAY, MINIMAL IN EARLY A.M.(GAS STATIONS) | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 7 | 7 | 3 |
| 33 | MAX ACTIVITY 7-9 A.M. & 7-11 P.M.,AVERAGE DURING DAY, LOW AT NIGHT (RESIDENTIAL FUEL COMBUSTION) | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 10 | 10 | 6 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 10 | 10 | 10 | 10 | 2 |
| 34 | ACTIVITY 1 TO 9 A.M.; NO ACTIVITY REMAINDER OF DAY (i.e. ORCHARD HEATERS) | 0 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 10 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 35 | MAX ACTIVITY 7 A.M. TO 1 A.M., REMAINDER IS LOW (i.e. COMMERCIAL AIRCRAFT) | 10 | 1 | 1 | 1 | 1 | 1 | 1 | 8 | 8 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

| Code | CODE DESCRIPTION | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|------|--|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 37 | ACTIVITY DURING DAYLIGHT HOURS; LESS CHANCE IN EARLY MORNING AND LATE EVENING | 0 | 0 | 0 | 0 | 0 | 1 | 3 | 6 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 6 | 3 | 1 | 0 | 0 | 0 |
| 38 | ACTIVITY DURING MEAL TIME HOURS (i.e. RESIDENTIAL COOKING) | 0 | 0 | 0 | 0 | 0 | 2 | 6 | 6 | 2 | 2 | 1 | 2 | 4 | 4 | 2 | 1 | 1 | 3 | 10 | 8 | 7 | 6 | 1 | 0 |
| 50 | PEAK ACTIVITY AT 7 A.M. & 4 P.M.; AVERAGE DURING DAY (ON-ROAD MOTOR VEHICLES) | 1 | 1 | 1 | 1 | 1 | 1 | 6 | 10 | 6 | 5 | 5 | 5 | 5 | 5 | 5 | 6 | 10 | 8 | 6 | 4 | 1 | 1 | 1 | 1 |
| 51 | ACTIVITY FROM 6 A.M. TO 12 P.M. (PETROLEUM DRY CLEANING) | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 52 | MAJOR ACTIVITY FROM 6 A.M.-12 P.M., LESS FROM 12-7 P.M. (PESTICIDES) | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 10 | 10 | 10 | 10 | 10 | 6 | 3 | 3 | 3 | 3 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| 53 | ACTIVITY FROM 7 A.M. TO 12 P.M. (AGRICULTURAL AIRCRAFT) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 2 | 2 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 54 | UNIFORM ACTIVITY FROM 7 A.M. TO 9 P.M. (DAYTIME BIOGENICS) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 |
| 55 | UNIFORM ACTIVITY FROM 9 P.M. TO 7 A.M. (NIGHTIME BIOGENICS) | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 56 | MAX ACTIVITY 8 A.M. TO 5 P.M., MINIMAL AT NIGHT & EARLY MORNING(CAN&COIL/METAL PARTS COATINGS) | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 3 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 57 | MAX ACTIVITY 7 A.M. TO 2 P.M., MINIMAL AT EVENING AND MORNING HOURS (CONSTRUCTION EQUIPMENT ON HOT DAYS) | 0 | 0 | 0 | 0 | 0 | 1 | 6 | 10 | 10 | 10 | 10 | 10 | 10 | 9 | 8 | 4 | 2 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |

| Code | CODE DESCRIPTION | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 |
|------|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| 58 | MAX ACTIVITY 7 A.M. TO NOON.;REDUCED ACTIVITY NOON TO 6 P.M. (AUTO REFINISHING) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 10 | 10 | 10 | 10 | 10 | 8 | 8 | 8 | 8 | 8 | 8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 59 | MAXIMUM ACTIVITY FROM 7:00 AM TO 3:00 PM; REDUCED ACTIVITY FROM 3:00 TO 6:00 PM.(CONSTRUCTION EQUIPMENT ON NORMAL DAYS) | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 60 | MAXIMUM ACTIVITY FROM NOON TO 7:00 PM; REDUCED ACTIVITY EVENING AND MORNING HOURS (RECREATIONAL BOAT EXHAUST) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 4 | 6 | 7 | 9 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 7 | 5 | 3 | 1 | 0 |
| 81 | MAX ACTIVITY 9 AM TO 3 PM; HALF THE ACTIVITY REMAINING HOURS (WASTE FROM DAIRY CATTLE) | 7 | 6 | 6 | 5 | 4 | 4 | 4 | 5 | 7 | 8 | 9 | 10 | 10 | 10 | 7 | 3 | 3 | 3 | 4 | 4 | 5 | 6 | 7 | 7 |
| 82 | ACTIVITY FROM 10 AM TO 9 PM RISING TO PEAK AT 3; NO ACTIVITY REMAINDER OF DAY (WASTE FROM POULTRY) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 3 | 7 | 7 | 7 | 10 | 10 | 7 | 3 | 3 | 3 | 3 | 0 | 0 | 0 |
| 83 | ACTIVITY FROM 9 AM TO 12 AM RISING TO PEAK AT 3; MINIMUM ACTIVITY REMAINDER OF DAY (WASTE FROM SWINE) | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 4 | 6 | 8 | 8 | 9 | 10 | 8 | 4 | 3 | 3 | 2 | 1 | 1 | 1 |
| 84 | MAJOR ACTIVITY FROM 11AM TO 6PM; REDUCED OTHER HOURS (EVAP-COASTAL COUNTIES) | 7 | 7 | 6 | 6 | 6 | 6 | 6 | 7 | 8 | 8 | 9 | 9 | 10 | 10 | 10 | 10 | 9 | 9 | 8 | 8 | 7 | 7 | 7 | 7 |
| 85 | MAJOR ACTIVITY FROM 11AM TO 6PM; REDUCED OTHER HOURS (EVAP-NON-COASTAL COUNTIES) | 5 | 5 | 5 | 5 | 4 | 4 | 5 | 5 | 6 | 7 | 8 | 9 | 9 | 10 | 10 | 10 | 9 | 9 | 8 | 7 | 6 | 6 | 6 | 5 |

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D. Spatial Allocation

Once the base case, reference, or future year inventories are developed, the next step of modeling inventory development is to spatially allocate the emissions. Air quality models attempt to replicate the physical (e.g., transport) and chemical processes that occur in the atmosphere within a modeling domain. Therefore, it is important that the physical location of emissions be specified as accurately as possible. Ideally, the actual location of all emissions would be known exactly. However, some categories of emissions would be virtually impossible to determine—for example, the actual amount and location of consumer products (e.g., deodorant) used every day. To the extent possible, the spatial allocation of emissions in a modeling inventory approximates as closely as possible the actual location of emissions.

Spatial allocation is typically accomplished by using spatial surrogates. These spatial surrogates are processed into spatial allocation factors to geographically distribute county-wide area source emissions to individual grid cells. Spatial surrogates are developed based on demographic, land cover, and other data that exhibit patterns geographically. Sonoma Technology, Inc. (STI) (Funk, et al., 2001) under CCOS contract, originally developed many of the spatial surrogates by creating a base year (2000) and various future year surrogate inventories. STI updated the underlying spatial data and developed new surrogates (Reid, et al., 2006), completing the project in 2008. CARB and districts have since continued to update and improve many of the spatial surrogates, adding new ones as more data become available.

Four basic types of data are used to develop the spatial allocation factors: land use and land cover, satellite imagery, facility location, and demographic and socioeconomic data. Land use and land cover data are associated with specific land uses, such as agricultural harvesting or recreational boats. Facility locations are used for sources such as gas stations and dry cleaners. Demographic and socioeconomic data, such as population and housing, are associated with residential, industrial, and commercial activities (e.g., residential fuel combustion). To develop spatial allocation factors of high quality and resolution, local socioeconomic and demographic data were used when available for developing base case, baseline, and future year inventories. These data were available from local Metropolitan Planning Organizations (MPO)s or Regional Transportation Planning Agency (RTPA), where they are used as inputs for travel demand models. In rural regions for which local data were not available, data from Caltrans' Statewide Transportation Model were used.

The current snapshot used for the Eastern Kern O₃ SIP emission inventory is defined as snapshot October 1st, 2021 (SNP20211001_SORE) with improvements to SORE categories. Detailed methodology for each surrogate can be found in the spatial surrogate methodology document (AMSS, Spatial Surrogate Methodology Document SNP2021-10-01, 2021). This working snapshot includes all previous updates noted in surrogate snapshot 2020-10-01 (AMSS, 2020), as well as recent improvements outlined below. A summary of the primary spatial surrogates by EICSUM is provided in Section X.

- Improvements to small off-road equipment (SORE) surrogates
 - Creation of SNOW-level allocation factors for single family housing and commercial activity related to locations that will only occur with snowfall (snowblowers, etc.).

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- Creation of forest roads spatial surrogate (191) based on the integration of NLCD forest data with the TIGER road network
- Updated to 2016 National Land Cover Database
- Improvements to the Dunn and Bradstreet based surrogates with integration of Digital Maps Products 2017 Parcel data
- Updates to ocean going vessel surrogates based on 2018 Automatic Identification System (AIS)
- Improvement to construction surrogates
 - Creation of a 90:10 ratio split of on-road to offroad construction surrogate
- Improvements to agriculture surrogates
 - Updated input data for Farm Road VMT and inclusion of California Department of Pesticide Regulation (CDPR) data
 - Updated input data to our poultry related surrogate from California Water Board, Southern California Association of Governments (SCAG), and San Diego Association of Governments (SANDAG)
- Creation of a Water bodies and Land mask to remove anomalies caused by AIS satellite bias.

1. Spatial Allocation of Area Sources

Area-wide emissions are modeled using a top-down approach where emission totals are estimated for a large geographic area of interest (GAI). Each area source category is assigned a primary spatial surrogate that is used to allocate emissions to a grid cell in CARB's 4 km statewide modeling domain. Examples of surrogates include population, land use, and other data with known geographic distributions for allocating emissions to grid cells, as described above.

