California Aircraft Emissions Inventory (CAI2024) Technical Documentation

December 2024

CALIFORNIA AIR RESOURCES BOARD

Table of Contents

List of Figures

List of Tables

List of Appendices Figures

Appendix A

Appendix B

Appendix C

Appendix D

Appendix E

Statewide California Aircraft Emissions Inventory (CAI2024) Technical Documentation

Executive Summary

Currently, air districts develop and submit aircraft emissions inventories to the California Air Resources Board (CARB) based on disparate data sources, growth projections, and modeling tools. Because aircraft are mobile sources that frequently travel between air district jurisdictions, and to standardize methodology across the State, CARB has developed a statewide aircraft emissions inventory estimation model referred to as the 2024 California Aircraft Emissions Inventory Model (CAI2024 or Model). The Model will be foundational to the development of future State Implementation Plans (SIP) as well as aircraft and airport specific regulations and control strategies.

CAI2024 harnesses the most up-to-date activity data from the U.S. Federal Aviation Administration's (FAA) 2023 Terminal Area Forecast (TAF)[1] and the Bureau of Transportation Statistics (BTS)[2] from 2024 to project the growth of most metropolitan and international airports in California. Detailed activity data was acquired from FlightAware for 857 aviation facilities in California, separated by airframe and engine, and utilized to run the latest FAA Aviation Environmental Design Tool version 3e (AEDT)[3]. This yielded a comprehensive and consistent modeling of the landing and take-off (LTO) aircraft emissions from all active aviation facilities encompassing a broad spectrum of aircraft types in California, including Air Carriers, Air Taxis, General Aviation, and Helicopters (also known as Rotorcraft). Additionally, CAI2024 includes the emissions inventory for Military and Agricultural (Crop Dusters also known as Aerial Applicators) aircraft, which are discussed further below.

To assess the impact of aircraft on regional and local air pollution, the Model takes into account the mixing height, or the height below which aircraft emissions contribute to air

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[1] Federal Aviation Administration (FAA). Terminal Area Forecast, 2023 *https://www.faa.gov/data_research/aviation/taf*

[2] Bureau of Transportation Statistics, 2024 *Bureau of Transportation Statistics 2024*

[3] Federal Aviation Administration (FAA), Aviation Environment Design Tool 2023 *https://aedt.faa.gov/Default.aspx*

pollution that impacts people at ground level. Instead of using the default mixing height of 3,000 ft for all airports in California, CARB staff used spatially resolved planetary boundary layer data to estimate the mixing height specific to each aviation facility in California, resulting in a more precise and consistent estimate of emissions that have ground level impacts. Emissions from Aerial Applicators, which are primarily used for pesticide spraying, are estimated from the annual fuel consumption associated with agricultural acreage sprayed[4] as shown in Table 14. Military emissions are based on the latest military activity reports[5] as shown in Table 21.

Figures 1-3 summarize the current statewide annual NOx, ROG, and fine PM (PM2.5) emissions for aircraft in California as reported by CARB's 2022 California Emissions Projection Analysis Model (CEPAM2022)[6] compared to CAI2024 for calendar years CY 2022, 2031, and 2037. CEPAM2022 reflects a recent snapshot of the latest local air district inventories, which in aggregate across all aircraft categories, the annual statewide NOx, ROG, and PM2.5 emissions are higher than in CAI2024.

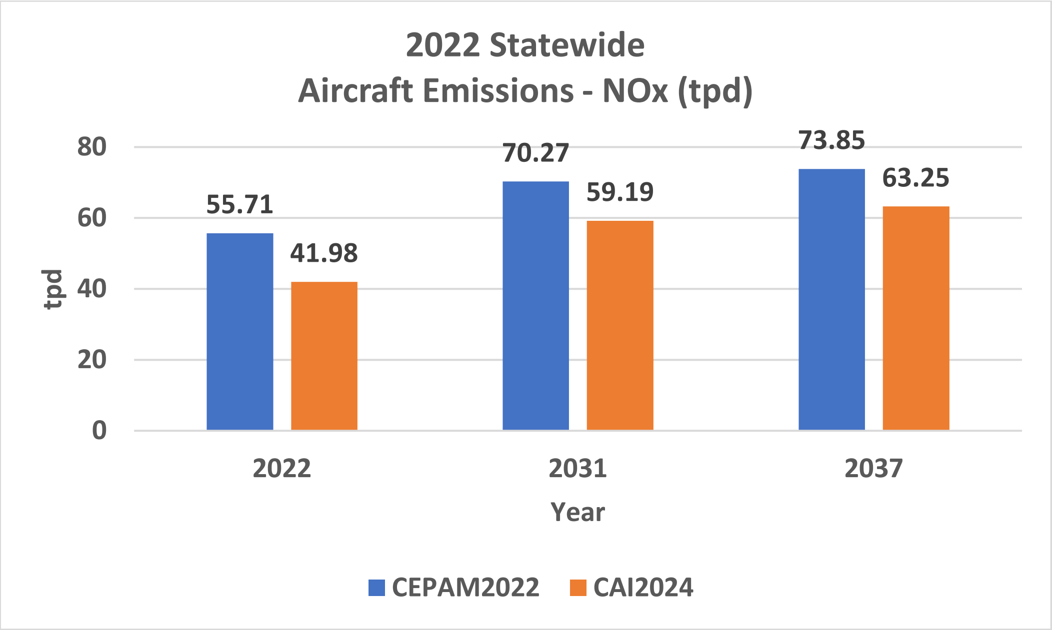

Figure 1: 2022 Annual Statewide NOx Aircraft Emissions (tpd)

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[4] Pesticide Use Report (PUR) database, *https://www.cdpr.ca.gov/docs/pur/purmain.htm*

[5] Air Force Civil Engineer Center, Air Emissions Guide for Air Force Mobile Sources - Methods for Estimating Emissions of Air Pollutants for Mobile Sources At United States Air Force, June 2021

[6] California Air Resources Board (CARB), California Emissions Projection Analysis Model (CEPAM), 2022 *https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool,%202022*

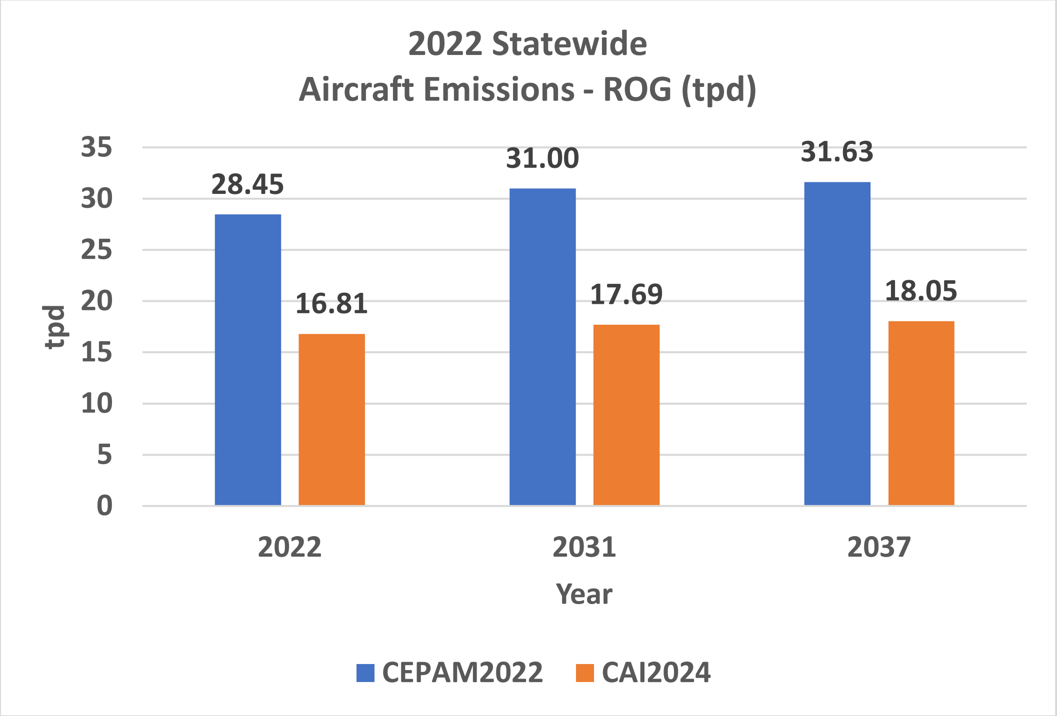


Figure 2: 2022 Annual Statewide ROG Aircraft Emissions (tpd)

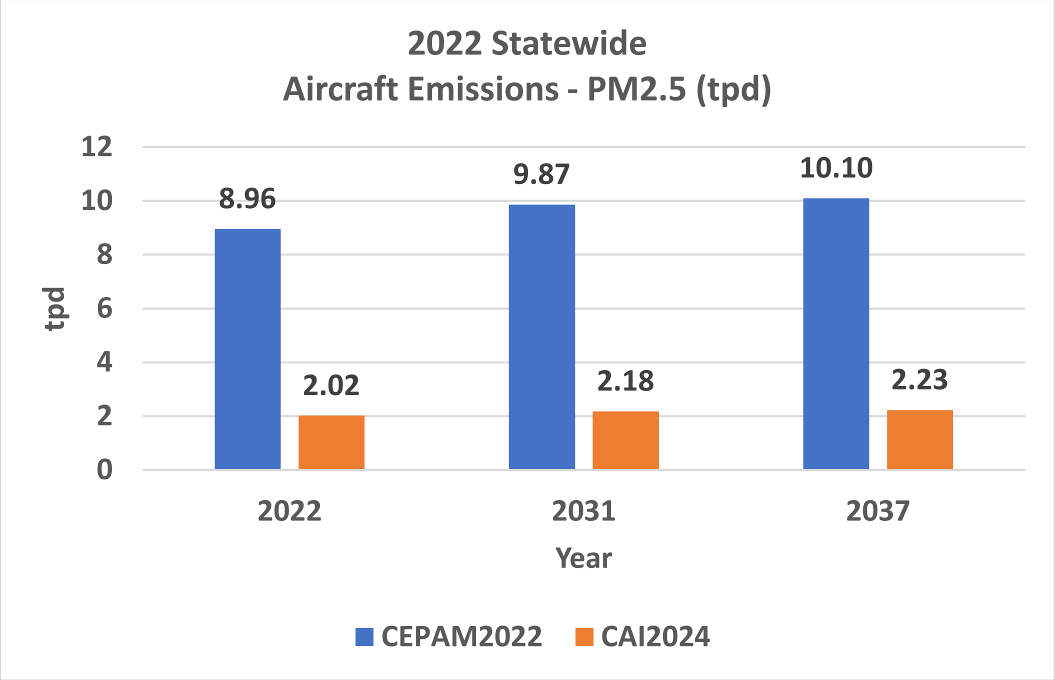
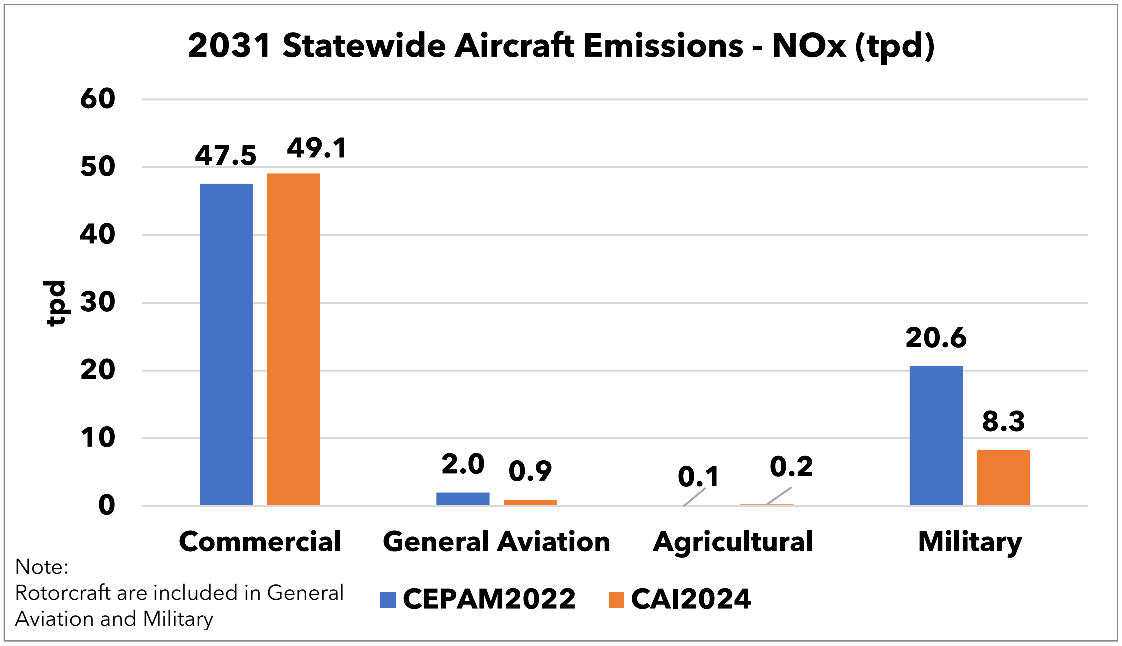


Figure 3: 2022 Annual Statewide PM2.5 Aircraft Emissions (tpd)

Figures 4 to 6 below illustrate the contribution of NOx, ROG, and PM2.5 from each of the four aircraft categories in CY 2031. NOx emissions from CAI2024 are lower than CEPAM2022 for General Aviation and Military but slightly higher in the Commercial and Agricultural categories, as shown in Figure 4. ROG emissions from CAI2024, portrayed in Figure 5, are lower for Commercial, General Aviation, and Military categories, but slightly higher for Agricultural as compared to CEPAM2022. PM2.5 emissions from CAI2024 are significantly lower than CEPAM2022 for the Military and General Aviation categories and slightly higher for Agricultural and Commercial, as shown in Figure 6.



Note:
Rotorcraft are included in General Aviation and Military

Figure 4: 2031 Annual Statewide NOx Aircraft Emissions (tpd)

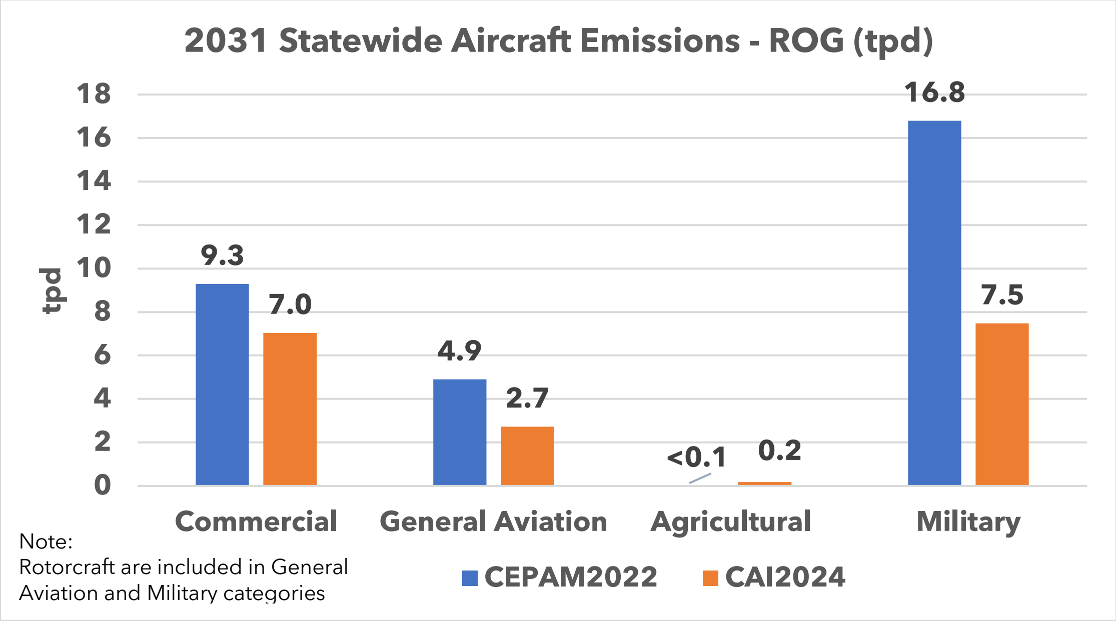


Figure 5: 2031 Annual Statewide ROG Aircraft Emissions (tpd)

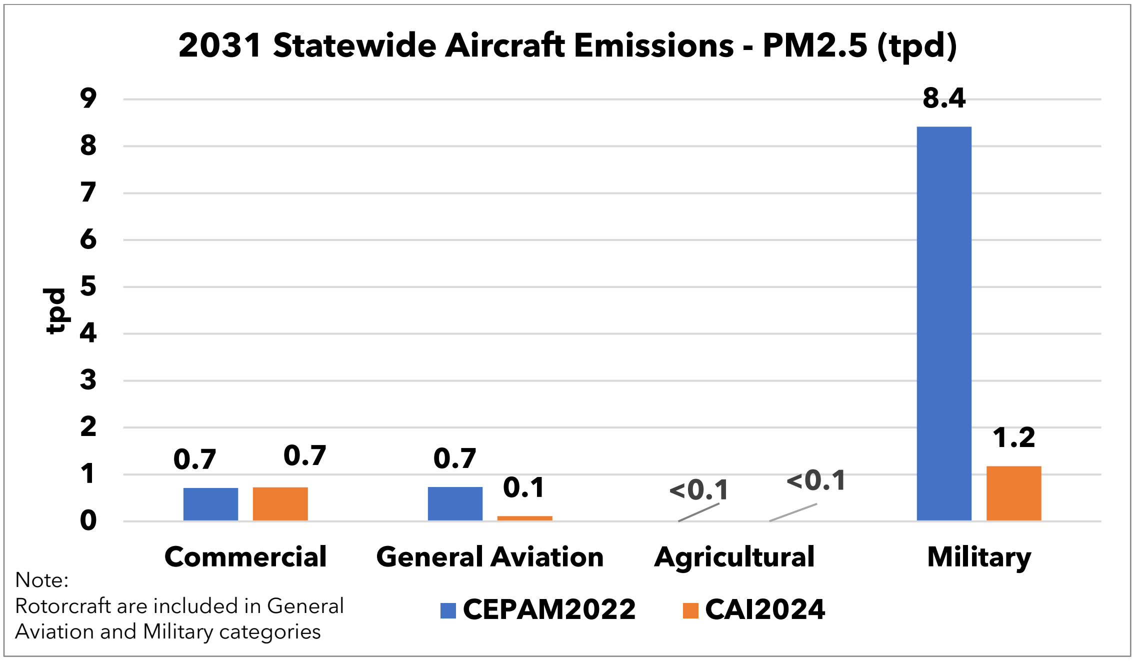


Figure 6: 2031 Annual Statewide PM2.5 Aircraft Emissions (tpd)

Background

Before releasing this statewide aircraft emissions inventory model, the local air districts prepared emissions inventories for the aviation sector. Every few years, districts reported their inventories to CARB as either area sources or point sources. CARB then reviewed the inventories and incorporated them into CEPAM to support the development of State Implementation Plans (SIP) and other air quality planning processes.

A benefit of the local air districts preparing their inventories was that airport or facility-specific information, such as the number or configuration of runways, terminals, and expansion plans, could be considered in the base year and forecasted year emissions. However, CARB staff identified opportunities to harmonize methodologies across air districts and developed a statewide emissions inventory model to replace the existing process and further support air quality planning processes moving forward. CARB's approach considers local specificity where available and defers to the FAA TAF 2023 for most other growth projections.

This technical documentation highlights the methodologies incorporated in the new CAI2024 Model (See Appendix A for description) and the revised emissions relative to previous air district calculations reported in CEPAM2022. In addition, it provides background on the airports and other aviation facilities in California, how emissions inventories are estimated for criteria pollutants, and aviation inventories at the federal level.

I. Approach for Calculating Aircraft Emissions

A unique element of aircraft emissions inventories for criteria pollutants is that only the portion of aircraft emissions below the vertical mixing height is included in the official inventory used for air quality planning. The mixing height is the level above which pollutants do not directly contribute to ground-level air quality. It is generally 3,000 feet according to Title 40, Code of Federal Regulations, § 93.153[7]. Therefore, emissions are typically calculated or based on a Landing and Take-Off (LTO) cycle, as illustrated in Figure 7. Emissions from aircraft and auxiliary power units during landing, take-off, and taxiing are included. Since the mixing height can be significantly higher or lower than 3,000 feet for some areas in California, Appendix B details the impact of these mixing height changes. Although CARB does consider emissions above the mixing height, up to 10,000 feet, in air quality dispersion and photochemical models, only emissions below

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[7] Code of Federal Regulations, 2011, Title 40 § 93.153 (2011): 598-602

the mixing height are considered in the CAI2024 Model, which will serve as aircraft emissions for air quality planning purposes.

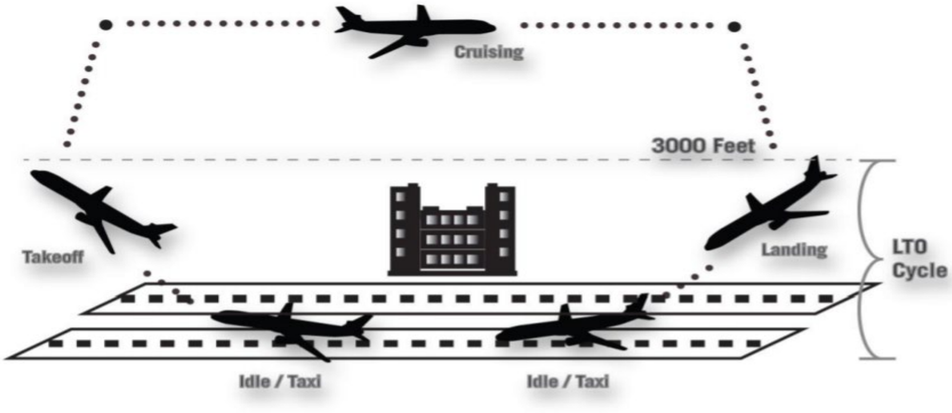

Figure 7: Landing and Take-Off (LTO) Cycle

II. Types of Aviation Facilities

According to BTS[8], there are currently 882 airport facilities in California, including private, Commercial, and heliport facilities. Note that CAI2024 only includes the 857 airport facilities from the FlightAware database that are active in operation, of which approximately 53 are medium to large airports (out of 53 airports, 13 are considered major Commercial airports), 439 small airports primarily for General Aviation, 21 Military airfields, and 344 heliports used by hospitals, law enforcement, and other entities for special use.

III. Types of Aircraft and Fuels

CAI2024 has four main categories of aircraft: Agricultural, Commercial, General Aviation, and Military. Each category includes jet and piston engines powered by jet fuel and aviation gasoline, as shown in Table 1. Rotorcraft (commonly known as helicopters) are any aircraft, including autogiro and gyrodyne, whose lift primarily comes from rotating airfoils. Due to the lack of data, Rotorcraft for General Aviation and Military operations were not considered in the previous inventory; however, they are included as separate subcategories in the CAI2024 Model.

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[8] Bureau of Transportation Statistics, 2024 Bureau of Transportation Statistics 2024

Table 1: Categories of Aircraft Operating in California

Category	Subcategory	Jet Engine (Jet Fuel)	Piston Engine (Aviation Gas)
Agricultural	Aerial Applicator (Crop Duster)	84.0%	16.0%
Commercial	Air Carrier	99.9%	0.1%
	Air Taxi	99.9%	0.1%
General Aviation	General Aviation Aircraft	6.6%	93.4%
	Rotorcraft	72.9%	27.1%
Military	Military Aircraft	99.4%	0.6%
	Rotorcraft	100.0%	0%

The Agricultural aircraft refers to Aerial Applicators, commonly known as Crop Dusters, that are used primarily to spray pesticides or fertilizer on farmland. Aerial Applicators can also include aircraft used for sowing seeds. The Commercial category includes Air Carriers and Air Taxis. An Air Carrier transports passengers or freight, whereas an Air Taxi is a smaller Commercial aircraft (less than 60 seats) used mainly for business travel. General Aviation includes aircraft (less than six seats) and Rotorcraft primarily for recreational flying, personal travel, law enforcement, news media, medical, and tourism. Finally, the Military category comprises Military aircraft and Rotorcraft for combat and non-combat purposes. Figure 8 below illustrates the types of aircraft discussed above.

Figure 8: Examples of Aircraft Types

IV. National Emissions Inventory (NEI)

Aircraft are also included in the United States Environmental Protection Agency (U.S. EPA) National Emissions Inventory (NEI)[9], which is a comprehensive emissions inventory of mobile and non-mobile sources updated every three years. Inventory data are provided by State, Local, and Tribal Air Agencies for sources in their jurisdiction and supplemented by data developed by U.S. EPA. The 2023 NEI is currently under development and review, with a scheduled release date of March 2026.

Except for California and Georgia, aircraft are modeled as point sources at the airport level in the 2020 NEI based on supplemental data from U.S. EPA's methodologies, including FAA's modeling tool (AEDT) and generic emissions factors based on activity data of flights from original airports.

Moving forward, any improvements CARB and local air districts in California make to the aircraft emissions inventory will be reflected in future releases of NEI. Due to the number of airports spanning General Aviation, Commercial, and Military operations in California and the unique topography that affects vertical mixing heights, it is essential to ensure adequate resources and attention are given to inventories for individual airports and regions to improve accuracy. For example, some airports may have growth constraints due to local noise reduction ordinances or limits on runway expansion, which are not reflected in federal growth estimates. Additionally, the fleet mix of Commercial aircraft operating in California may differ from the national average, impacting the base year and projected emissions.

Methodology

I. Commercial/General Aviation

a. Activity

The base year upon which emissions are estimated and forecasted for this inventory is calendar year 2022. Deriving emissions values for prior years may be performed based on available data and assumptions. There are two components to Commercial aircraft activity – the number of flights at a given airport and the fleet mix (combination of airframe and engine) that makes up those flights. For Commercial aircraft, this inventory

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[9] United States Environmental Protection Agency (U.S. EPA), The Nation Emission Inventory for 2023 *https://www.epa.gov/air-emissions-inventories/2023-national-emissions-inventory-nei-documentation*

used flight activity consistent with the 2023 TAF and a fleet mix from activity records in FlightAware as observed in CY 2022 (the base year).