2. Spatial Allocation of Point Sources

Each point source is allocated to grid cells using the latitude and longitude reported for each stack. If there are no stack latitude and longitude, the facility coordinates are used. There are two types of point sources: elevated and non-elevated sources. Stationary point sources with stacks are regarded as elevated sources. Those without physical stacks that provide only latitude/longitude, such as airports or landfills, are considered non-elevated. Emissions are allocated vertically for elevated sources using the SMOKE (Sparse Matrix Operator Kernel Emissions) modeling system's in-line plume rise calculation within the CMAQ (Community Multi-scale Air Quality) photochemical model. SMOKE will select the sources that will receive the CMAQ in-line plume rise treatment, and group together sources with nearly identical stack parameters to reduce the number of calculations performed by the CMAQ in-line plume rise module. SMOKE will then output the emissions by grouped sources and the accompanying stack/facility coordinates and stack parameters for CMAQ's in-line plume rise module to handle the vertical allocation of the elevated sources.

3. Spatial Allocation of Wildfires, Prescribed Burns, and Wildland Fire Use

Emissions from wildfires, prescribed burns, and wildland fires are event- and location-based. A fire event can last a few hours or span multiple days. Each fire is spatially allocated to grid cells using the final extent of each fire event while the temporal distribution also reflects the actual duration of the fire. The spatial information to allocate the fire emissions comes from a statewide interagency fire perimeters geodatabase maintained by the Fire and Resource Assessment Program (FRAP) of the

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California Department of Forestry and Fire Protection (CALFIRE). More details on the methodology and estimation of the wildfire emissions can be found in Section III.F.1.

4. Spatial Allocation of Ocean-going Vessels (OGV)

CARB OGV emissions consist of four activity types: hoteling, maneuvering, anchorage and transit. Since hoteling is stationary in port areas, it was treated as a point source. The remaining activity types are regarded as area sources. Individual berths were identified from a combination of AIS telemetry data, satellite and aerial photography, and detailed port maps where available. The centroids of grid cells on the Statewide domain containing berth locations were then associated with hoteling emissions for each GAI. Transit, spatial surrogates were constructed based on the National Waterway Network and AIS data from 2017. Maneuvering spatial surrogates were drawn to connect the transit lanes with the berth locations for each port. Anchorage locations were determined based on raster data from the National Oceanic and Atmospheric Administration (NOAA) which reflects anchorage locations codified in the Federal Register.

5. Spatial Allocation of On-road Motor Vehicles

The spatial allocation of on-road motor vehicles is based on data from the latest travel demand models provided by local Metropolitan Planning Organizations (MPOs). These model outputs are combined into a statewide transportation network using the Integrated Transportation Network (ITN). For areas without a regional travel demand model, data from the California Department of Transportation (Caltrans) California Statewide Travel Demand Model (CSTDM). For more details, see Section III.B.3.

E. Speciation Profiles

CARB's emission inventory lists the amounts of pollutants discharged into the atmosphere by source in a certain geographical area during a given time period. It currently contains estimates for CO, NH₃, NO_x, SO_x, total organic gases (TOG) and particulate matter (PM). CO and NH₃ each are single species; NO_x emissions are composed of NO, NO₂ and HONO; and SO_x emissions are composed of SO₂ and SO₃. TOG and PM potentially contain over hundreds of different chemical species, and speciation is the process of disaggregating these inventory pollutants into individual chemical species components or groups of species. CARB maintains and updates such speciation profiles for organic gases (OG) and PM for a variety of source categories.

Photochemical models simulate the physical and chemical processes in the lower atmosphere and include all emissions of the important classes of chemicals involved in photochemistry as well as less reactive compounds that are of concern from a health or visibility standpoint. TOG includes all organic compounds that can become airborne (through evaporation, sublimation, as aerosols, etc.), excluding CO, CO₂, carbonic acid, metallic carbides or carbonates, and ammonium carbonate. TOG emissions reported in the CARB's emission inventory are the basis for deriving the reactive organic gas (ROG) emission components, which are also reported in the inventory. ROG is defined as TOG minus CARB's exempt compounds (e.g., methane, ethane, various chlorinated fluorocarbons, acetone, perchloroethylene, volatile methyl siloxanes, etc.). ROG is nearly identical to U.S. EPA's Volatile Organic Compounds (VOC), which is based on EPA's exempt list. For all practical purposes, use of the terms ROG and VOC are interchangeable.

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The OG speciation profiles are applied to estimate the amounts of various organic compounds that make up TOG emissions. A speciation profile contains a list of organic compounds and the weight fraction that each compound comprises of the TOG emissions from a particular source type. In addition to the chemical name for each chemical constituent, the file also shows the 5-digit CARB internal identification chemical code. The speciation profiles are applied to TOG to develop both the photochemical model inputs and the emission inventory for ROG. It should be noted that districts are allowed to report their own reactive fraction of TOG that is used to calculate ROG rather than use the information from the assigned OG speciation profiles. These district-reported fractions are not used in developing modeling inventories because the information needed to calculate the amount of each organic compound is not available.

The PM emissions are size-fractionated by using PM size distribution profiles, which contain the total weight fraction for PM_{2.5} and PM₁₀ out of total PM. The fine and coarse PM chemical compositions are characterized by applying the PM chemical speciation profiles for each source type, which contain the weight fractions of each chemical species for PM_{2.5}, PM₁₀, and total PM. PM chemical speciation profiles may also vary for different PM size fractions even for the same emission source. PM size profiles and speciation profiles are typically generated based on source testing data. In most previous source testing studies aimed at determining PM chemical composition, filter-based sampling techniques were used to collect PM samples for chemical analyses.

The most current OG profiles and PM profiles are available for download from [CARB's speciation profile web page](#). Based on these original profiles, a model-ready speciation file, *gspro*, was generated for a specific chemical mechanism (for example, *SAPRC07T*) to separate aggregated inventory pollutant emission totals into emissions of model species required by the air quality model.

Each process or product category is keyed to one of the OG profiles and one of the PM profiles. Also available for download from CARB's web site (see link in previous paragraph) is a cross-reference file that indicates which OG profile and PM profile are assigned to each category in the inventory. The inventory source categories are represented by an 8-digit source classification code (SCC) for point sources, or a 14-digit emission inventory code (EIC) for area and mobile sources. Some of the OG profiles and PM profiles related to motor vehicles, ocean going vessels, and fuel evaporative sources vary by the inventory year of interest, due to changes in fuel composition, vehicle fleet composition, and emissions control devices such as diesel particulate filters (DPFs). Details can be found in CARB's references of speciation profile development available on the [Consolidated List for Speciation Profiles site](#). Mapping of each category to OG and PM profiles is summarized in *rogpm* and *gsref* files.

Research studies are conducted regularly to improve CARB's speciation profiles. These profiles support ozone and PM modeling studies and can also be used for regional toxics modeling. Speciation profiles need to be as complete and accurate as possible. CARB has an ongoing effort to update speciation profiles as data become available through testing of emission sources or surveys of product formulations. New speciation data generally undergo technical and peer review; updates to the profiles are coordinated with end users of the data. The recent additions to CARB's speciation profiles include:

- OG profiles
 - Off-road recreational vehicle exhaust and evaporation

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- Biomass burning
- Consumer products
- Architectural coating
- Gasoline fuel and headspace vapor
- Gasoline vehicle hot soak and diurnal evaporation
- Gasoline vehicle start and running exhaust
- Silage
- Aircraft exhaust
- Compressed Natural Gas (CNG) bus running exhaust
- PM profiles
 - Tire burning
 - Gasoline vehicle exhaust
 - On-road diesel exhaust
 - Off-road diesel exhaust
 - Ocean going vessel exhaust
 - Aircraft exhaust
 - Concrete batching
 - Commercial cooking
 - Residential fuel combustion-natural gas
 - Coating/painting
 - Cotton ginning
 - Stationary combustion
 - OGV auxiliary boiler combustion
 - Compressed Natural Gas (CNG) vehicle running exhaust

IV. Methodology for Developing Base Case, Baseline, and Future Projected Emissions Inventories

As mentioned in Section II.C, the base case and reference inventories include temperature, humidity, and solar insolation effects for some emission categories; development of these data is described in Sections IV.F. Sections IV.A through IV.H detail how the base case and reference inventories were created for different sectors of the inventory such as point, area, on-road motor vehicles, biogenic, OGV, other day-specific sources, Northern Mexico, and Western States.

A. Estimation of Gridded Area and Point sources

Emissions inventories that are temporally, chemically, and spatially resolved are needed as inputs for the photochemical air quality model. Point sources and area sources (area-wide, off-road mobile, and aggregated stationary) are processed into emissions inventories for photochemical modeling using the SMOKE modeling system (<https://www.cmascenter.org/smoke/>). The current SIP modeling uses SMOKE v4.8 (referred as Official SMOKE hereafter) following in-house testing of this version of the software.

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Inputs for SMOKE are annual emissions totals from CEPAM and information for allocating to temporal, chemical, and spatial resolutions. Temporal inputs for SMOKE are screened for missing or invalid temporal codes as discussed in Section V.A. Temporal allocation of emissions using SMOKE involves the disaggregation of annual emissions totals into monthly, day-of-week, and hour-of-day emissions totals. The temporal codes from Table 3 and Table 4 are reformatted into an input-ready format as explained in the SMOKE user's manual. Chemical speciation profiles, as described in Section III.E, and emissions source cross-reference files used as inputs for SMOKE are developed by CARB staff. SMOKE uses the files for the chemical speciation of NO_x, SO_x, TOG, and PM to produce the species needed by photochemical air quality models.

Emissions for area sources are allocated to grid cells defined by the modeling grid domain in Section I.D. Emissions are spatially disaggregated using spatial surrogates as described in Section II.C. These spatial surrogates are converted to a SMOKE-ready format as described in the SMOKE user's manual. Emissions for point sources are allocated to grid cells by SMOKE using the latitude and longitude coordinates reported for each stack.