Automatic Dependent Surveillance-Broadcast (ADS-B) is a technology used for air traffic control in the National Airspace system, allowing real-time flight status tracking of any aircraft equipped with an active ADS-B device. Aviation is deemed safer with the ADS-B enabled for traffic, weather, and flight information services. As of January 2, 2020, all aircraft must deploy an ADS-B device in the continental U.S. while flying in controlled airspace, as defined in Title 14 CFR 91.225[10]. If an aircraft is not equipped with an ADS-B device and plans to fly in the controlled airspace, the pilot must receive an Air Traffic Control (ATC) authorization before flying using the FAA's ADS-B Deviation Authorization Preflight Tool (ADAPT). These occurrences where flight operations occur without ADS-B broadcast may result in an underestimation of flight operation data collected. Details regarding ADS-B and controlled airspace can be found on the FAA website[11].

b. Aircraft Operations - FlightAware

FlightAware dataset was purchased for aircraft operating historical data from 2012 to 2022. The following columns were included in the dataset:

- Year
- Month
- Original International Civil Aeronautics Organization (ICAO) Airport Name
- Airport City
- Airport State
- Aircraft Type
- ICAO Aircraft Model Name
- Engine Type (Turbine/Piston)
- Engine Manufacture
- Engine Model Name
- Engine Size (Rated Power or Thrust)
- Average Year of Manufacture
- Count Total Departures
- Count Total Arrivals
- Count Total Unique Tails Seen

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[10] Electronic Code of Federal Regulations e-CFR, 91.225 Automatic Dependent Surveillance-Broadcast (ADS-B) Out equipment and use *Title 14 Section 91.225*

[11] FAA, *https://www.faa.gov/air_traffic/technology/equipadsb*

For CY 2022, FlightAware reported aircraft operations at 857 airports and heliports in California. The FlightAware dataset captures more airports than the TAF reported. In addition, FlightAware includes Rotorcraft operations. However, the dataset was missing some airframe and engine models for some airport flights. In such situations, CARB staff used the best engineering judgment to fill in some missing information, as described below. Generally, most air carriers and air taxis had complete information. Missing General Aviation aircraft information usually consisted of unknown aircraft engine models with piston engines (note that Lycoming engines are popular for General Aviation with piston engines). In this case, a surrogate, Cessna Skyhawk 172, was substituted for the missing aircraft engine model with the Lycoming engine. In general, FlightAware datasets match closely with TAF operation data for air carriers and air taxis. Table 2 below compares the annual operation between FlightAware and TAF for CY 2022.

Table 2: Comparison of Annual Operation for CY 2022 (FlightAware vs. TAF)

Sources		**2022 Operations**		
		Air Carrier	**Air Taxi**	**General Aviation**
FlightAware Dataset	Non-TAF airports	1,686	27,052	227,739
	TAF airports	1,719,958	753,910	3,349,100
TAF Operations (191 airports)		1,687,402	537,553	8,091,537

Since the FlightAware dataset substantially underreported General Aviation operations, likely due to pilots opting out of tracking where permissible as discussed above, CARB staff developed a method to include the breadth of airports included in FlightAware (which had high-resolution data on fleet mix), to correctly account for total operations that are included in FAA's TAF. To scale up the General Aviation operation count, staff compared the TAF annual operation of 191 publicly owned airports in California to the FlightAware annual operation for General Aviation. Additional FAA data not listed in the TAF report were obtained from fltplan.com, which tracks the annual operation of smaller private and public airports excluded in the TAF database. For airports listed in the TAF database and fltplan.com, the annual operation for General Aviation in FlightAware was scaled up to match the annual operation. For data not found in the TAF database and fltplan.com, the FlightAware dataset remained untouched. Table 3 shows an example of scaled-up operations for General Aviation.

Table 3: Scaling of General Aviation Operation

Source	Airport Name	Category	Engine Type	Operations		
				Original FlightAware	TAF/Fltplan.com	Final Scaled-Up
TAF	Van Nuys	Air Carrier	Jet	1,211		1,211
			Piston	4		4
			Turboprop/Turboshaft	4		4
		Air Taxi	Jet	70,903		70,903
			Turboprop/Turboshaft	2,681		2,681
		General Aviation	Piston	73,613	242,202	234,768
			Turboprop/Turboshaft	2,331		7,434
		Rotorcraft	Piston	3,564		3,564
			Turboprop/Turboshaft	15,438		15,438
		Military	Jet	23		23
			Piston	548		548
			Turboprop/Turboshaft	33		33
Fltplan.com	Perris Valley	Air Taxi	Turboprop/Turboshaft	5,574		5,574
		General Aviation	Piston	811	27,000	6,442
			Turboprop/Turboshaft	2,651		21,058
		Rotorcraft	Piston	6		6
			Turboprop/Turboshaft	54		54

The FlightAware and no other known datasets include information specifying the type of aircraft for each operation as Air Carrier, Air Taxi, or General Aviation. Therefore, staff aligned with FAA by designating aircraft with 60 seats or more as Air Carriers. Air Taxis are identified by FAA's list of certificated Part 135[12] aircraft operators with specific tail numbers; however, the FlightAware dataset does not contain tail number descriptions. Therefore, in CAI2024, staff designated Air Taxis as aircraft with cabin pressurization, equipped with turbine engines, and six seats or more. Staff acknowledges that there may be some privately operated aircraft that are classified as Air Taxi instead of General Aviation in CAI2024. Nevertheless, the classification of airframes will have no impact on total emissions in the base year, and only minimal impact on the total emissions in forecasted years due to the similarity in growth trends of Air Taxis and General Aviation.

c. Aircraft Emissions Factors

CARB staff estimated Commercial aircraft emissions using version 3e of AEDT, developed by the FAA and maintained by the Department of Transportation (DOT). In May 2015, AEDT replaced the Emissions and Dispersion Modeling System (EDMS) as the gold standard for estimating emissions from Commercial and other types of aircraft based on certification data collected by ICAO.

CARB staff used AEDT to estimate fuel consumption, carbon dioxide (CO2), carbon monoxide (CO), hydrocarbons (HC), volatile organic compounds (VOC), total organic gases (TOG), NOx, oxides of sulfur (SOx), and particulate matter (PM). CARB staff assumed ROG and VOC are quantitatively the same for inventory planning purposes. For HC and TOG emissions factors for categories not provided by AEDT (such as Agricultural or Military), CARB staff estimated those emission factors based on average ratios of AEDT outputs separated by piston and jet engines. For piston engines, the ratios for HC/ROG and TOG/ROG are 1.1931 and 1.1712, respectively. Similarly, for jet engines, the ratios are 0.8381 and 1.0052.

To run AEDT, specific information regarding the airport, aircraft, and annual operations must be selected from the lists embedded in the AEDT or utilizing customized files. The data needed to estimate an airport-specific aircraft emission using AEDT includes the airframe, engine model, and flight profile of a particular airport. AEDT has amassed an extensive database of airports across the globe for the user to choose from, where specific information needed for the airport, airframe, and engine model are typically selected from the embedded lists. Default values may be used for meteorological information if no specific information is available.

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[12] FAA-certificated Aircraft Operators (Legal Part 135 holders) *https://www.faa.gov/about/officeorg/headquartersoffices/avs/faa-certificated-aircraft-operators-legal-part-135-holders*

For each airport with operation data from FlightAware, CARB staff calculated emissions by selecting and using appropriate aircraft model and engine combinations in AEDT. CARB staff first used a default setting of 3,000 feet for mixing height, airport-specific defaults taxi-in and taxi-out times, APU run times (26 minutes per LTO), and a stage length of 1 (which estimates the approximate take-off weight of each aircraft). Subsequently, CARB staff developed and applied correction factors to AEDT model outputs to customize mixing heights, taxi times, and stage lengths for each airport, aircraft, and calendar year, as appropriate. CARB developed and incorporated these adjustments into the CAI2024 model code, based on analysis of additional outputs from AEDT.

(i) Mixing Height

The mixing height refers to the elevation above ground level, beyond which air pollution no longer readily mixes with ground-level air and does not substantially impact ground-level air pollution levels. The aircraft inventory only includes emissions from the ground level up to the mixing height, typically 3,000 feet above ground.

For this Model, CARB staff calculated a unique mixing height for each airport and applied a single static mixing height for operations regardless of the time of day or season of the year. Mixing heights were calculated using the Planetary Boundary Layer (PBL) from the ERA5[13] reanalysis data from 2021. CARB staff used a mixing height based on the 95th percentile of the averages for each combination of hour of day and month of year. Given there are 24 hours in a day and 12 months in a year, a total of 288 mixing height values were obtained for each airport. The highest 95th percentile was selected to represent the mixing height for that airport for all operations of the year. For the 288 hourly average mixing heights, the 14th highest value (or 95th percentile) was selected for each airport, as illustrated in Figures 9 to 11 below and listed in Table 4. See Appendices C and D for the list of California airports with spatial coordinates and the corresponding annual, winter, and summer mixing heights.

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[13] Copernicus Climate Change Service (C3S): ERA5: Fifth generation of ECMWF atmospheric reanalysis of the global climate, 2017

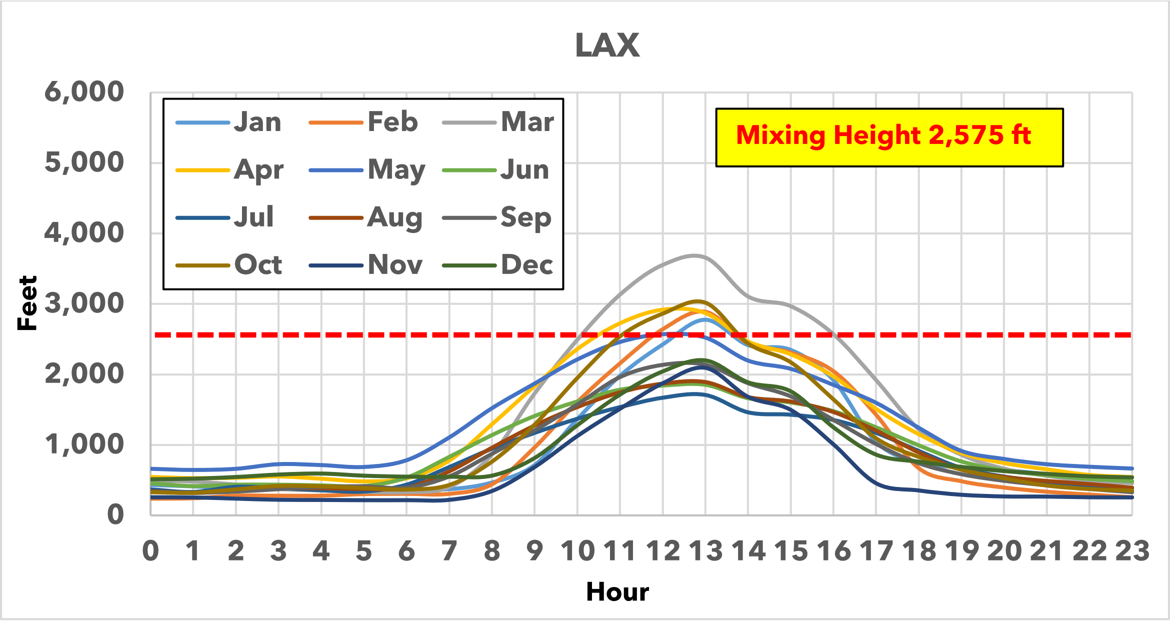

Figure 9: Mixing Height for LAX

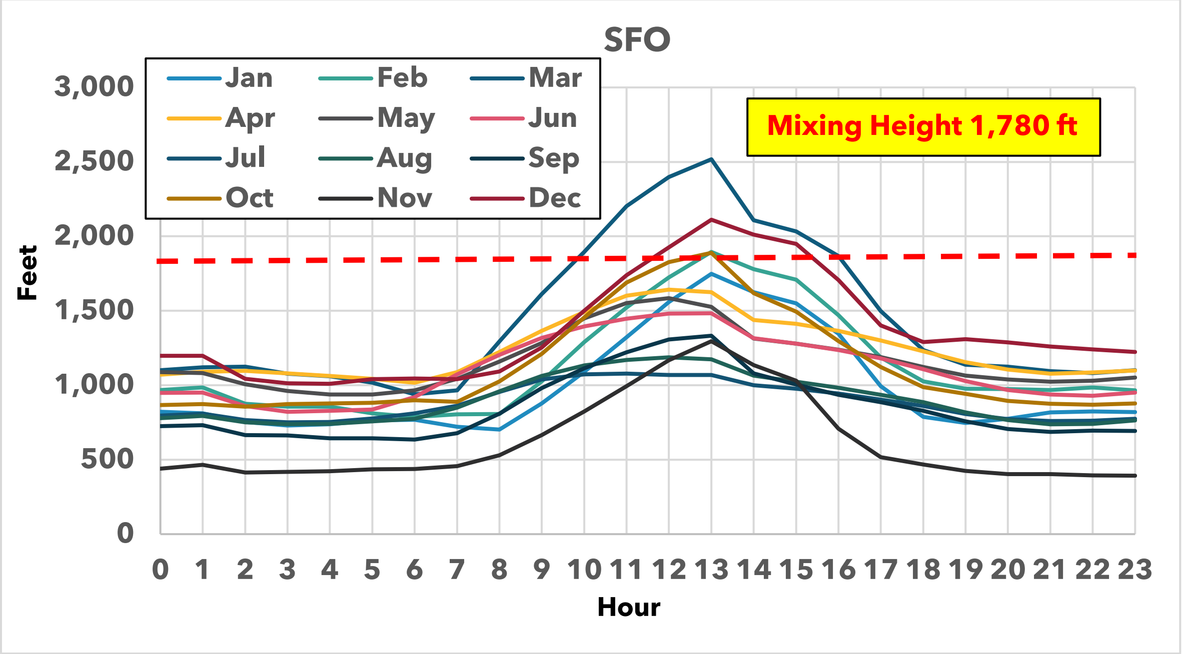

Figure 10: Mixing Height for SFO

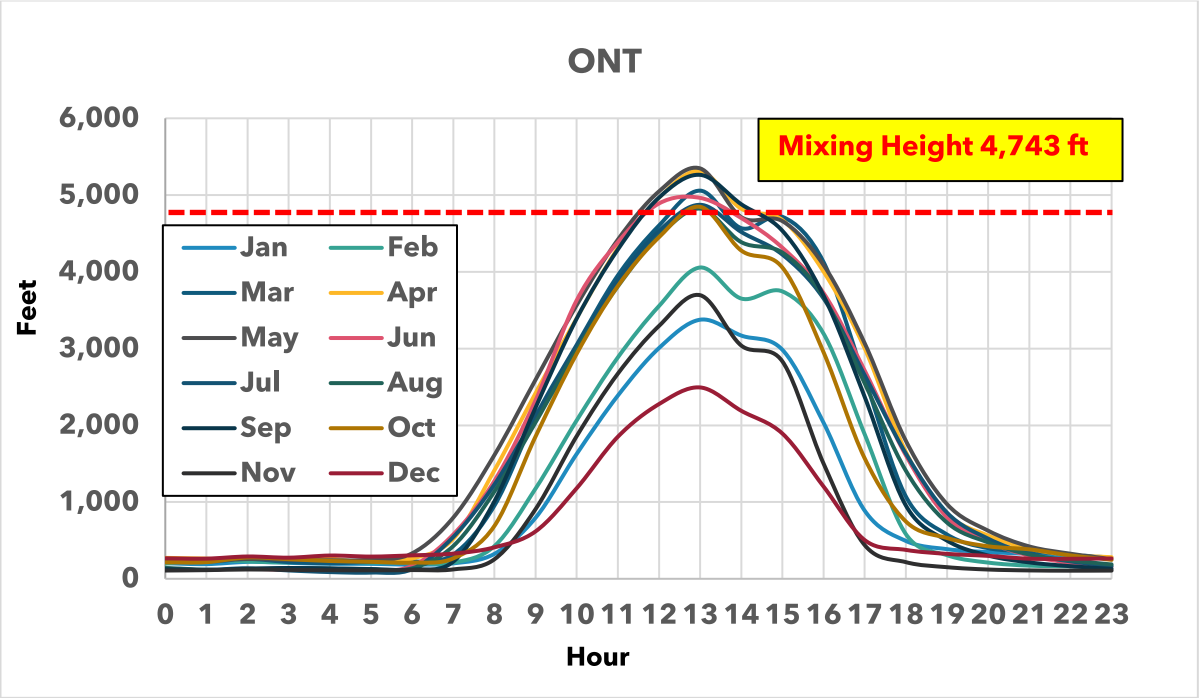

Figure 11: Mixing Height for ONT

Table 4: Mixing Height Comparison for Major Airports in California

Airport	Code	Mixing Height from CEPAM2022 (ft)	Proposed Mixing Height (ft)
Los Angeles International Airport	LAX	1,800	2,575
San Francisco International Airport	SFO	2,300	1,780
San Diego International Airport	SAN	3,000	1,797
San Jose International Airport	SJC	2,300	2,833
Oakland International Airport	OAK	2,300	2,503
Sacramento International Airport	SMF	3,000	4,375
John Wayne Airport	SNA	1,900	2,330
Hollywood Burbank Airport	BUR	2,500	3,930
Ontario International Airport	ONT	3,000	4,743
Long Beach Airport	LGB	1,800	3,235
Palm Springs Airport	PSP	4,000	7,046
Fresno International Airport	FAT	3,000	5,198
Santa Barbara Airport	SBA	3,000	1,592
San Bernardino Airport	SBD	3,500	5,771

(ii) Changes to Taxi-In and Taxi-Out Duration

The Taxi-In and Taxi-Out times for each airport are based on the default value in the AEDT model except where otherwise provided by local air districts. Table 5 summarizes the Taxi-In and Taxi-Out duration for the top fifteen airports in California as provided in AEDT.

Table 5: Taxi-In and Taxi-Out Duration for Top 15 Airports in CA (AEDT)

Airport	Code	(min)	
		Taxi-In	Taxi-Out
Los Angeles	LAX	8.02	14.92
San Francisco	SFO	5.68	16.18
San Diego	SAN	3.70	13.28
John Wayne	LGB	6.13	13.15
Metro Oakland	OAK	5.35	10.75
San Jose	SJC	4.15	12.07
Sacramento	SMF	4.22	10.08
Bob Hope	BUR	2.72	11.70
Ontario	ONT	4.32	10.58
Van Nuys	VNY	6.10	12.30
Palm Springs	PSP	4.42	10.80
Daugherty Field	LGB	4.70	14.15
Fresno-Yosemite	FAT	4.38	9.92
Santa Barbara	SBA	4.15	9.80
Monterey Regional	MRY	3.50	10.05

CAI2024 is structured such that major airport custom taxi times could be adjusted to modify the total emissions outputs for arrival and departure. Table 6 shows the magnitude of the emissions increase or decrease for the respective portion of the LTO due to a one-minute change in the taxi time. More specifically, the values shown are presented as a fraction of LTO emissions separated into two groups according to departure or arrival. This means the percentage increase for Taxi-In includes all operations of descent below the mixing height, landing, and taxiing to the gate. Similarly, the percent increase for Taxi-Out includes all emissions starting with taxiing to the runway, taking off, and ascending to the mixing height.

Table 6: Example of Taxi Time Impact on Emission Factors (8 to 9 Minutes)

Aircraft/Engine Average	Correction +/- per 1 minute change from 8 to 9 minutes							
	ROG		NOx		CO2		PM2.5	
	Taxi-In	Taxi-Out	Taxi-In	Taxi-Out	Taxi-In	Taxi-Out	Taxi-In	Taxi-Out
All Aircraft	10.7%	11.9%	2.8%	0.8%	5.2%	4.1%	5.9%	4.0%

Extending or decreasing taxi time generally affects ROG emissions and NOx emissions to a lesser degree. For example, by increasing the taxi time by one minute (e.g., from 8 to 9 minutes), the ROG emissions increased on average by 10.7 and 11.9 percent for Taxi-In and Taxi-Out, respectively. The average increases for NOx for these two modes were substantially lower – 2.8 and 0.8 percent for Taxi-In and Taxi-Out. Staff additionally compared the taxi time changes for a given aircraft (same airframe and engine model) between BUR and LAX, but the difference was less than 0.5 percent. Therefore, the differentiation between airports was not a factor in the impact of taxi time emission based on AEDT model outputs. As a result, CARB staff incorporated the linear adjustments outlined in Table 6 into CAI2024 and matched the specific taxi times for the major airports within the SCAQMD[14], as shown in Table 7 below. For the in-between years not listed, as shown in the example of LAX 2018, the same Taxi-In time of 12.18 minutes remained the same for all years through CY 2022. LAX's new Taxi-In time increased to 13.26 minutes starting in CY 2023.

Table 7: Taxi Times for Major Airports in SCAQMD

Airport	SCAQMD	
	Taxi-In (min)	Taxi-Out (min)
BUR (2018, 2023)	1.25	4.67
BUR (2031,2037)	2.49	2.97
LAX (2018)	12.18	19.24
LAX (2023)	13.26	21.01
LAX (2031)	15.76	24.97
LAX (2037)	17.91	28.39
LGB	4.39	13.17
ONT (2019)	5.28	12.18
ONT 2023	5.28	13.53
ONT 2031	5.43	14.42
ONT 2037	5.43	14.47
PSP	5.00	5.00
SNA	5.75	9.63

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[14] SCAQMD, Revised Draft 2022 AQMP Aircraft Emissions Inventory Report, October 2021 *http://www.aqmd.gov/docs/default-source/Agendas/aqmp/2022-aqmp-ag/revised-draft-2022-aqmp-aircraft-emissions-inventory-report.pdf*

(iii) Stage Length

When running AEDT to obtain emission factors, stage length can be varied for each airframe/engine combination. Stage length is a parameter in AEDT[15] that represents the flight distance from take-off to landing and is a proxy for the aircraft weight. The weight associated with the stage length is based on the assumed fuel needed for the flight distance. Table 8 lists the trip length corresponding to each stage number.

Table 8: List of Stage Number and Trip Length

Stage Number	Trip Length (nautical miles)
1	0-500
2	500-1,000
3	1,000-1,500
4	1,500-2,500
5	2,500-3,500
6	3,500-4,500
7	4,500-5,500
8	5,500-6,500
9	6,500-11,000
M	Maximum range/take-off weight

Most aircraft in General Aviation and air taxi categories have a stage length equal to 1; however, air carrier aircraft typically have a stage length greater than 1. Most air carrier short flights are stage length 2 to 3. The highest stage length belongs to the international wide-body aircraft, which has a stage length of 7 to 8. Presently, SCAQMD provides stage lengths for the major airports in their district, which CARB staff reflected in CAI2024 for the respective airports. Since no other districts provided stage length data, CARB staff used composite stage length data from SCAQMD combined from all airports, but separated by airframe/engine combinations, as a surrogate and applied them to all airports statewide.

(iv) Startup Emissions

Startup emissions are included in the emissions outputs from AEDT and apply only to departure operations for HC. According to the ICAO Air Quality Manual[16], "During the

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[15] Federal Aviation Administration (FAA). Aviation Environment Design Tool AEDT 3E Technical Manual, Tables11-16, p410 *https://aedt.faa.gov/Documents/AEDT3e_TechManual.pdf*

[16] ICAO Air Quality Manual, *https://www.icao.int/environmental-protection/Documents/Doc%209889.SGAR.WG2.Initial%20Update.pdf*

starting sequence, there is very little NOx emissions produced compared to the LTO cycle due to the very low engine temperatures and pressures, and the only emissions that require consideration during the starting sequence are HC. Aircraft main engine starting can generally be broken down into two phases: pre-ignition and post-ignition." Startup emissions for some airframe/engine combinations can account for a large percentage of the HC departure cycle.

(v) PM Emissions from Tire Wear

The 2013 National Academies of Sciences, Engineering, and Medicine paper titled "Measuring PM Emissions from Aircraft Auxiliary Power Units, Tires, and Brakes"[17] measured emissions from tires during aircraft landing events. It was determined that particles are emitted when aircraft land, which is visually observable by a puff of smoke. More than 100 aircraft landings were monitored and the measurements collected from 23 of the landings were used to characterize tire emissions by aircraft type as shown in Table 9.

Table 9: Average Tir Wear Loss by Aircraft Body Type

Aircraft Type	Tire Wear Loss (g)
Large Narrowbody	0.246
Widebody	1.041
Small Narrowbody (Air Carrier+Air Taxi)	0.112

From the study, the weighed activity tire wear PM emission factor was calculated to be 0.263 grams. For comparison, the weighted exhaust PM emission factor derived from AEDT (from Air Carrier and Air Taxi aircraft) was calculated to be 30.247 grams. Thus, the ratio of tire wear PM to exhaust PM is 0.0087 (0.87%), and tire wear PM is included in the total PM emissions.

(vi) Evaporative Emissions

Evaporative emissions are not accounted for in CAI2024. Staff will evaluate the methodology to incorporate evaporative emissions for future updates of the Model. Evaporative emissions are most likely applicable only to piston engine aircraft from General Aviation using aviation gasoline, which is slightly denser than the current California retail gasoline used in on-road and off-road applications and has a lower Reid

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[17] National Academies of Sciences, Engineering, and Medicine. 2013 *https://nap.nationalacademies.org/catalog/22457/measuring-pm-emissions-from-aircraft-auxiliary-power-units-tires-and-brakes*

Vapor Pressure (RVP). The main factors for determining evaporative emissions will be the fuel line, fuel tank size, and the temperature profile of where the aircraft is stored. Staff assumed that aviation fuel will behave similarly to diesel due to their similar densities and physical properties, thus evaporative emissions are considered negligible from jet fuel used in turbine engines.

d. Auxiliary Power Units

An auxiliary power unit (APU) is a small gas turbine engine that runs on jet fuel inside the back section of an aircraft that provides electrical and pneumatic power when the aircraft's main engines are not running. A 2018 research paper written by Anil Pahdra[18] details the data collection for APU usage, which was utilized to determine how APU emissions are estimated. Figure 12 shows the typical aircraft turnaround procedure.