B. Estimation of On-road Motor Vehicle Emissions

1. General Methodology

The EMFAC2017 with Metropolitan Planning Organizations specific activity version 10 (MPOv10) emissions are processed into on-road emissions inventories using ESTA developed by CARB. The ESTA model applies spatial and temporal surrogates to emissions to create top-down emission inventory files.

More information on ESTA is available at the following [GitHub repository for Emissions Spatial and Temporal Allocator](#).

2. Activity Data Updates

Link-based and Traffic Analysis Zone (TAZ)-based travel activity from travel demand models provided by different MPOs, Caltrans and other California RTPAs. Parameters such as vehicle mix and VMT are compared between the default EMFAC and Caltrans databases prior to spatial allocation to ensure values lie within reasonable limits.

3. Spatial Adjustment

CARB works with local Metropolitan Planning Organizations (MPOs) to obtain the latest available output from regional travel demand models. The output link networks from these models are combined into a statewide link network using the Integrated Transportation Network (ITN) framework (CARB, 2021). For regions where no local travel demand model data are available, data from the Caltrans California Statewide Travel Demand Model (CSTDm) are used (Caltrans, 2020). Data are quality assured by checking network/link volume, vehicle miles traveled (VMT), and spatial rendering. Overlapping networks are checked for duplicate links to avoid overallocation in these regions. Model output years vary between all regional data sources for ITN. The networks are normalized into

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modeling years used for air quality modeling using county level growth factors from EMFAC. Table 6 contains the data vintages used in the current working version of the statewide ITN.

Spatial allocation of on-road activity surrogates is split into two vehicle groups, light-duty and heavy-duty. Some major MPOs and Caltrans provide vehicle classification splits in their model link outputs. When possible, this information is incorporated into the ITN. However, when no vehicle splits are provided by the regional models the total network volumes must be used for both light-duty and heavy-duty spatial distribution. Travel demand model output provides network volume information organized by peak and off-peak time periods. This peak period volume information is disaggregated to create 24 hourly surrogates for an average modeling day.

The link networks are processed through the spatial allocator tool to create gridded surrogates weighted by VMT.

Table 5: Network information for data sources used in current version of ITN

| Network | Counties in Network | Data Vintage |
|--|---|--------------|
| Association of Monterey Bay Area Governments (AMBAG) | Monterey, San Benito, Santa Cruz | 2018 RTDM |
| Butte County Association of Governments (BCAG) | Butte | 2020 RTP/SCS |
| California Statewide Travel Demand Model (CSTDM) | Statewide | Version 3.0 |
| Fresno Council of Governments (FCOG) | Fresno | 2019 RTP/SCS |
| Kings County Association of Governments (KCAG) | Kings | 2018 RTP/SCS |
| Kern Council of Governments (KCOG) | Kern | 2018 RTP/SCS |
| Merced County Association of Governments (MCAG) | Merced | 2018 RTP/SCS |
| Madera County Transportation Commission (MCTC) | Madera | 2018 RTP/SCS |
| Metropolitan Transportation Commission (MTC) | Alameda, Contra Costa, Marin, Napa, San Francisco, San Mateo, Santa Clara, Solano, Sonoma | 2017 RTP/SCS |
| Sacramento Area Council of Governments (SACOG) | El Dorado, Placer, Sacramento, Solano, Sutter, Yolo, Yuba | 2020 MTP/SCS |
| San Diego Association of Governments (SANDAG) | San Diego | 2018 RTP/SCS |

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| Network | Counties in Network | Data Vintage |
|---|---|--------------|
| Santa Barbara County Association of Governments (SBCAG) | Santa Barbara | 2017 FSTIP |
| Southern California Association of Governments (SCAG) | Imperial, Los Angeles, Orange, Riverside, San Bernardino, Ventura | 2020 RTP/SCS |
| San Joaquin Council of Governments (SJCOG) | San Joaquin | 2018 RTP/SCS |
| San Luis Obispo Council of Governments (SLOCOG) | San Luis Obispo | 2019 RTP |
| Shasta Regional Transportation Agency (SRTA) | Shasta | 2018 RTP |
| Stanislaus Council of Governments (StanCOG) | Stanislaus | 2018 RTP |
| Tulare County Association of Governments (TCAG) | Tulare | 2018 RTP |
| Tahoe Metropolitan Planning Organization (TMPO) | El Dorado, Placer | 2015 FSTIP |

Evaporative surrogates were created using registration data from the California Department of Motor Vehicles (DMV). Vehicle registration was provided by census block group for the entire state. Registration data were split into five vehicle types and two fuel types. Table 7 shows the vehicle type categories used for the evaporative emission surrogates. Registration counts were totaled over a three-year period (2015-2018) and assigned to the corresponding census block group polygons. Data from the NASA Nighttime Lights (Mills, 2013) dataset was used to clip the census block group into areas with active population.

Table 6: Registration Data Vehicle Type Classes.

| Vehicle Class Group Name | Description |
|--------------------------|-------------------------|
| MC | Motorcycles |
| MH_BUS | Motorhomes and Buses |
| P | Passenger Vehicles |
| T1_T4 | Light-Heavy Duty Trucks |
| T5_T7 | Heavy-Heavy Duty Trucks |

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4. Temporal Adjustment (Day-of-week adjustments for EMFAC daily totals)

EMFAC2017 produces average day-of-week (DOW) estimates that represent Tuesday, Wednesday, and Thursday. To more accurately represent daily emissions, DOW adjustments are made to all emissions estimated on a Friday, Saturday, Sunday or Monday. The DOW adjustment factors were developed using CalVAD data. The California Vehicle Activity Database (CalVAD), developed by UC Irvine for CARB, is a system that fuses available data sources to produce a “best estimate” of vehicle activity by class. The latest activity from the CalVAD database was released in 2012. There are no expected upcoming updates. The CalVAD data set includes actual daily measurements of VMT on the road network for 43 of the 58 counties in California. However, there are seven counties that can’t be used because the total vehicle miles traveled are less than the sum of the heavy heavy-duty truck vehicle miles traveled and trucks excluding heavy heavy-duty vehicle miles traveled. Furthermore, two more counties that have high vehicle miles traveled on Sunday are also excluded. Therefore, only 34 of these counties had useful data. To fill the missing 24 counties’ data to cover all of California, a county which is nearby and similar in geography is selected to represent each of the missing counties. The CalVAD fractions were developed for three categories of vehicles: passenger cars (LD), light- and medium-duty trucks (LM), and heavy-heavy duty trucks (HHDT). Table 87 also shows the corresponding assignment to each vehicle type. Furthermore, the CalVAD fractions are scaled so that a typical workday (Tuesday, Wednesday, or Thursday) gets a scaling factor of 1.0. All other days of the week receive a scaling factor where their VMT is related back to the typical workday. This means there are a total of five weekday scaling factors. Lastly, the CalVAD data were used to create a typical holiday, because the traffic patterns for holidays are quite different than a typical weekday. Thus, in the end, there are six daily fractions for each of the three vehicle classes, for all 58 counties. The DOW factors and vehicle type can be found in Section VII.

Heavy-heavy duty vehicle fractions were updated using 2018 Performance Measurement System (PeMS) data. Truck volumes were pulled for each county. Day of year specific fractions were calculated relative to an average weekday for each county. Fractions were manually reviewed by staff to check data integrity. Counties without data or poor data quality were screened out and replaced with an older version of fractions from CalVAD.

Table 7: Vehicle classification and type of adjustment

| Vehicle Class | Vehicle type | Type of adjustment |
|---------------|--------------|--------------------|
| 1 | LDA | LD |
| 2 | LDT1 | LD |
| 3 | LDT2 | LD |
| 4 | MDV | LD |
| 5 | LHDT1 | LM |

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| Vehicle Class | Vehicle type | Type of adjustment |
|---------------|--------------|--|
| 6 | LHDT2 | LM |
| 7 | T6 | LM |
| 8 | T7 HHDT | HHDT |
| 9 | Other Bus | LM |
| 10 | School Bus | Unadjusted on weekdays, zeroed on weekends |
| 11 | Urban Bus | LD |
| 12 | Motorhomes | LD |
| 13 | Motorcycles | LD |