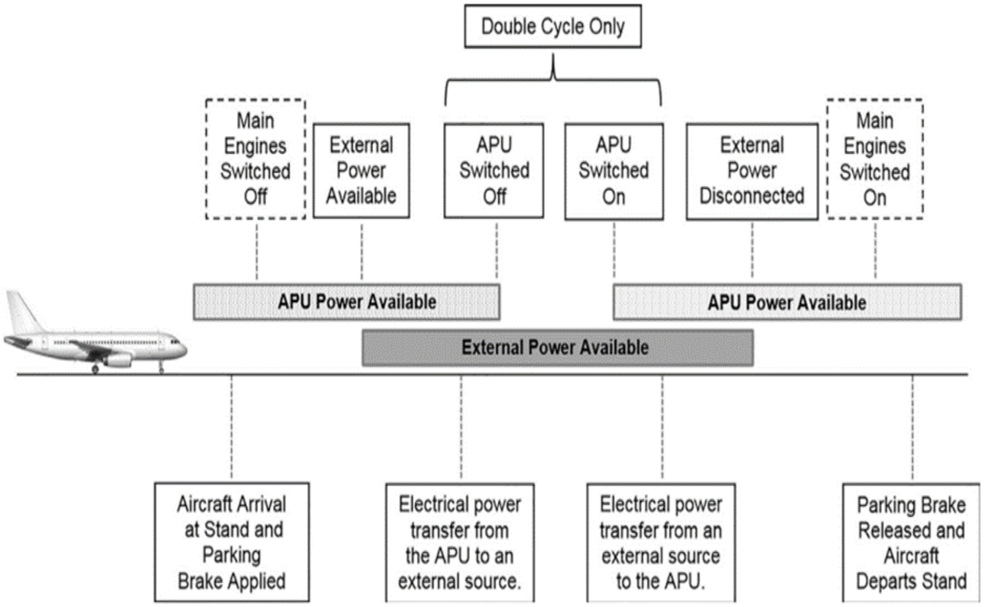

Figure 12: Typical Aircraft Turnaround Procedure (Source: Pahdra[18])

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[18] Padhra, Anil, Emissions from auxiliary power units and ground power units during intraday aircraft turnarounds at European airports, University of West London, UK, June 2018

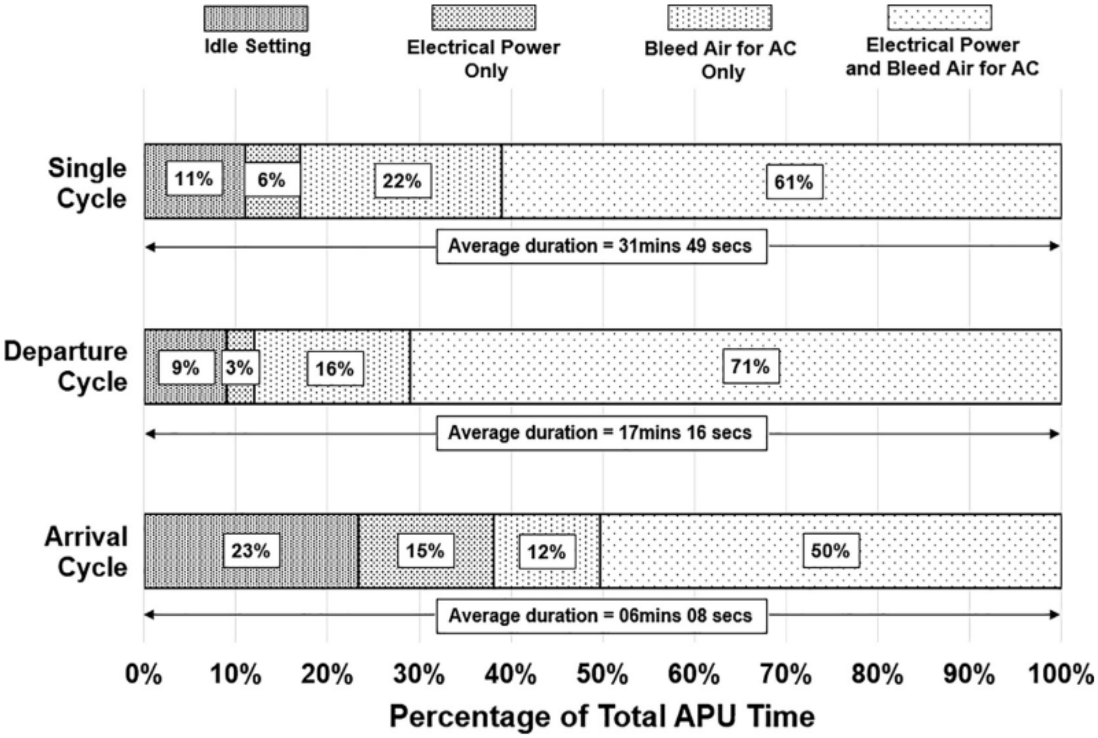

Figure 13: APU Single vs Double Cycle Event (Source: Pahdra[18])

Pahdra's research paper categorizes APU events into a single-cycle event (26% of the time) or a double-cycle event (74% of the time). The average duration of a single-cycle event is about 31 minutes compared to 22 minutes for a double-cycle event, as illustrated in Figure 13 above. In Europe, the composite average APU usage for aircraft turnaround is approximately 26 minutes as described in the study. The data from the study mostly consisted of narrow-body jets, which typically have lower turnaround times.

In another case study[19] authored by the University of California, Berkley, the data collected on SFO operations in 2019 indicated a much higher APU usage time, where "Despite the apparent incentive to use less expensive power, gate turnaround operations appear to use GP (ground power) at a fraction of its potential. 64% of operations use GP for an average of 62.5% of their turnaround time, and 36% do not use GP at all." Additionally, OAG, a flight data collection company, completed a 2023 study[20] that compared the turnaround times from different airlines, which showed an average

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[19] University of California, Berkley, "Reducing Emissions through Monitoring and Predictive Modeling of Gate Operations of Idle Aircraft: A Case Study on San Francisco International Airport," 2019

[20] OAG Aviation Worldwide Limited (OAG), *https://www.oag.com/blog/science-aircraft-turnarounds*

turnaround time of 72 minutes, with narrow-body jets having a lower turnaround time compared to wide-body jets. This equates to an APU usage time of approximately 42 minutes when the turnaround times averaged 72 minutes.

The default time for an APU in the AEDT is 13 minutes per arrival or departure operation. The aircraft inventory was adjusted to increase the APU usage time due to the turnaround time (42 minutes, or 21 minutes per arrival or departure) and the additional APU runtime for departure as indicated in Table 7. In the future, APU times are forecasted to increase due to the taxi-out time during departure, specifically for LAX and ONT. Appendix E contains a list of all aircraft with corresponding APU models from the AEDT database. Most air carriers and some air taxis have APUs, whose emissions contribute 6 percent of NOx and 15 percent of PM2.5 out of the total statewide aircraft emissions in CY 2022, as shown below in Table 10.

Table 10: Percent Contribution of APU Emissions to LTO Emissions (CY 2022)

Emissions	ROG (tpd)	NOx (tpd)	PM2.5 (tpd)
APU Emissions	0.25	2.66	0.31
Total Emissions	16.52	41.25	2.04
APU Contribution (%)	1.48%	6.45%	15.13%

e. Forecasting

Fleet mix information of aircraft will continue to change to reflect newer aircraft and engine models that enter the market. Flight operations will also fluctuate and may be seen as an indicator of the condition of the economy and local or global crises (e.g., the COVID-19 pandemic). Default operations listed in the 2023 TAF are used to forecast activity to CY 2050 for air carriers, air taxis, and General Aviation. Military growth is modeled by the TAF (2023) Military growth rate which is close to zero, and Rotorcraft growth is assumed to be the same as General Aviation. The annual growth (-0.3634%) for Aerial Applicators was adopted from CARB's 2021 Agricultural inventory[21] and the growth estimate was based on the trend of total harvested acreage in California (CY 2022 to CY 2024) from the U.S. Department of Agriculture[22].

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[21] CARB, 2021 Agricultural Equipment Emission Inventory *https://ww2.arb.ca.gov/sites/default/files/2021-08/AG2021_Technical_Documentation_0.pdf*

[22] U.S. Department of Agriculture, NASS California Field Office, *https://www.nass.usda.gov/Statistics_by_State/California/index.php*

In developing CAI2024, CARB staff engaged with the local air districts through the Emissions Inventory Technical Advisory Committee (EITAC), and several other direct meetings with inventory staff at multiple districts. Through these efforts, CARB identified how and where local air districts used constraints for certain airports due to space or other factors and custom fleet mix projections for future years to reflect turnover to newer aircraft models. Where provided by local air districts, CARB used custom future fleet mix growth files and fleet mixes. The major airports with custom files included LAX, LGB, ONT, SNA, SBD, PSP, SFO, and SAN. The SCAQMD's Revised Draft 2022 AQMP Aircraft Emissions Inventory[23] has specific fleet mix growth for CY 2031 and CY 2037, while SAN[24] has a projected operation for 2030 and 2040. In addition, the future growth rates for SFO[25] are based on the 2023 TAF and capped at CY 2030 to reflect long-term forecasts of high constraint levels attained by the early 2030s.

Whereas future fleet mix for the Bay Area Air Quality Management District (BAAQMD) airports could be modeled similarly to the SCAQMD and San Diego Air Pollution Control District (SDAPCD) fleet mix for consistency because airplanes travel consistently up and down the State, CARB staff forecasted Bay Area airport operations using only TAF growth rates with the same fleet mix as reported by FlightAware for CY 2022 (base year). The forecasts of operation for the future years from SCAQMD and SDAPCD were incorporated into the inventory using a specific matrix and illustrated in Table 11.

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[23] SCAQMD, Revised Draft 2022 AQMP Aircraft Emissions Inventory Report, October 2021 *http://www.aqmd.gov/docs/default-source/Agendas/aqmp/2022-aqmp-ag/revised-draft-2022-aqmp-aircraft-emissions-inventory-report.pdf*

[24] Leigh, Fisher, San Diego Regional Airport Authority, Final Technical Memorandum: Aviation Activity Forecast Update – San Diego International Airport, April 2019

[25] San Francisco International Airport: Upcoming Construction Projects Overview, February 2024

Table 11: Forecasts for SCAQMD and SDAPCD CY 2022 and CY 2031+

Type	Airport	2022	2031+
Air Carrier	John Wayne	FlightAware Activity and Fleet Mix Data	South Coast Activity and Fleet Mix[23]
	San Bernardino		
	Ontario		
	Long Beach		
	Burbank		
	Los Angeles		
	Palm Springs		
	San Diego		San Diego Activity and Fleet Mix[24]
Air Taxi	Orange County		FlightAware Activity and Fleet Mix
	San Bernardino		
	Ontario		
	Long Beach		
	Burbank		
	Los Angeles		
	Palm Springs		
	San Diego		San Diego Activity and Fleet Mix[24]

As discussed in the published reports by SCAQMD and SDAPCD, the main goal of future fleet mix projections is the introduction of newer engines that replace older engine aircraft. From the 2022 SCAQMD report, newer Boeing 737 MAX aircraft with LEAP engines will replace older Boeing aircraft with CFM engines. Likewise, newer Airbus NEO aircraft will replace older Airbus models, as shown in Table 12.

Table 12: Replacement Aircraft Engines

Existing/Older	Replacement/Newer
Aircraft/Engine	Aircraft/Engine
Boeing 737-800 CFM56-7B27E	Boeing 737-MAX8 LEAP-1B25
Boeing 737-700 CMF56-7B24	Boeing 737-8MAX LEAP-1B28
Airbus A319-100 CFM56-5B7/3	Airbus A220-100 PW1519G

II. Freight

The Model does not differentiate the air carrier operation, whether passenger or freight. Future updates will be able to differentiate passenger and freight air carriers and airline operators. Staff analyzed the current air carrier data and schedules of several freight company flights and estimated that 4 to 5 percent of air carrier operations that travel through California are dedicated freight aircraft. Major airports that receive freight air carriers are ONT, SBD, LAX, BUR, LGB, SNA, FAT, OAK, SFO, SJC, SMF, and Mather Airport (MHR). Additional freight is transported on passenger-carrying aircraft, and their emissions are included, but not disaggregated, in CAI2024.

III. Rotorcraft

The FlightAware dataset captured many Rotorcraft operations, most of which operated out of heliports. Typical heliport usage included hospitals, law enforcement, fire, Military, and others. AEDT provided Rotorcraft emission factors, and the mixing height for Rotorcraft was under 1,000 feet. However, since AEDT's Rotorcraft emission factor did not include PM emissions, staff applied PM emission factors obtained from the Swiss Federal Office of Civil Aviation (FOCA)[26].

IV. Agricultural - Aerial Applicators

a. Aerial Applicator Methodology

The FlightAware database also includes aircraft and Rotorcraft used in agricultural applications. Identifying which particular aircraft are used is difficult because the dataset only provides airframe and engine models, but not for the purpose of operation. Additionally, most Rotorcraft models can be modified and equipped for aerial applications. Table 13 contains fixed-wing aircraft that can be used in Agricultural applications.

Table 13: Aircraft Used in Agricultural Applications

Manufacturer	Model	Engine Type
PZL Mielec	PZL-106 Kruk	Piston
	PZL-106 Kruk Turbo	Turboprop
	PZL M14	Turboprop
	PZL M15 Belphegor	Piston
	PZL M18 Dromader	Piston
	PZL M21 Dromader Mini	Piston
	PZL M24 Dromader Super	Piston
	PZL M25 Dromader Micro	Piston

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[26] Swiss Federal Office of Civil Aviation (FOCA), "Guidance on the Determination of Rotorcraft Emissions, Edition 2, Dec 2015 *https://www.bafu.admin.ch/dam/bafu/en/dokumente/klima/klima-climatereporting-referenzen-cp1/foca_2009a.pdf.download.pdf/foca_2009a.pdf*

Manufacturer	Model	Engine Type
	PZL M30	Turboprop
Air Tractor	AT300/AT301/AT301B/AT302/AT302A	Piston
	AT402B	Turbine
	AT502B	Turbine
	AT504	Turbine
	502XP	Turbine
	AT802A	Turbine
Aero Commander	S-2D Ag Commander	Piston
Thrush Aircraft	Thrush 510	Turboprop
	Thrush 550	Turboprop
	Thrush 710	Turboprop
Cessna	Cessna 188	Piston
Piper	Piper PA-25 Pawnee	Piston
Grumman	Grumman Ag Cat	Piston
	Super Ag	Piston
	Turbo Ag	Turboprop
Embraer	EMB 202 Ipanema/202A/203	Piston
Zlin	Zlin Z-37	Piston
	Zlin Z-37 Turbo	Turboprop
Pacific Aerospace	PAC Cresco 08-600	Turbine
	Cresco 08-750	Turboprop
	Cresco II	Turboprop
Aero Boero 260AG	AG.235/260	Piston

Since the FlightAware dataset only contained a few specific models, namely the Air Tractor and Grumman models, CARB staff used a methodology based on the acreage sprayed, as detailed in the San Joaquin Valley Air Pollution Control District (SJVAPCD) 2012 Area Source Emissions Inventory Methodology[27], to capture the emissions inventory of Aerial Applicators. The methodology consisted of:

1. Obtaining acreage sprayed aerially by the county based on the California Department of Pesticides Regulations.
2. Identifying the proportion of aircraft and Rotorcraft used for aerial applications.
3. Determining the acreage spray per hour for fixed-wing aircraft and Rotorcraft.
4. Determining the fuel consumption (gallons/hour) for fixed-wing aircraft and Rotorcraft.
5. Calculating emissions per gallon using AEDT software.

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[27] San Joaquin Valley Air Pollution Control District, 2012 Area Source Emissions Inventory Methodology, 810 – Civilian Aircraft, October 2013 *https://ww2.valleyair.org/permitting/emission-inventory/areawide-inventory/*

The equation used to calculate emissions is as follows:

Emissions (tons/yr) = (acreage sprayed aerially/yr) x [(percent aircraft x acre/hour) + (percent Rotorcraft x acre/hour)] x [(percent of aircraft x gallons/hour) + (percent Rotorcraft x gallons/hour)] x [(percent aircraft x emissions/gallon) + (percent Rotorcraft x emissions/gallon)]

The California Department of Pesticides Regulation (CDPR) publishes a yearly accounting of pesticides applied to crops in the Pesticide Use Report (PUR)[28] database as shown in Table 14. The database includes information about crop type, acreage, and pesticides used along with the application method of ground, aerial, or other. The acreage sprayed is the cumulative total, whereas some crop acreage can be sprayed multiple times. San Joaquin Valley counties have the highest acreage sprayed. In contrast, more populated counties such as the Bay Area and Los Angeles and less populated mountain regions in California have minimal acreage sprayed aerially.

Table 14: 2021 CDPR Acreage Sprayed Aerially by County (PUR Database)

Area	Acreage Treated	Area	Acreage Treated
Alameda	2	Orange	15
Alpine	0	Placer	41,580
Amador	2,437	Plumas	948
Butte	570,471	Riverside	198,856
Calaveras	2,793	Sacramento	123,201
Colusa	629,491	San Benito	6,843
Contra Costa	23,470	San Bernardino	712
Del Norte	0	San Diego	27,236
El Dorado	1,805	San Francisco	3
Fresno	1,955,831	San Joaquin	596,499
Glenn	564,129	San Luis Obispo	18,352
Humboldt	0	San Mateo	4
Imperial	1,498,985	Santa Barbara	49,313
Inyo	0	Santa Clara	11,062
Kern	425,871	Santa Cruz	791
Kings	2,567,470	Shasta	13,474
Lake	1,599	Sierra	0
Lassen	38,573	Siskiyou	39,098
Los Angeles	825	Solano	126,270
Madera	415,415	Sonoma	10,965
Marin	0	Stanislaus	235,816

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[28] Pesticide Use Report (PUR) database, *https://www.cdpr.ca.gov/docs/pur/purmain.htm*

Area	Acreage Treated	Area	Acreage Treated
Mariposa	198	Sutter	353,755
Mendocino	821	Tehama	62,535
Merced	743,900	Trinity	0
Modoc	64,405	Tulare	359,046
Mono	0	Tuolumne	223
Monterey	606,260	Ventura	64,471
Napa	5,958	Yolo	190,110
Nevada	37	Yuba	146,858
Statewide Total	**12,798,784**		

The types of equipment used for aerial spraying are provided by fixed-wing aircraft, Rotorcraft, and drones, as shown below in Table 15. Since equipment characteristic data on applying pesticides with gasoline-powered drones was not available, CARB staff did not consider those emissions in CAI2024. Likewise, aerial seeding operations used in rice crop farming are not included. The National Agricultural Aviation Association (NAAA)[29] lists the percentage of aircraft versus Rotorcraft for aerial applications as 84 percent aircraft and 16 percent Rotorcraft. Likewise, of the combined fleet, 81 percent are turbine-powered, and 19 percent have piston engines, according to NAAA.

Table 15: Types of Equipment Used for Aerial Spraying

Aerial Applicator Type	Use Percentage	Acres/hour[2]	Fuel Consumption (gal/hr)
Aircraft	84%	112	48
Rotorcraft	16%	25	15
Weighted		**98.1**	**42.7**

The fuel consumption numbers for fixed-wing aircraft are based on the fuel consumption of Air Tractors. Table 16 below contains the average fuel consumption used.

Table 16: Average Fuel Consumption Based on Air Tractor Models

Air Tractor Models	Estimated Fuel Consumption (gal/hr)
ATI AT-300	25
ATI AT-400	37
ATI AT-502/P615AG	48
ATI AT-602/P660AG	61
ATI AT-802/P665AG	68
Average	**48**

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[29] National Agricultural Aviation Association (NAAA), *https://www.agaviation.org/about/about-ag-aviation/industry-facts-faqs/*

AEDT provides emission factors for Aerial Applicator aircraft and Rotorcraft. The major Agricultural aircraft listed in AEDT and found in the FlightAware dataset include Air Tractor models, specifically the AT-500, AT-600, and AT-800 series. Since most Rotorcraft can also be equipped with agricultural sprayer equipment, staff averaged all the Rotorcraft models from AEDT. Table 17 lists the emission factor in tons per million gallons, and Table 18 contains the emissions from aerial applications by county.

Table 17: Emission Factors for Aerial Applicator Aircraft (tons per million gallons)

AEDT Equipment Type	Operation	Mode	ROG	NOx	PM2.5
All ATI Models Avg	Arrival	Descend Below Mixing Height-Taxi Time	14.08	14.43	0.35
	Departure	Climb Below Mixing Height-Taxi Time	14.03	14.44	0.15
All Rotorcraft Avg	Arrival	Descend Below 1,000 ft	4.15	26.48	-
	Departure	Climb Below 1,000 ft	4.48	25.62	-
Aircraft (84%) + Rotorcraft (16%)	Arrival		12.49	16.36	0.35
	Departure		12.50	16.23	0.15

Table 18: CY 2022 Aerial Application Emissions by County (tpd)

County	(tons/day)			
	ROG	NOx	CO2	PM2.5
Alameda	2.64×10^{-8}	3.44×10^{-8}	2.23×10^{-5}	4.69×10^{-10}
Alpine	0	0	0	0
Amador	3.63×10^{-5}	4.73×10^{-5}	3.07×10^{-2}	6.46×10^{-7}
Butte	8.50×10^{-3}	1.11×10^{-2}	7.19×10^{0}	1.51×10^{-4}
Calaveras	4.16×10^{-5}	5.43×10^{-5}	3.52×10^{-2}	7.40×10^{-7}
Colusa	9.38×10^{-3}	1.22×10^{-2}	7.93×10^{0}	1.67×10^{-4}
Contra Costa	3.50×10^{-4}	4.56×10^{-4}	2.96×10^{-1}	6.22×10^{-6}
Del Norte	0	0	0	0
El Dorado	2.69×10^{-5}	3.51×10^{-5}	2.27×10^{-2}	4.78×10^{-7}
Fresno	2.91×10^{-2}	3.80×10^{-2}	2.46×10^{1}	5.18×10^{-4}
Glenn	8.41×10^{-3}	1.10×10^{-2}	7.11×10^{0}	1.50×10^{-4}
Humboldt	0	0	0	0
Imperial	2.23×10^{-2}	2.91×10^{-2}	1.89×10^{1}	3.97×10^{-4}
Inyo	0	0	0	0
Kern	6.35×10^{-3}	8.27×10^{-3}	5.37×10^{0}	1.13×10^{-4}
Kings	3.83×10^{-2}	4.99×10^{-2}	3.24×10^{1}	6.81×10^{-4}

County	(tons/day)			
	ROG	NOx	CO2	PM2.5
Lake	2.38 x 10^{-5}	3.11 x 10^{-5}	2.01 x 10^{-2}	4.24 x 10^{-7}
Lassen	5.75 x 10^{-4}	7.49 x 10^{-4}	4.86 x 10^{-1}	1.02 x 10^{-5}
Los Angeles	1.23 x 10^{-5}	1.60 x 10^{-5}	1.04 x 10^{-2}	2.19 x 10^{-7}
Madera	6.19 x 10^{-3}	8.07 x 10^{-3}	5.23 x 10^{0}	1.10 x 10^{-4}
Marin	0	0	0	0
Mariposa	2.95 x 10^{-6}	3.85 x 10^{-6}	2.50 x 10^{-3}	5.25 x 10^{-8}
Mendocino	1.22 x 10^{-5}	1.59 x 10^{-5}	1.03 x 10^{-2}	2.17 x 10^{-7}
Merced	1.11 x 10^{-2}	1.45 x 10^{-2}	9.37 x 10^{0}	1.97 x 10^{-4}
Modoc	9.60 x 10^{-4}	1.25 x 10^{-3}	8.12 x 10^{-1}	1.71 x 10^{-5}
Mono	0	0	0	0
Monterey	9.04 x 10^{-3}	1.18 x 10^{-2}	7.64 x 10^{0}	1.61 x 10^{-4}
Napa	8.88 x 10^{-5}	1.16 x 10^{-4}	7.51 x 10^{-2}	1.58 x 10^{-6}
Nevada	5.52 x 10^{-7}	7.20 x 10^{-7}	4.67 x 10^{-4}	9.82 x 10^{-9}
Orange	2.26 x 10^{-7}	2.95 x 10^{-7}	1.91 x 10^{-4}	4.02 x 10^{-9}
Placer	6.20 x 10^{-4}	8.08 x 10^{-4}	5.24 x 10^{-1}	1.10 x 10^{-5}
Plumas	1.41 x 10^{-5}	1.84 x 10^{-5}	1.19 x 10^{-2}	2.51 x 10^{-7}
Riverside	2.96 x 10^{-3}	3.86 x 10^{-3}	2.51 x 10^{0}	5.27 x 10^{-5}
Sacramento	1.84 x 10^{-3}	2.39 x 10^{-3}	1.55 x 10^{0}	3.27 x 10^{-5}
San Benito	1.02 x 10^{-4}	1.33 x 10^{-4}	8.62 x 10^{-2}	1.81 x 10^{-6}
San Bernardino	1.06 x 10^{-5}	1.38 x 10^{-5}	8.98 x 10^{-3}	1.89 x 10^{-7}
San Diego	4.06 x 10^{-4}	5.29 x 10^{-4}	3.43 x 10^{-1}	7.22 x 10^{-6}
San Francisco	3.99 x 10^{-8}	5.20 x 10^{-8}	3.37 x 10^{-5}	7.10 x 10^{-10}
San Joaquin	8.89 x 10^{-3}	1.16 x 10^{-2}	7.52 x 10^{0}	1.58 x 10^{-4}
San Luis Obispo	2.74 x 10^{-4}	3.57 x 10^{-4}	2.31 x 10^{-1}	4.86 x 10^{-6}
San Mateo	5.55 x 10^{-8}	7.23 x 10^{-8}	4.69 x 10^{-5}	9.87 x 10^{-10}
Santa Barbara	7.35 x 10^{-4}	9.58 x 10^{-4}	6.21 x 10^{-1}	1.31 x 10^{-5}
Santa Clara	1.65 x 10^{-4}	2.15 x 10^{-4}	1.39 x 10^{-1}	2.93 x 10^{-6}
Santa Cruz	1.18 x 10^{-5}	1.54 x 10^{-5}	9.97 x 10^{-3}	2.10 x 10^{-7}
Shasta	2.01 x 10^{-4}	2.62 x 10^{-4}	1.70 x 10^{-1}	3.57 x 10^{-6}
Sierra	0	0	0	0
Siskiyou	5.83 x 10^{-4}	7.60 x 10^{-4}	4.93 x 10^{-1}	1.04 x 10^{-5}
Solano	1.88 x 10^{-3}	2.45 x 10^{-3}	1.59 x 10^{0}	3.35 x 10^{-5}
Sonoma	1.63 x 10^{-4}	2.13 x 10^{-4}	1.38 x 10^{-1}	2.91 x 10^{-6}
Stanislaus	3.51 x 10^{-3}	4.58 x 10^{-3}	2.97 x 10^{0}	6.25 x 10^{-5}
Sutter	5.27 x 10^{-3}	6.87 x 10^{-3}	4.46 x 10^{0}	9.38 x 10^{-5}
Tehama	9.32 x 10^{-4}	1.22 x 10^{-3}	7.88 x 10^{-1}	1.66 x 10^{-5}

County	(tons/day)			
	ROG	NOx	CO2	PM2.5
Trinity	0	0	0	0
Tulare	5.35 x 10^{-3}	6.98 x 10^{-3}	4.52 x 10^{0}	9.52 x 10^{-5}
Tuolumne	3.32 x 10^{-6}	4.33 x 10^{-6}	2.81 x 10^{-3}	5.91 x 10^{-8}
Ventura	9.61 x 10^{-4}	1.25 x 10^{-3}	8.12 x 10^{-1}	1.71 x 10^{-5}
Yolo	2.83 x 10^{-3}	3.69 x 10^{-3}	2.40 x 10^{0}	5.04 x 10^{-5}
Yuba	2.19 x 10^{-3}	2.85 x 10^{-3}	1.85 x 10^{0}	3.89 x 10^{-5}
Grand Total	**0.1907**	**0.2487**	**161.2780**	**0.0034**

V. Military Aircraft

a. Military Operations Data Sources

Some flights arriving and departing Military installations are captured by FlightAware, such as Air Taxis or General Aviation, but not aircraft used for Military training or combat operations. Therefore, additional sources are needed. Outside of the Bay Area Air Basin, CARB staff were not successful in receiving current operations data, or other aircraft emissions data, from most of the Military bases in California. As a result, staff searched for publicly available data to obtain Military operation flight data from Military airstrips and airfields. Table 19 shows the relevant Military facilities and airbases in California.