5. Temporal Adjustment (Hour-of-day profiles for EMFAC daily totals)

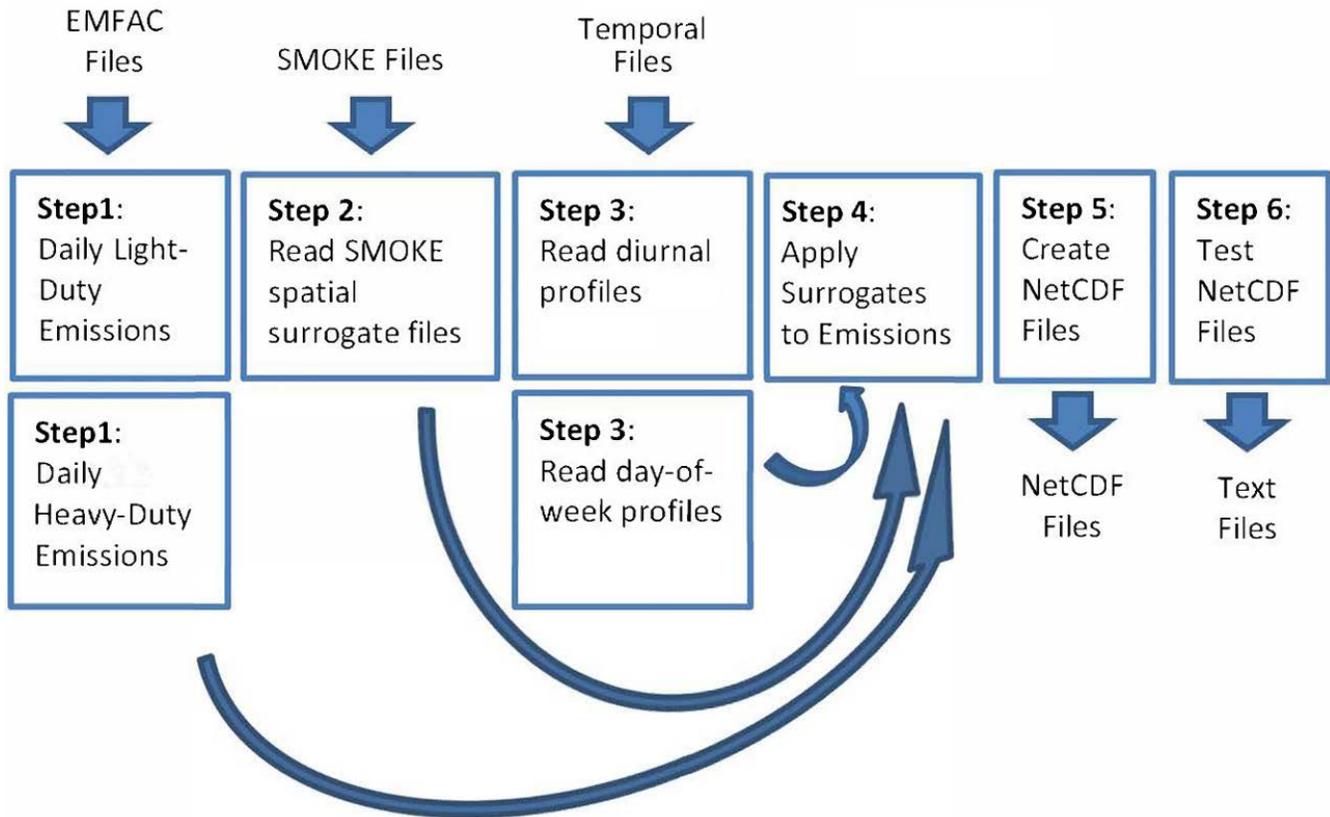
EMFAC produces emission estimates for an average weekday and lacks the day-of-week hour-of-day temporal variations that are known to occur on specific days of the week. To rectify this, the CALVAD data were used to develop hour-of-day profiles for Friday through Monday, a typical weekday and a typical holiday. Heavy-heavy duty hourly vehicle fractions were updated using 2018 Performance Measurement System (PeMS) data from Caltrans in counties where data were available. The hour-of-day profiles for passenger cars (LD), light- and medium-duty trucks (LM), and heavy heavy-duty trucks (HH) can be found in Appendix B: Hour-of-day Profiles by Vehicle Type and County.

6. Summary of On-road Emissions Processing Steps

The six steps to process on-road emissions for regional air quality modeling with CMAQ are represented below in Figure 3. Step 1 reads daily emissions input data from EMFAC. Step 2 reads SMOKE-ready spatial surrogates files. Step 3 reads day of week and diurnal temporal activity profiles from CALVAD. Step 4 applies both the spatial surrogates and temporal allocations to the daily emissions from EMFAC. Step 5 creates the gridded, hourly NETCDF files for each day of the year being modeled. Lastly, step 6 produces text files for use in quality assurance and quality checks of the emissions data.

Modeling Emission Inventory

Figure 3: Workflow for spatial and temporal allocation of on-road emissions



7. Adjustment to the Future Year On-road Emissions

The future year on-road mobile source emissions were adjusted to incorporate emission reduction programs for heavy duty vehicles. The reductions applied to the inventory reflect the Low NOx Standard (CARB, Heavy-Duty Low NOx, 2020), Advanced Clean Truck (ACT) (CARB, Advanced Clean Trucks, 2020), and Heavy Duty Inspection and Maintenance Regulation (CARB, Heavy-Duty Inspection and Maintenance Regulation, 2021) for both future years. The State SIP Strategy was applied only for 2032 (CARB, 2022 State Strategy for the State Implementation Plan, 2022). The combined factors for 2026 and 2032 are shown in Table 8.

Table 8: NOx Reductions (TPD) by Air Basin for 2026 and 2032

| Region | 2026 Reductions (Tpd) | 2032 Reductions (Tpd) |
|----------------------------|-----------------------|-----------------------|
| Eastern Kern | 0.99 | 1.555 |
| San Joaquin Valley | 16.99 | 28.29 |
| Total Statewide reductions | 65.8 | 123.12 |

Modeling Emission Inventory

C. Estimation of Gridded Biogenic Emissions

Biogenic emissions were generated using the MEGAN3.0 biogenics emissions model (<https://bai.ess.uci.edu/megan/versions>). MEGAN3.0 incorporates a new pre-processor (MEGAN-EFP) for estimating biogenic emission factors based on available landcover and emissions data. The MEGAN3.0 default datasets for plant growth form, ecotype, and emissions were utilized. Leaf Area Index (LAI) for non-urban grid cells was based on the 8-day 500-m resolution MODIS Terra/AQUA combined product (MCD15A2H) for 2018 (<https://earthdata.nasa.gov/>). The LAI data was converted to LAI_v, which represents the LAI for the vegetated fraction within each grid cell, by dividing the gridded MODIS LAI values by the Maximum Green Vegetation Fraction (MGVF) for each grid cell (https://archive.USGS.gov/archive/sites/landcover.USGS.gov/green_veg.html). The MODIS LAI product does not provide information on LAI in urban regions, so urban LAI_v was estimated from the US Forest Service's Forest Inventory and Analysis (FIA) urban tree plot data, processed through the i-Tree v6 software (<https://www.itreetools.org/tools/i-tree-eco>). Hourly meteorology was provided by 4-km WRF simulations for 2018, and all stress factor adjustments were turned off.

D. Aircraft Emissions

Aircraft emissions were generated using the Gridded Aircraft Trajectory Emissions Model (GATE) developed by CARB (AQPSD CARB, 2019). The GATE model distributes aircraft emissions in three dimensions. The GATE model takes annual aircraft emissions during landing, taxiing, and take-off, and converts this data into gridded, hourly emissions as follows:

- Read aircraft emissions from an annual inventory
- Split the emissions into hourly components
- Split any county-wide emissions into individual runways
- Geometrically model the 3D flight paths at each runway
- Intersect the above 3D paths with the 3D modeling grid
- Distribute the hourly aircraft emissions into the 3D grid

More information on GATE is available at the following [GitHub repository for GATE](#).

E. Estimation of Ocean-going Vessel (OGV) Emissions

Annual emissions are provided through CEPAM for commercial and military OGV. The Mobile Source Analysis Branch compiled port activity data for 2016 reported for Long Beach, Port of Los Angeles, Bay Area, and San Diego. The activity data consisted of daily visits by vessel types for the full calendar year. This data was used to derive monthly and weekly temporal profiles for OGV sources. No activity data was available to create temporal profiles for the military sector; default SMOKE temporal profiles were assumed.

After applying the port activity factors mentioned above, emissions were separated by at-berth and everything else. At-berth emissions are processed through SMOKE and plume rise is calculated for every day of the year (Kwok, 2015). For transit, maneuvering, and anchorage, emissions are distributed evenly in two vertical layers (2 and 3) (Kwok, 2015).

Modeling Emission Inventory

F. Estimation of Other Day-specific Sources

Day-specific data were used for preparing base case inventories when data were available. CARB and district staff were able to gather hourly/daily emission information for 1) wildfires and prescribed burns, 2) paved and unpaved road dust, and 3) agricultural burns in six districts (more details highlighted below).

For the reference and future year inventories, day-specific emissions for wildfires, prescribed burns, and wildland fires use (WFU) are left out of the inventory. All other day-specific data are included in both reference and future year modeling inventories.

1. Wildfires and Prescribed Burns

Day-specific, base case estimates of emissions from wildfires and prescribed fires were developed in a two-part process. The first part consisted of estimating micro-scale, fire-specific emissions (i.e. at the fire polygon scale, which can be at a smaller spatial scale than the grid cells used in air quality modeling). The second part consisted of several steps of post-processing fire polygon emission estimates into gridded, hourly emission estimates that were formatted for use in air quality modeling.

Fire event-specific emissions were estimated using a combination of geospatial databases and a federal wildland fire emission model (Clinton, 2006). A series of pre-processing steps were performed using GIS to develop fuel loading and fuel moisture inputs to the First Order Fire Effects (FOFEM) fire emission model (Lutes, et al., 2012). Polygons from a statewide interagency fire perimeters geodatabase (Fire17_1.zip, downloaded May 8, 2018) maintained by the Fire and Resource Assessment Program (FRAP) of the California Department of Forestry and Fire Protection (CALFIRE) provided georeferenced information on the location, size (area), spatial shape, and timing of wildfires and prescribed burns. Under interagency Memorandums of Understanding, federal, state, and local agencies report California wildfire and prescribed burning activity data to FRAP. Using GIS software, fire polygons were overlaid upon a vegetation fuels raster dataset called the Fuel Characteristic Classification System (FCCS) (Ottmar, et al., 2007). The FCCS maps vegetation fuels at a 30-meter spatial resolution, and is maintained and distributed by LANDFIRE.GOV, a state and federal consortium of wildland fire and natural resource management agencies. With spatial overlay of fire polygons upon the FCCS raster, fuel model codes were retrieved and component areas within each fire footprint tabulated. For each fuel code, loadings (tons/acre) for fuel categories were retrieved from a FOFEM look-up table. Fuel categories included dead woody fuel size classes, overstory live tree crown, understory trees, shrubs, herbaceous vegetation, litter, and duff. Fuel moisture values for each fire were estimated by overlaying fire polygons on year- and month-specific 1 km spatial resolution fuel moisture raster files generated from the national Wildland Fire Assessment System (WFAS.net) and retrieving moisture values from fire polygon centroids. Fire event-specific fuel loads and fuel moisture values were compiled and formatted to a batch input file and run through FOFEM.

A series of post-processing steps were performed on the FOFEM batch output to include emission estimates (pounds/acre) for three supplemental pollutant species (NH₃, TNMHC, and N₂O) in addition to the seven species native to FOFEM (CO, CO₂, PM_{2.5}, PM₁₀, CH₄, NO_x, and SO₂), and to calculate total emissions (tons) by pollutant species for each fire. Emission estimates for NH₃, TNMHC, and N₂O were based on mass ratios to emitted CO and CO₂ (Gong, 2003).

Modeling Emission Inventory

Fire polygon emissions were apportioned to CMAQ model grid cells using area fractions, developed using GIS software, by intersecting fire polygons to the grid domain.

Another set of post-processing steps were applied to allocate fire polygon emissions by date and hour of the day. Fire polygon emissions were allocated evenly between fire start and end dates, taken from the fire perimeters geodatabase. Daily emissions were then allocated to hour of day and to the model grid cells by using a script developed by CARB. A stack file and a 2-D hourly emissions file are generated for each day that has fire emissions. The stack file includes the fire locations, stack parameters and the number of acres burned for a fire in one day. The 2-D hourly emissions file includes the emissions for each specie and the heat flux (BTU/hr). CMAQ's in-line plume rise module will handle the vertical allocation of the fire emissions.

2. Paved and Unpaved Road Dust

Statewide emissions of total particulate matter from both paved and unpaved road dust are also a part of the CEPAM inventory. However, the sectors that have been embedded in any CEPAM version are already pre-adjusted. The unadjusted emissions are what is required before making any adjustment. Therefore, the unadjusted paved road dust is based upon CEPAM SIP2019v1.02-v1.01, while the unadjusted unpaved road dust uses an older CEPAM version with 20161130 snapshot. To adjust for precipitation, daily precipitation data for 2018 were used, provided by an in-house database maintained by CARB staff that stores meteorological data collected from outside sources. The specific data sources for these data include Remote Automated Weather Stations (RAWS), Atmospheric Infrared Sounder (AIRS), California Irrigation Management Information System (CIMIS) networks, and Federal Aviation Administration (FAA). FAA data provide precipitation data collected from airports in California.

When the precipitation reaches or exceeds 0.01 inches (measured anywhere within a county or county/air basin boundary on a particular day), the uncontrolled emissions are reduced on that day only: 25% for paved road dust, and total removal for the unpaved. The reductions can be achieved by running SMOKE with control matrices.

3. Agricultural Burning

Agricultural burn 2018 data processed were reported by air districts. The tons burned provided by the air districts were converted to acres using fuel loading data. With date of the burns, the location of the burns (latitude and longitude coordinates), crop type, and burn duration, the agricultural burn data were processed and then projected onto a statewide grid for each hour of a specific day.

4. Residential Wood Combustion Curtailment

Emissions were reduced to reflect residential wood curtailment (RWC) in San Joaquin Valley APCD and Sacramento Metropolitan AQMD.

A pre-SMOKE utility program called GenTpro is used to generate county-specific temporal profiles based on average temperature by grid cell (UNC Chapel Hill - The Institute for the Environment, 2016). Emissions for any given county are only allocated whenever the daily average temperature by grid cell is below 50 °F based on WRF simulated meteorology.

Modeling Emission Inventory

San Joaquin Valley APCD provided areas of curtailment, which are used to mask the spatial surrogates for woodstoves and fireplaces. The masked surrogates were used to apply day-specific curtailment. The corresponding complimentary surrogates were also constructed by subtracting the masked surrogates from the original spatial surrogates. These complimentary surrogates apply to areas without curtailment. For winter months (January, February, November, December) SJVAPCD provided no-burn days by county, from which day-specific CNTLMAT curtailment files were constructed. With these settings, processing of winter months using SMOKE is enabled by merging the outputs of two separate runs. The first run is for the portion with masked surrogates with curtailment via CNTLMAT, and the second run is for the portion that includes complimentary surrogates without curtailment. For non-winter months, SMOKE is only run once with the original spatial surrogates without any curtailment. When curtailment is applied to any county in SJV, wood burning emissions are reduced by 51%.

Areas under Sacramento Metropolitan AQMD (SACAQMD) have their RWC emissions reduced by 70% (i.e. 30% remaining) whenever no-burn days are designated. Curtailment is applied to the full spatial surrogates without exceptions.

5. Estimation of Agricultural Ammonia Emissions

Ammonia emissions from fertilizers/pesticides and livestock are separated from the aggregated area source inventory as they are affected by local meteorology. For fertilizers/pesticides, emissions vary by hour based on WRF's two-meter temperature and ten-meter wind speed. For livestock, WRF's ground temperature and aerodynamic resistance drive hourly variations in emissions. Through GenTpro these meteorological factors are averaged by county before creating year-long hourly profiles for each of the respective sectors. All algorithms are described in the SMOKE Manual 4. (UNC Chapel Hill - The Institute for the Environment, 2016), while the results of CARB in-house tests were summarized in an internal report (Kwok, Meteorology-adjusted Temporal Profiles for Agricultural and Residential Wood Combustion Sectors Using Smoke Gentpro Utility Program, 2016). In general, higher temperature and/or wind speeds favor ammonia emissions. Monthly surrogates based upon the frequency of pesticides applications were also applied to fertilizer NH₃. The sector also has emissions reported by a few individual facilities whose latitudes/longitudes are known.

Thus, the facility-reported livestock were represented as point sources. Another hourly GenTpro file was created just for them. To preserve the spatial distribution, emissions were apportioned to those individual facilities by GAI. SMOKE runs with these spatio-temporal allocations covered criteria pollutants NH₃, PM and TOG.

G. Northern Mexico Emissions

Transboundary flow of pollutants between California and Mexico must be considered and accounted for in air quality simulations of Southern California. Affected areas in California include the border regions of San Diego, Imperial and given the right meteorological conditions, more northern counties such as Riverside, Orange, and Los Angeles. As a result, emissions within the five municipal districts of Mexico's State of Baja California and one municipal district in Sonora must be included when running regional air quality models on the California Statewide Domain.

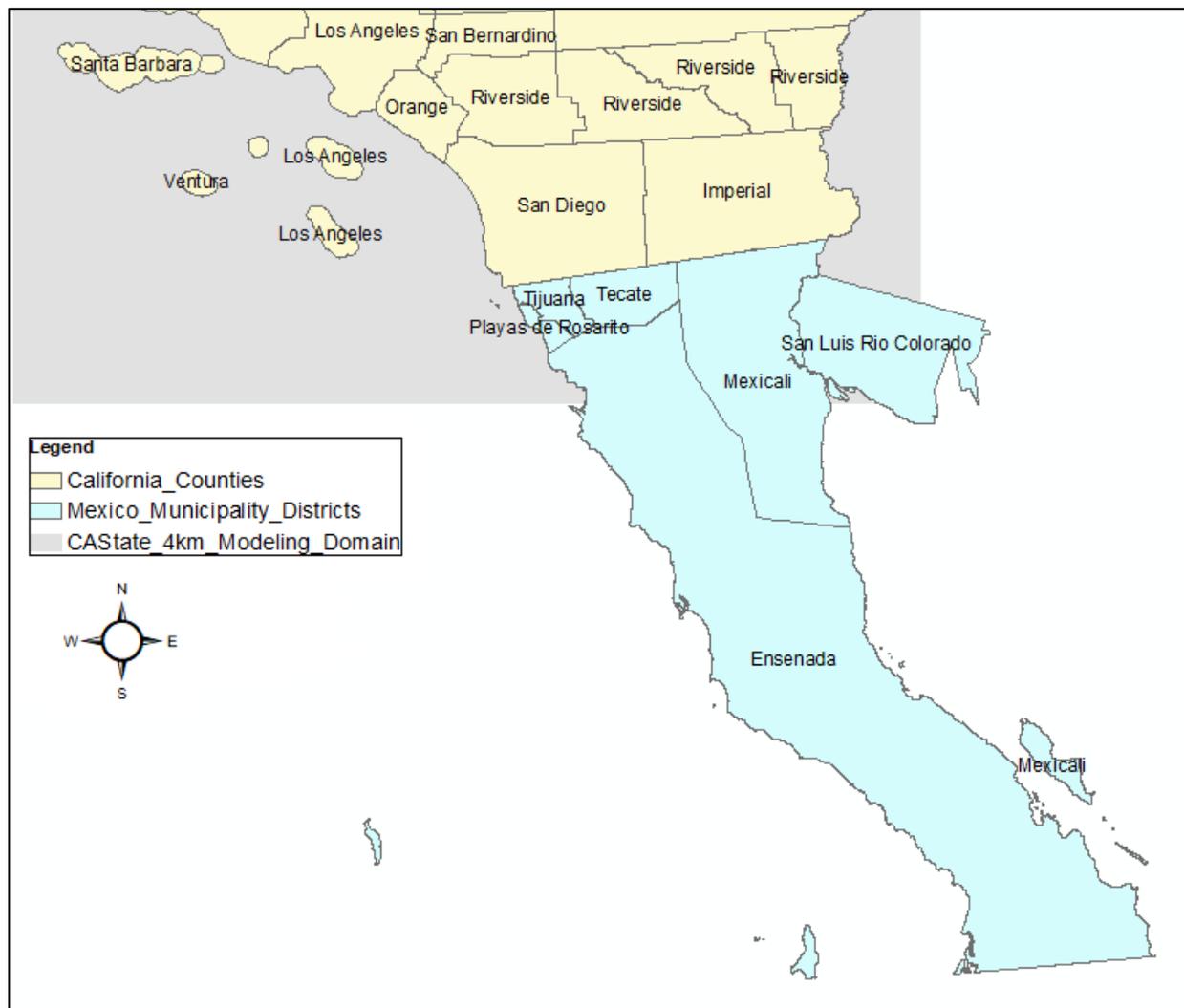
Modeling Emission Inventory

CARB's Mexico emissions inventory for area, point and non-road emission sources have been processed using an updated inventory developed by Eastern Research Group Inc. (ERG). This inventory is based on the 2014 Mexico National Emissions Inventory (MNEI) with additional improvements made by ground truthing agricultural burning, brick kilns and improving methods to calculate idling mobile emissions at the border entries (ERG, 2019). Base year 2017 emission estimates were developed by projecting the 2014 emissions to 2017. Future year 2037 emissions estimates were developed by interpolating 2014, 2020 and 2025 emission estimates to 2037.