Table 19: Military Facilities in California

Facility	Airport	City	County	Owner
AMEDEE AAF	AHC	Herlong	Lassen	ATCA-ASO, Army
BEALE AIR FORCE BASE	BAB	Marysville	Yuba	U.S. Air Force
TRAVIS AFB	SUU	Fairfield	Solano	US Air Force
MOFFETT FED AIRFIELD NASA	NUQ	Mountain View	Santa Clara	NASA ARC
LEMOORE NAS /REEVES	NLC	Lemoore	Kings	U.S. Navy
ROBERTS AHP	SYL	CP Roberts/San Miguel	Monterey	U.S. Army
VANDENBERG AFB	VBG	Lompoc	Santa Barbara	US Air Force
CHINA LAKE NAWS /ARMITAGE	NID	China Lake	Kern	U.S. Navy
EDWARDS AFB	EDW	Edwards	Kern	U.S. Air Force
PALMDALE REG USAF PL42	PMD	Palmdale	Los Angeles	U.S. Air Force
POINT MUGU NAWS	NTD	Point Mugu	Ventura	U.S. Navy
SAN NICOLAS ISLAND NOLF	NSI	San Nicolas Island	Orange	U.S. Navy
BICYCLE LAKE AAF/NG	BYS	Fort Irwin/Barstow	San Bernardino	ATCA-ASO, Army
MARCH AF RESERVE BASE	RIV	Riverside	Riverside	U.S. Air Force
LOS ALAMITOS AAF	SLI	Los Alamitos	Orange	U.S. Army
CAMPEN MCAS/MUNN	NFG	Oceanside	San Diego	US Navy

Facility	Airport	City	County	Owner
MIRAMAR MCAS /MITSCHER	NKX	San Diego	San Diego	U.S. Navy
SAN CLEMENTE ISLAND NALF	NUC	San Clements Island	Orange	U.S. Navy
N. ISLAND NAS/HALSEY	NZY	San Diego	San Diego	US Navy
IMPERIAL BEACH NOLF	NRS	Imperial Beach	San Diego	US Navy
EL CENTRO NAF	NJK	El Centro	Imperial	US Navy

The Department of Defense (DOD) established the Air Installation Compatibility Use Zones Report (AICUZ) program to promote proactive, collaborative planning for compatible development to sustain mission and community goals, with the reports detailing Military operations by aircraft model. The report, issued by several Military bases in California, analyzes the operational noise footprint, aircraft accident potential zones (APZs), and hazards to aircraft flight and land use development. A few drawbacks to the program include selective participation by Military bases and the lack of scheduled updates resulting in data from 2009. Only a few installations have released a current report, such as the 2020 AICUZ report for Miramar MCAS (NKX) and Beale AFB (BAB) as shown in Table 20.

Table 20: List of Available AICUZ Reports

Facility	Owner	Last Updated
BEALE AIR FORCE BASE	US Air Force	2020
TRAVIS AFB	US Air Force	2009
LEMOORE NAS / REEVES FIELD	US Navy	2010
POINT MUGU NAWS	US Navy	2015
MARCH AIR FORCE RESERVE BASE	US Air Force	2018
MIRAMAR MCAS / MITSCHER FIELD	US Navy	2020
NORTH ISLAND NAS/HALSEY FIELD	US Navy	2011
IMPERIAL BEACH NOLF	US Navy	2011

b. Military Aircraft Emission Factors

The Air Force Civil Engineer Center published a comprehensive guide[30] that encompasses all Military aircraft and corresponding engines, including non-site specific, assumed time in mode for each idle, approach, intermediate, and Military phase to determine the LTO emission factor. The guide also provides an example methodology for

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[30] Air Force Civil Engineer Center, Air Emissions Guide for Air Force Mobile Sources - Methods for Estimating Emissions of Air Pollutants for Mobile Sources At United States Air Force, June 2021

accurately calculating the LTO emission factor. Table 21 below shows the emissions for a USAF Combat Aircraft.

Table 21: Emissions for USAF Combat Aircraft

USAF Aircraft Engine	Power Setting	(lb/hr) Fuel Flow Rate	Emissions/Cycle (lb) per engine NOx	CO	ROG	PM10	PM2.5	CO2
F119-PW-100	Idle (Taxi)	1,377	2.06	32.93	4.67	1.66	1.20	2,198.49
F119-PW-100	Approach	2,740	1.05	1.27	0.05	0.31	0.28	513.80
F119-PW-100	Intermediate	10,110	1.67	0.29	0.07	0.19	0.15	433.33
F119-PW-100	Military	18,612	1.23	0.05	<0.01	0.07	0.06	199.43
F119-PW-100	Afterburner	50,170	1.23	2.69	<0.01	0.14	0.13	537.59

The BAAQMD submitted updated Military aircraft emission factors for BAB, Edwards (EDW), March (RIV), and Travis (SUU) Air Force Bases that were incorporated into the CAI2024 Model.

CAI2024 Aircraft Emissions Model

CAI2024 is developed based on an Emission Factor Model (EFM) framework, in which emissions estimates are calculated by:

Total Emissions = Emission Factor (mass/LTO)*Activity (# of LTO/yr)* Correction Factors

For Aerial Applicators, the emissions are specific to each Geographic Area Index (GAI), which is the geometric intersection of the county, air basin, and air district. For Military, Commercial, and General Aviation, the emissions are estimated based on the airport or air base, for which the corresponding GAI can be determined from the location of the airport. Emissions by GAI are aggregated together to calculate total statewide California emissions. Corrections are also applied to adjust each airport's mixing height, taxi time, and stage length as discussed above. See Appendix A for more details on the CAI2024 Model.

Emissions Results

I. Emissions – CA Statewide

Table 22 compares the statewide annual aircraft emissions from CEPAM2022 and CAI2024, with the trends illustrated in Figure 14 to Figure 16. The ROG, NOx, and PM2.5 emissions from CAI2024 are less than those reported in CEPAM2022. Although Rotorcraft emissions are included in the General Aviation and Military categories, the emissions contribution is minimal.

CAI2024's seasonality is based on the average mixing heights for the summer months (May to October) and winter months (November to April) only. CAI2024 does not adjust any other factor for seasonality, such as ambient temperature or seasonality of operations volume. Since there is minimal change in the average mixing heights, the overall impact on the annual and summer emissions is trivial, as shown in Table 23 and Table 24 for summer and winter, respectively. Table 25 contains the projected annual tons per day emissions for CY 2031 and CY 2037.

Table 22: Base Year 2022 Statewide Annual Aircraft Emissions (tpd)

Category	**Type**	**(tons/day)**					
		CAI2024			**CEPAM**		
		ROG	**NOx**	**PM2.5**	**ROG**	**NOx**	**PM2.5**
Commercial	Air Carrier	3.69	29.44	0.44	7.85	35.82	0.61
	Air Taxi	2.15	1.98	0.07			
General Aviation	General Aviation Aircraft	2.46	0.53	0.11	4.62	1.87	0.71
	Rotorcraft	0.10	0.34	<0.01	n/a	n/a	n/a
Agricultural	Aerial Applicator	0.19	0.25	<0.01	0.02	0.14	<0.01
Military	Military Aircraft	6.66	8.62	1.21	15.97	17.88	7.64
	Rotorcraft	1.55	0.81	0.19	n/a	n/a	n/a
Total		**16.81**	**41.98**	**2.02**	**28.45**	**55.71**	**8.96**

*n/a – not available

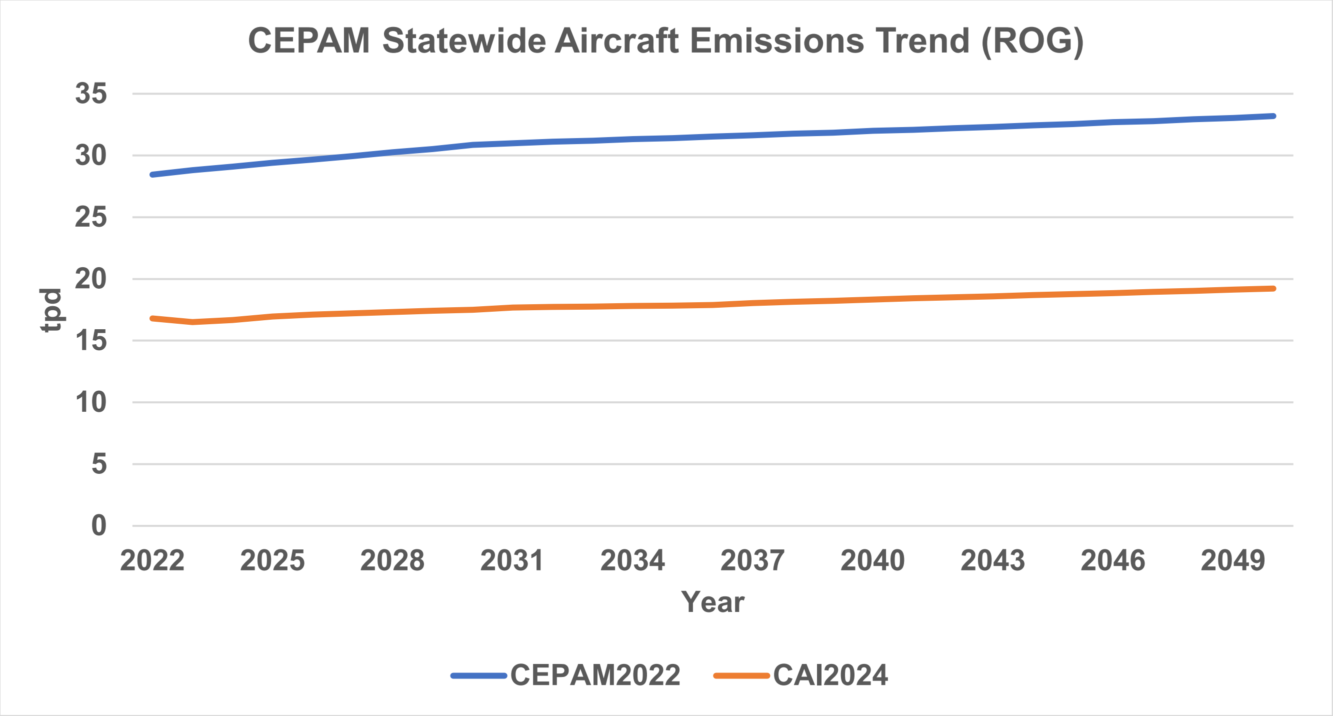

Figure 14: ROG Trend Comparison (CEPAM2022 vs CAI2024)

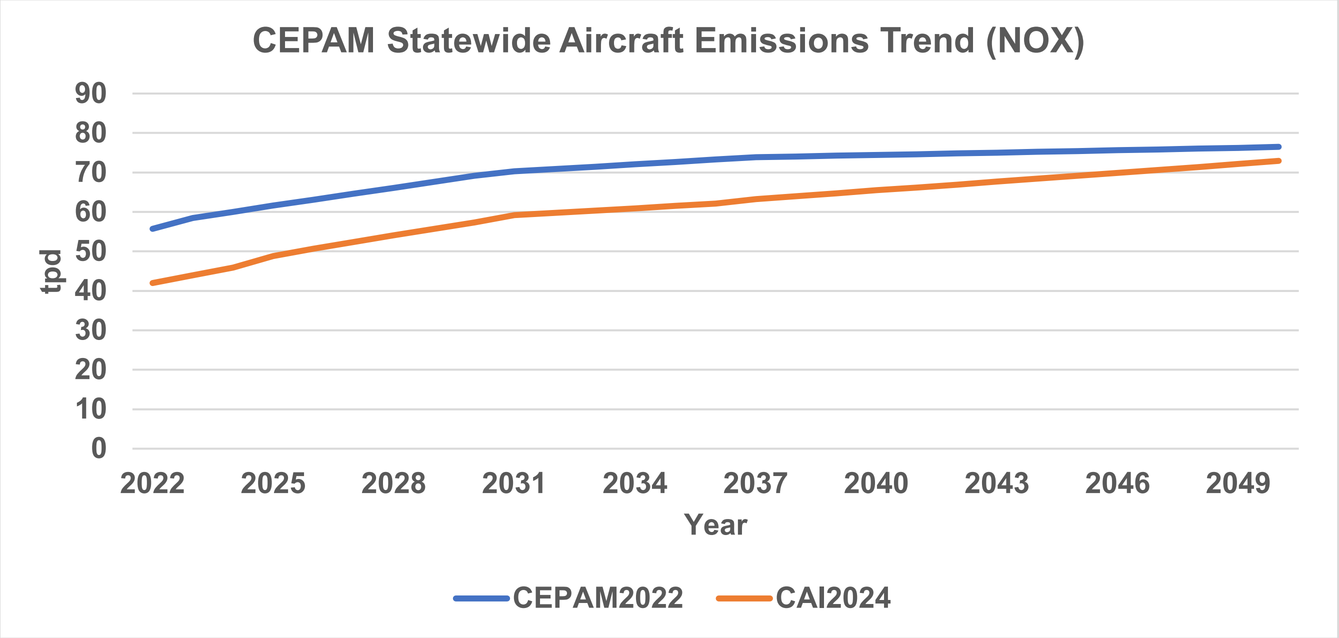

Figure 15: NOx Trend Comparison (CEPAM2022 vs CAI2024)