For mobile sources, the U.S. EPA on-road emissions model SMOKE-MOVES (Sparse Matrix Operator Kernel Emissions – Motor Vehicle Emission Simulator) Mexico was used to produce an on-road emissions inventory. The on-road sector is reflective of true 2017 emissions. Future year 2037 emission estimates used the U.S. EPA on-road emissions model SMOKE-MOVES Mexico for future year 2028. SMOKE-MOVES is more comprehensive than the data provided for the on-road sector in the 2014 MNEI, and after discussions with U.S. EPA it was suggested to use SMOKE-MOVES over the 2014 MNEI estimates.

Modeling Emission Inventory

Figure 4: Outline of Mexico municipalities included in California air quality simulations. The grey box outlines the boundaries of the CAState_4km modeling domain



Under contract to CARB, ERG recently completed an update to the spatial distribution of Mexico’s area, non-road and on-road emissions (ERG, 2019). These updates include additional spatial surrogates such as the location of brick kilns, bakeries, ports, airports etc. for the state of Baja California. In addition, the project supports large improvements on emission estimates at two major border crossings (ERG, 2019). These updates have been included in the base and future year inventories and the surrogates used are listed in Table 11.

EPA’s National Emission Inventory (NEI) has been used by ARB as a foundation for identifying spatial surrogates that will aid in allocating emissions in the northern part of Mexico. While searching for improved surrogates, different online databases were investigated to find shapefiles relevant to established source sectors. The updated population surrogate was pulled from Instituto Nacional de Estadística y Geografía (INEGI) using information from Mexico’s 2010 Population and Housing Census. INEGI provides spatial information about Mexico such as resources, population, and land use. The population surrogate was also used to update the following residential heating sources: wood,

Modeling Emission Inventory

distillate oil, coal, and LP gas. The total road miles surrogate that is used to spatially allocate on-road emissions was also updated using data provided by INEGI's dataset containing information on urban and rural roads and highways. Agriculture and forests spatial surrogates were updated using the same dataset from Comisión Nacional Forestal (CONAFOR). Using satellite images taken by the MODIS sensor (Moderate Resolution Imaging Spectroradiometer), the resulting vector data set from CONAFOR was produced to characterize Mexico's land. The border crossings surrogate was updated using statistics from the U.S. Bureau of Transportation, which provided points of entry along California and Mexico's border. Once the shapefiles were collected, they were converted to the standard projection used in CARB's modelling. These EPA-based surrogates are used within the state of Sonora, which was not covered in the ERG contract, and as secondary spatial allocation for the state of Baja CA. Table 12 lists the EPA-based Mexico surrogates dated as of May 2018.

Table 9: List indicating ERG developed spatial surrogates for the state of Baja California

| Spatial Surrogate ID | Description | Year |
|-----------------------------|---------------------------|-------------|
| 100 | Mexicali Agriculture | 2014 |
| 110 | Mexicali Agburn | 2014 |
| 111 | Mexicali Agburn Asparagus | 2014 |
| 112 | Mexicali Agburn Bermuda | 2014 |
| 113 | Mexicali Agburn Wheat | 2014 |
| 120 | Airports | 2014 |
| 130 | Autoshop | 2014 |
| 140 | Bakeries | 2014 |
| 150 | Border Crossing | 2014 |
| 160 | Brick Kilns | 2014 |
| 170 | Charbroiling | 2014 |
| 180 | Feedlots | 2014 |
| 190 | Gas Stations | 2014 |
| 200 | Graphic Arts | 2014 |
| 210 | Hospitals | 2014 |

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| Spatial Surrogate ID | Description | Year |
|----------------------|------------------|------|
| 220 | Landfills | 2014 |
| 230 | Total Population | 2014 |
| 231 | Rural Population | 2014 |
| 232 | Urban Population | 2014 |
| 240 | Ports | 2014 |
| 250 | Railroads | 2014 |
| 260 | Wastewater | 2014 |
| 270 | Windblown Dust | 2014 |

Table 10: List of EPA's Mexico surrogates as of May 2018

| # | Surrogate | Year | Shapefile | Weight field |
|----|------------------------------------|------|-----------------------------|--------------|
| 10 | Population | 2010 | north_mexico_population.shp | population |
| 12 | Housing | 2010 | north_mexico_population.shp | population |
| 14 | Residential Heating Wood | 2010 | north_mexico_population.shp | population |
| 16 | Residential Heating Distillate Oil | 2010 | north_mexico_population.shp | population |
| 18 | Residential Heating Coal | 2010 | north_mexico_population.shp | population |
| 20 | Residential Heating LP Gas | 2010 | north_mexico_population.shp | population |
| 22 | Total Road Miles | 2011 | MEX_roads.shp | WEIGHT |
| 24 | Total Railroad Miles | 2000 | mexico_rr_MM5.shp | LENGTH |
| 26 | Total Agriculture | 2015 | MEX_agriculture.shp | WEIGHT |
| 28 | Forest Land | 2015 | MEX_Forests.shp | WEIGHT |
| 30 | Land Area | 2000 | REPMEX_ES_HEAT1_MM5.shp | P001 |

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| # | Surrogate | Year | Shapefile | Weight field |
|----|---|------|-------------------------------|--------------|
| 32 | Commercial Land | 1999 | com_ind_viv_MM5.shp | A500_2000 |
| 34 | Industrial Land | 1999 | com_ind_viv_MM5.shp | A505_2000 |
| 36 | Commercial Plus Industrial | 1999 | com_ind_viv_MM5.shp | A510_2000 |
| 38 | Commercial plus Industrial Land | 1999 | com_ind_viv_MM5.shp | A515_2000 |
| 40 | Residential Commercial Industrial Institutional | 1999 | com_ind_viv_MM5.shp | a535_2000 |
| 42 | Personal Repair | 1999 | REP_CRUCES_MM5.shp | a545_1999 |
| 44 | Airports Area | 1999 | mexico_air_MM5.shp | WEIGHT |
| 46 | Marine Ports | 1999 | mexico_ports_MM5.shp | VALUE |
| 48 | Brick Kilns | 1999 | BOSQUE_LAD_MM5.shp | LAD_2000 |
| 50 | Mobile Sources Border Crossing | 2014 | Border_Crossing_Years_MM5.shp | Y20** |

H. Western States Emissions

In addition to transboundary flow from Mexico into California cities, pollutants can travel between various bordering states such as Nevada, Arizona, Oregon, Idaho, and Utah. The current statewide modeling domain includes grid cells that cover these regions and therefore emission estimates from the four major source sectors (area, point, non-road and on-road) need to be included for a complete California State modeling domain inventory. As CARB or California air districts are not responsible for the development of emission estimates in those geographic regions, the national emission inventory developed by the U.S. EPA was used.

CARB's Western US emissions inventory has been developed using the U.S. Environmental Protection Agency (EPA) 2011 National Emissions Inventory (NEI) platform version 3 with future year projections for 2017 and 2028¹.

Base year 2017 emissions were developed with "2011v3 NEI 2017ek_cb6v2_v6_11g" which are 2017 projections from the 2011 national emissions inventory version three, while the future year 2026 and 2032 emissions were processed from "2011v3 NEI 2028el_cb6v2_v6_11g" 2028 projections based on the 2011 National Emissions Inventory version three. Spatial and temporal allocations were applied

¹ All inventory and ancillary files for spatial and temporal allocation are available for download at: <ftp://newftp.epa.gov/air/emismod/2011/v3platform/> (U.S. EPA, 2018).

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using the U.S. EPA ancillary files however, all spatial surrogates were processed through the spatial allocator tool with the California statewide map projection applied.

I. Application of Control Measure Reduction Factors

Future year onroad vehicle emissions were adjusted to reflect statewide reduction commitments for CARB's Low NO_x, ACT, and HD I&M for 2026 and 2032. SSS adjustments for onroad were applied to the 2032 projected inventory. The onroad adjustments are summarized in Section B.7.

V. Quality Assurance of Modeling Inventories

As mentioned in Section II.C.1., base case modeling is intended to demonstrate confidence in the modeling system. Quality assurance of the data is necessary to detect outliers and potential problems with emission estimates. The most important quality assurance checks of the modeling emissions inventory are summarized in the following sections.

A. Area and Point Sources

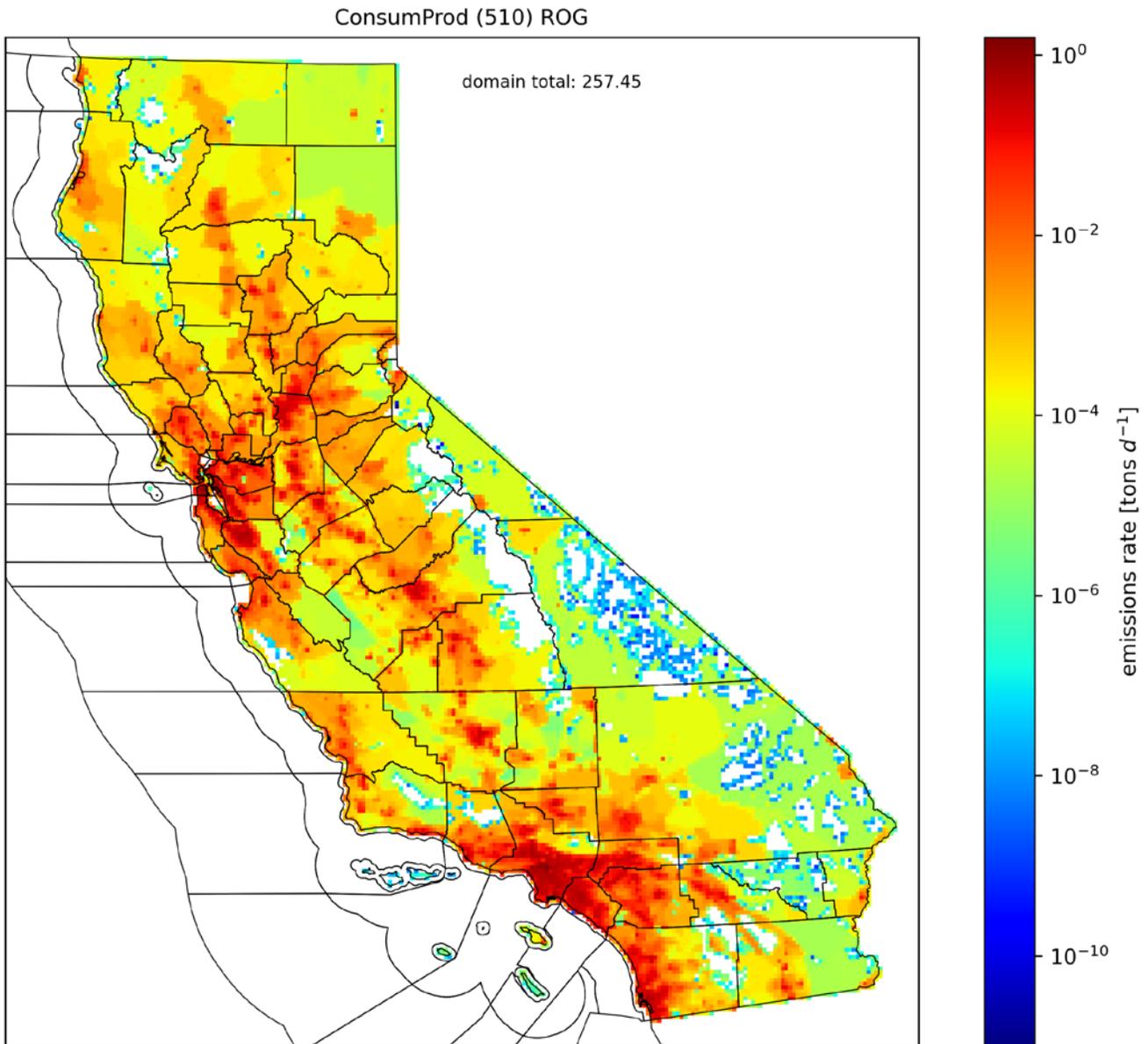
All SMOKE inputs are subject to extensive quality assurance procedures performed by CARB staff. Annual and forecasted emissions are carefully reviewed prior to running SMOKE. CARB and district staff review data used to calculate emissions along with other ancillary data, such as temporal profiles and the location of facilities and assignment of SCC to each process. Growth and control information are reviewed and updated as needed.

We also compare annual average emissions from CEPAM with planning inventory totals to ensure data integrity. The planning and modeling inventories start with the same annual average emissions. The planning inventory is developed for an average summer day and an average winter day, whereas the modeling inventory processes daily emissions. Both inventory types use the same temporal data described in Section II.B. The summer planning inventory uses the monthly throughputs from May through October. Similarly, the winter planning inventory uses the monthly throughputs from November through April. The modeling inventory produces emissions for every day of the year.

Annual, gridded emissions totals are plotted on the statewide modeling domain and visually inspected to check the spatial allocation of emissions. Spatial plots by source category like the one shown in Figure 5 are carefully screened for proper spatial distribution of emissions.

Modeling Emission Inventory

Figure 5: Example of an ROG spatial plot by source category (Consumer Products)



Before air quality model-ready emissions files are generated by SMOKE, the run configurations and parameters set within the SMOKE environment are checked for consistency for both the reference and future years.

To aid in the quality assurance process, SMOKE is configured to generate inventory reports of temporally, chemically, and spatially-resolved emissions inventories. CARB staff utilize the SMOKE reports by checking emissions totals by source category and region. Staff also create and analyze time series plots, and compare aggregate emissions totals with the pre-SMOKE emissions totals obtained from CEPAM.

Modeling Emission Inventory

Checks for missing or invalid temporal assignments are conducted to ensure accurate temporal allocation of emissions. Special attention is paid to checking monthly throughputs and appropriate monthly temporal distribution of emissions for each source category. In addition, checks for time-invariant temporal assignments are done for certain source categories and suitable alternate temporal assignments are determined and applied.

Further improvements to temporal profiles used in the allocation of area source emissions are performed using suitable alternate temporal assignments determined by CARB staff. Select sources from manufacturing and industrial, degreasing, petroleum marketing, mineral processes, consumer products, residential fuel combustion, farming operations, aircraft, off-road equipment, and commercial harbor craft sectors are among the source categories included in the application of adjustments to temporal allocation.

B. On-road Emissions

There are several processes to conduct quality assurance of the on-road mobile source modeling inventory at various stages of the inventory processing. The specific steps taken are described below.

- Plot MPO provided data spatially to find any missing or incomplete links.
- Compare spatial distribution of VMT between on and off-peak periods for each MPO.
- Generate time series plots for the on-road emissions files to check the diurnal pattern.
- Compare the daily total emissions for the on-road emissions files and the EMFAC 2017 emissions files for each county to ensure that the emissions are the same.
- Generate the spatial plot for the on-road emissions files to check if there were any missing emissions.

C. Aircraft Emissions

There are two steps to conduct quality assurance of the aircraft emissions.

- Compare the daily total emissions for the aircraft emissions files and the raw emissions files for each county to ensure that the emissions are the same.
- Generate the spatial plot for the aircraft emissions files to check if there were any missing emissions.

D. Day-specific Sources

1. Wildfires

GIS records for 413 wildfires, 166 prescribed wildland burn events, and 28 wildland fires use reported for 2018 were downloaded from *The California Department of Forestry and Fire Protection's Fire and Resource Assessment Program (FRAP)* and imported to a geodatabase. Data fields included wildfire or burn project name, burned area, and start and end dates. A series of geoprocessing steps were used to map and overlay wildfire and prescribed burn footprint polygons on the statewide vegetation fuels (FCCS) and moisture raster datasets, to retrieve associated fuel loadings and moisture values for use as

Modeling Emission Inventory

input to FOFEM. Wildfire and prescribed burn footprint polygons were also overlaid on the statewide 4-km modeling grid to assign grid cell IDs to each wildfire and prescribed burn. Emission estimates for each wildfire and prescribed burn event were generated by FOFEM and summarized in an Access database. To check the location of the fires and the daily total emissions, a script is used to make a netCDF file from the stack file and the 2-D hourly emissions file for each day. The spatial plot and the daily total emissions from processing the netCDF file are then compared to the raw fire emissions data to check for accuracy.

2. Agricultural Burning

Checks were done to verify the quality of the agricultural burn data. The day-specific emissions from agricultural burning were compared to the emissions from CEPAM for each county to check for agreement between the planning and modeling inventories. Time series plots were reviewed for each county to see that days when burning occurred matched the days provided by the local air district. For each county, a few individual fires were calculated by hand starting from the raw data through all the steps to the final model-ready emissions files to make sure the calculations were done correctly. Spatial plots were made to verify the location of each burn.

E. Additional Quality Assurance

In addition to the quality assurance described above, comparisons are made between annual average inventories from CEPAM and modeling inventories. The modeling inventory shows emissions by month and subsequently calculates the annual average for comparison with CEPAM emissions. Annual average inventories and modeling inventories can be different, but differences should be well understood. For example, modeling inventories are adjusted to reflect different days of the week for on-road motor vehicles as detailed in Section III.B; since weekend travel is generally less than weekday travel, modeling inventory emissions are usually lower when compared to annual average inventories from CEPAM. Figure 6 is an example of a QA report that summarizes NO_x emissions by category for EIC3 10 through 499 for the San Joaquin Valley air basin. The report compares the monthly and annual processed emissions totals against CEPAM. Please note that this report is only an example since emissions have been updated from what is displayed here.

Modeling Emission Inventory

Figure 6: Comparison of inventories report

2018 Ozone SIP, Base Year 2018 -- CEPAM 2019 Ozone SIP Ver 1.03 with off-Road Patch (CEPAM2022v1.01) And Zero Out 430-995-7000-0000 NOx in E. Kern Byr:2018 MYR:2018

Basin:MD County:15 Spec:NOx

| EIC | Description | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual | RF3064_19v1.02 | RF3084_19v1.03 | RF3108_19v1.04 | RF3089_22v1.01 | |
|-----|--|-------|------|-------|-------|------|-------|-------|-------|------|-------|------|------|--------|----------------|----------------|----------------|----------------|-------|
| 10 | Electric Utilites | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| 20 | Cogeneration | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.42 | 0.48 | 0.42 | 0.42 | 0.42 | 0.39 |
| 30 | Oil And Gas Production (Combustion) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 40 | Petroleum Refining (Combustion) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 50 | Manufacturing And Industrial | 0.99 | 1.10 | 1.30 | 1.50 | 1.71 | 1.71 | 1.70 | 1.71 | 1.70 | 1.71 | 1.50 | 1.19 | 1.49 | 1.54 | 1.49 | 1.49 | 1.49 | 1.37 |
| 52 | Food And Agricultural Processing | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.02 | 0.02 | 0.02 | 0.00 | 0.00 | 0.00 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.03 |
| 60 | Service And Commercial | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.45 | 0.49 | 0.20 |
| 99 | Other (Fuel Combustion) | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.23 | 0.18 | 0.18 | 0.18 | 0.18 | 0.15 |
| 110 | Sewage Treatment | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 120 | Landfills | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 130 | Incinerators | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 140 | Soil Remediation | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 199 | Other (Waste Disposal) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 210 | Laundering | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 220 | Degreasing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 230 | Coatings And Related Process Solvents | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.00 |
| 240 | Printing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 250 | Adhesives And Sealants | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 299 | Other (Cleaning And Surface Coatings) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 310 | Oil And Gas Production | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 320 | Petroleum Refining | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 330 | Petroleum Marketing | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 399 | Other (Petroleum Production And Marketing) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 410 | Chemical | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 420 | Food And Agriculture | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 430 | Mineral Processes | 10.51 | 8.37 | 10.51 | 10.72 | 7.95 | 10.81 | 11.23 | 11.31 | 9.44 | 10.55 | 9.70 | 9.53 | 10.06 | 17.37 | 17.28 | 10.06 | 18.09 | 18.09 |
| 440 | Metal Processes | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 | 0.01 |
| 450 | Wood And Paper | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 460 | Glass And Related Products | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 470 | Electronics | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 499 | Other (Industrial Processes) | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |

Notes:

- CEPAM refers to annual average emissions from 2019 SIP Baseline Emission Inventory Tool with external adjustments: [CEPAM External Adjustment Reporting Tool](#)
- Monthly gridded emissions come from GeoVAST mo-yr/avg tabular summary - gid 657

Staff also review how modeling emissions vary over a year. Figure 7 provides an example of a modeling inventory time series plot for San Luis Obispo County for area-wide sources, on-road sources and off-road sources. Again, this figure is only an example.

Modeling Emission Inventory

Figure 7: Daily variation of NOx emissions for sources in Eastern Kern County in 2018

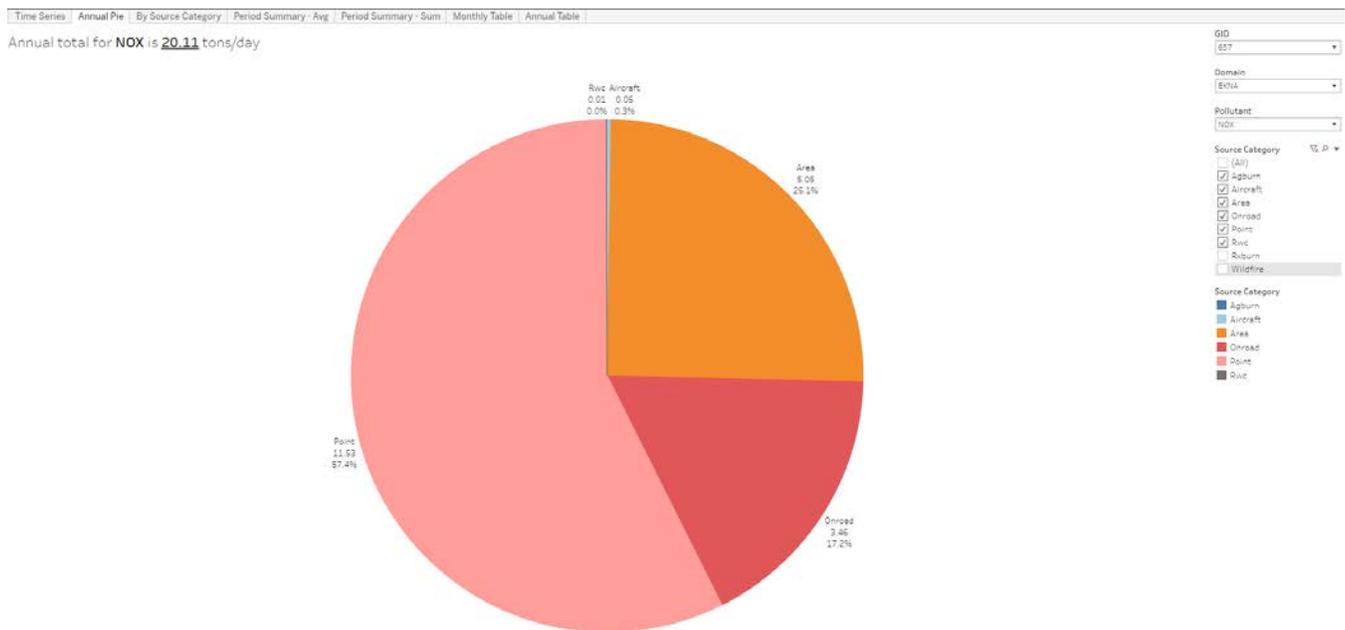


Modeling Emission Inventory

F. Model-ready Files Quality Assurance

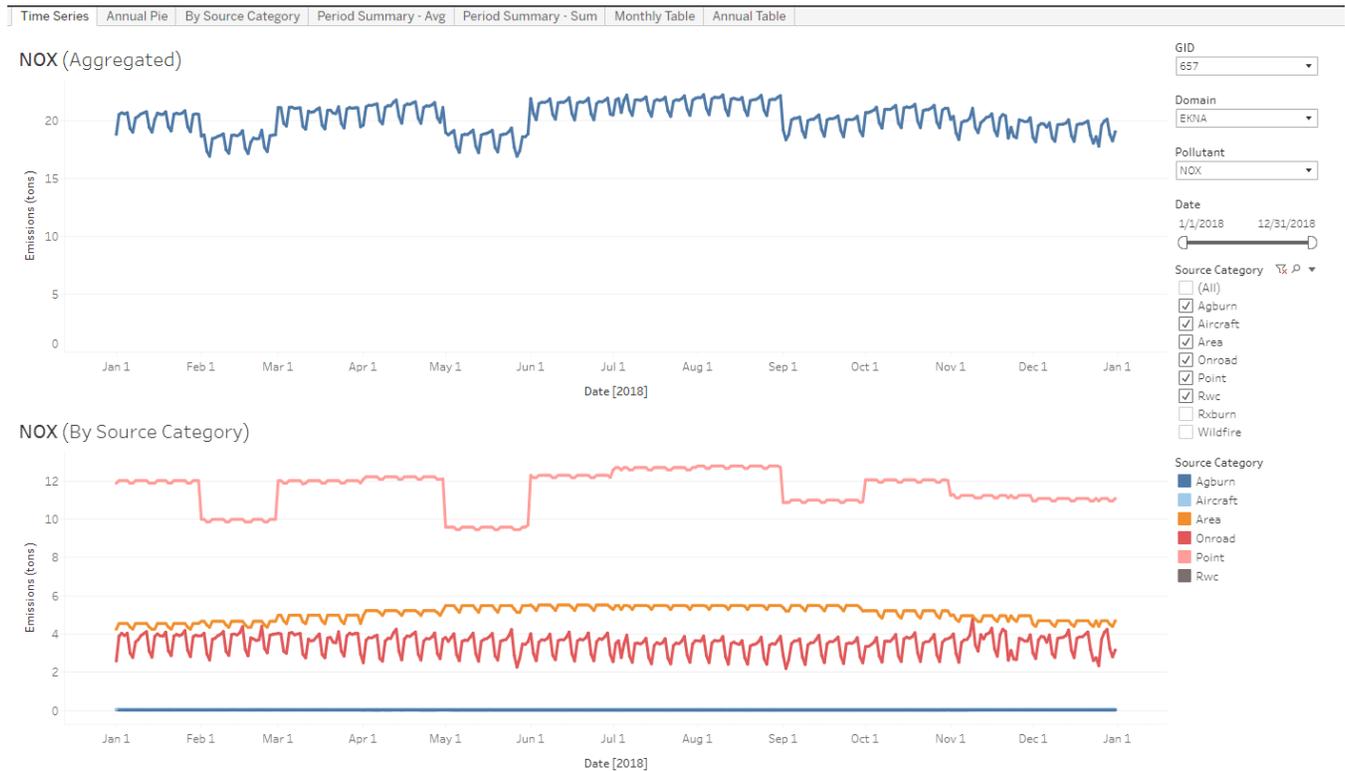
Prior to developing the modeling inventory emissions files used in the photochemical models, the same model-ready emissions files developed for the individual source categories (e.g., on-road, area, point, day-specific sources) are checked for quality assurance. Extensive quality assurance procedures are already performed by CARB staff on the intermediate emissions files (e.g., SMOKE-generated reports); however, further checks are needed to ensure data integrity is preserved when the model-ready emissions files are generated from those intermediate emissions files. Figure 8 shows the share of area, on-road, and point sources contribution to annual NOx emissions are shown for San Joaquin Valley Nonattainment area in 2018. These same sources are shown as a daily timeseries for San Joaquin Valley Nonattainment area in Figure 9. These figures are only examples and do not reflect the inventory totals used for SIP attainment modeling.

Figure 8: Annual processed emissions example for 2018 Eastern Kern Nonattainment Area NOx for area, on-road, and point sources



Modeling Emission Inventory

Figure 9: Example timeseries plot for daily 2018 NOx emissions from area, on-road, and point sources for Eastern Kern Nonattainment Area



Comparisons of the totals for both the intermediate and model-ready emissions files are made. Emissions totals are aggregated spatially, temporally, and chemically to single-layer, statewide, daily values by inventory pollutant. Spatial plots are also generated for both the intermediate and model-ready emissions files using the same graphical utilities and aggregated to the same spatial, temporal, and chemical resolution to allow equal comparison of emissions. Any discrepancies in the emissions totals are reconciled before proceeding with the development of the model-ready inventory emissions files.

Before combining the model-ready emissions files of the individual source category inventories into a single model-ready inventory, they are checked for completeness. Most sources should have emissions for every day in the modeling period. Exceptions to this apply to sources like fires since burning (natural or planned) does not occur every day. It is important that during these checks source inventories with missing files are identified and resolved. Once all constituent source inventories are complete, they are used to develop the model-ready inventory used in photochemical modeling. When the modeling inventory files are generated, log files are also generated documenting the constituents of each daily model-ready emissions file as an additional means of verifying that each daily model-ready inventory is complete.

Modeling Emission Inventory

VI. References

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