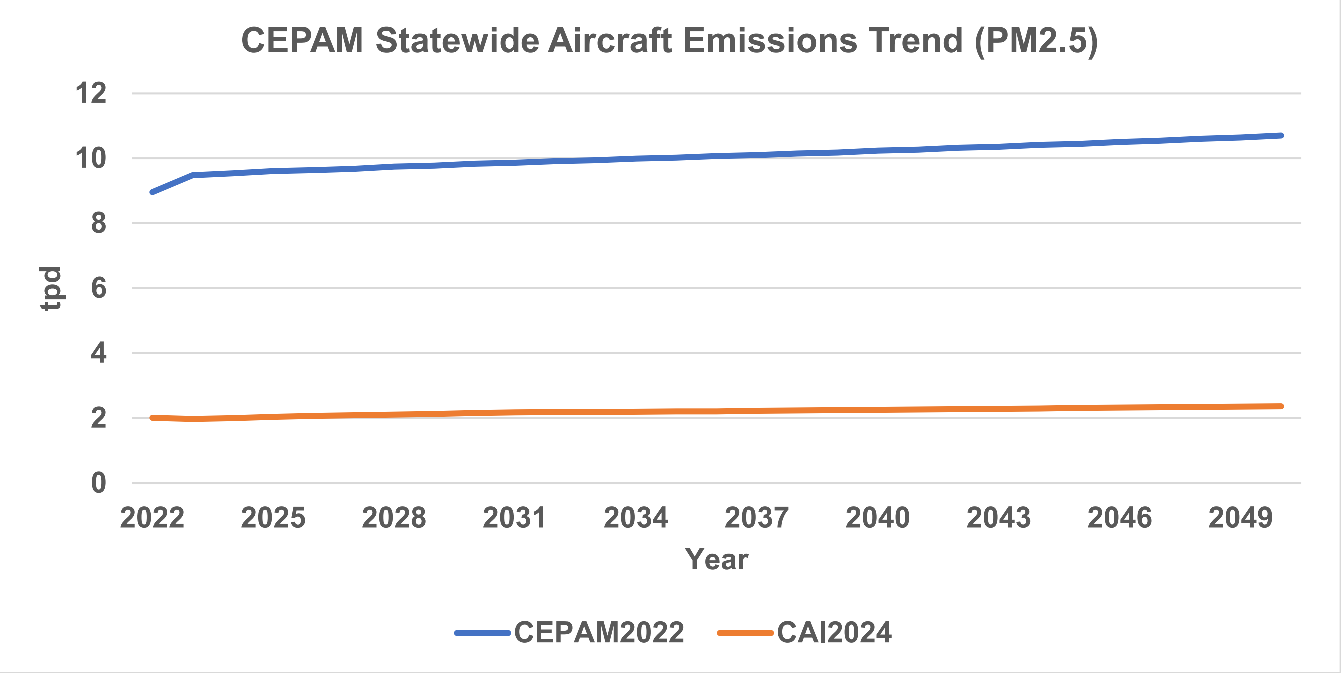

Figure 16: PM2.5 Trend Comparison (CEPAM2022 vs CAI2024)

Table 23: CY 2022 Statewide Summer Aircraft Emissions (tpd)

Category	Type	CAI2024		
		ROG	NOx	PM 2.5
Commercial	Air Carrier	3.68	28.68	0.43
	Air Taxi	2.15	1.96	0.07
General Aviation	General Aviation Aircraft	2.46	0.53	0.11
	Rotorcraft	0.10	0.34	<0.01
Agricultural	Aerial Applicator	0.19	0.25	<0.01
Military	Military	6.68	8.68	1.22
	Military Rotorcraft	1.55	0.81	0.19
Total		**16.82**	**41.24**	**2.03**

Table 24: CY 2022 Statewide Winter Aircraft Emissions (tpd)

Category	Type	CAI2024		
		ROG	NOx	PM 2.5
Commercial	Air Carrier	3.69	29.92	0.44
	Air Taxi	2.15	1.98	0.07
General Aviation	General Aviation Aircraft	2.46	0.52	0.10
	Rotorcraft	0.10	0.34	<0.01
Agricultural	Aerial Applicator	0.19	0.25	<0.01
Military	Military	6.64	8.55	1.19
	Military Rotorcraft	1.55	0.81	0.19
Total		**16.78**	**42.36**	**2.00**

Table 25: Projected Annual CY 2031 and CY 2037 Emissions (tpd)

Pollutant	2031	2037
ROG	17.69	18.05
NOx	59.19	63.25
PM2.5	2.18	2.23

II. Emissions – By Air District

Table 26 to Table 28 below contain the annual statewide aircraft emissions (tpd) for each air district including Commercial, General Aviation, General Aviation (Rotorcraft), Military, and Agricultural categories.

Table 26: Oxides of Nitrogen (NOx) Emissions by Air District (tpd) for CY 2022

Air District	Commercial	General Aviation	Rotorcraft	Aerial Applicator	Military	Total
AMADOR COUNTY APCD	0.0001	0.0016	0.0008	<0.0001	<0.0001	**<0.01**
ANTELOPE VALLEY AQMD	0.0169	0.0026	0.0024	<0.0001	0.1019	**0.12**
BAY AREA AQMD	9.1932	0.0828	0.0363	0.0027	4.1131	**13.43**
BUTTE COUNTY AQMD	0.0041	0.0051	0.0075	0.0111	0.0002	**0.03**
CALAVERAS COUNTY APCD	<0.0001	0.0013	0.0003	0.0001	<0.0001	**<0.01**
COLUSA COUNTY APCD	<0.0001	0.0014	0.0007	0.0122	<0.0001	**0.01**
EASTERN KERN APCD	0.0199	0.0108	0.0025	0.0016	0.5791	**0.61**
EL DORADO COUNTY APCD	0.0074	0.0054	0.0029	<0.0001	0.0001	**0.02**
FEATHER RIVER AQMD	0.0014	0.0039	0.0031	0.0097	0.3020	**0.32**
GLENN COUNTY APCD	0.0001	0.0016	0.0004	0.0110	<0.0001	**0.01**
GREAT BASIN UNIFIED APCD	0.0169	0.0060	0.0009	<0.0001	0.0006	**0.02**
IMPERIAL COUNTY APCD	0.0039	0.0026	0.0056	0.0291	0.1404	**0.18**
LAKE COUNTY AQMD	<0.0001	0.0035	0.0013	<0.0001	<0.0001	**<0.01**
LASSEN COUNTY APCD	0.0001	0.0015	0.0008	0.0007	<0.0001	**<0.01**
MARIPOSA COUNTY APCD	<0.0001	0.0005	0.0014	<0.0001	0.0001	**<0.01**
MENDOCINO COUNTY AQMD	0.0005	0.0100	0.0010	<0.0001	<0.0001	**0.01**
MODOC COUNTY APCD	<0.0001	0.0122	<0.0001	0.0013	<0.0001	**0.01**
MOJAVE DESERT AQMD	0.0528	0.0076	0.0101	0.0001	0.0008	**0.07**
MONTEREY BAY UNI APCD	0.0844	0.0142	0.0044	0.0119	0.0007	**0.12**
NORTH COAST UNI AQMD	0.0305	0.0178	0.0009	<0.0001	0.0003	**0.05**
NORTH SONOMA CTY APCD	<0.0001	0.0012	0.0002	<0.0001	<0.0001	**<0.01**
NORTHERN SIERRA AQMD	0.0179	0.0142	0.0023	<0.0001	0.0003	**0.03**
PLACER COUNTY APCD	0.0015	0.0065	0.0059	0.0008	0.0001	**0.01**
SACRAMENTO AQMD	1.7148	0.0157	0.0152	0.0024	0.0177	**1.77**
SAN DIEGO COUNTY APCD	2.2292	0.0376	0.0287	0.0005	1.1483	**3.44**
SAN JOAQUIN VALLEY APCD	0.4524	0.0635	0.0259	0.1403	1.8049	**2.49**
SAN LUIS OBISPO CO APCD	0.0623	0.0060	0.0040	0.0004	0.0002	**0.07**
SANTA BARBARA CO APCD	0.1626	0.0134	0.0068	0.0010	0.0023	**0.19**
SHASTA COUNTY AQMD	0.0370	0.0062	0.0081	0.0003	0.0004	**0.05**
SISKIYOU COUNTY APCD	0.0006	0.0052	0.0006	0.0008	0.0002	**0.01**
SOUTH COAST AQMD	17.2723	0.1379	0.1436	0.0038	1.1414	**18.70**
TEHAMA COUNTY APCD	0.0003	0.0030	0.0017	0.0012	0.0008	**0.01**
TUOLUMNE COUNTY APCD	0.0012	0.0020	0.0019	<0.0001	0.0004	**0.01**
VENTURA COUNTY APCD	0.0399	0.0142	0.0054	0.0013	0.0766	**0.14**
YOLO/SOLANO AQMD	0.0012	0.0144	0.0017	0.0044	0.0001	**0.02**
Statewide	**31.43**	**0.53**	**0.34**	**0.25**	**9.43**	**41.98**

Table 27: Reactive Organic Gases (ROG) Emissions by Air District (tpd) for CY 2022

Air District	Commercial	General Aviation	Rotorcraft	Aerial Applicator	Military	Total
AMADOR COUNTY APCD	0.0003	0.0094	0.0001	<0.0001	0.0003	**0.01**
ANTELOPE VALLEY AQMD	0.0130	0.0209	0.0004	<0.0001	0.0466	**0.08**
BAY AREA AQMD	1.5288	0.3825	0.0101	0.0021	1.4146	**3.34**
BUTTE COUNTY AQMD	0.0061	0.0255	0.0010	0.0085	0.0002	**0.04**
CALAVERAS COUNTY APCD	0.0002	0.0091	<0.0001	<0.0001	<0.0001	**0.01**
COLUSA COUNTY APCD	0.0003	0.0099	0.0001	0.0094	<0.0001	**0.02**
EASTERN KERN APCD	0.0200	0.0355	0.0004	0.0012	0.5789	**0.64**
EL DORADO COUNTY APCD	0.0095	0.0436	0.0028	<0.0001	<0.0001	**0.06**
FEATHER RIVER AQMD	0.0018	0.0273	0.0005	0.0075	0.0078	**0.04**
GLENN COUNTY APCD	0.0003	0.0138	0.0001	0.0084	<0.0001	**0.02**
GREAT BASIN UNIFIED APCD	0.0113	0.0175	0.0002	0.0000	0.0001	**0.03**
IMPERIAL COUNTY APCD	0.0058	0.0067	0.0007	0.0223	0.1846	**0.22**
LAKE COUNTY AQMD	0.0002	0.0227	0.0002	<0.0001	<0.0001	**0.02**
LASSEN COUNTY APCD	0.0002	0.0048	0.0001	0.0006	<0.0001	**0.01**
MARIPOSA COUNTY APCD	0.0002	0.0031	0.0003	<0.0001	<0.0001	**0.00**
MENDOCINO COUNTY AQMD	0.0017	0.0101	0.0001	<0.0001	0.0001	**0.01**
MODOC COUNTY APCD	0.0001	0.0231	<0.0001	0.0010	<0.0001	**0.02**
MOJAVE DESERT AQMD	0.0090	0.0567	0.0013	<0.0001	0.0002	**0.07**
MONTEREY BAY UNI APCD	0.0745	0.0795	0.0022	0.0091	0.0008	**0.17**
NORTH COAST UNI AQMD	0.0116	0.0429	0.0001	<0.0001	0.0003	**0.05**
NORTH SONOMA CTY APCD	<0.0001	0.0079	0.0001	<0.0001	<0.0001	**0.01**
NORTHERN SIERRA AQMD	0.0326	0.0533	0.0004	<0.0001	0.0004	**0.09**
PLACER COUNTY APCD	0.0028	0.0390	0.0011	0.0006	0.0002	**0.04**
SACRAMENTO AQMD	0.2268	0.0551	0.0029	0.0018	0.0032	**0.29**
SAN DIEGO COUNTY APCD	0.4626	0.2217	0.0095	0.0004	1.8571	**2.55**
SAN JOAQUIN VALLEY APCD	0.1538	0.2457	0.0040	0.1076	3.4649	**3.98**
SAN LUIS OBISPO CO APCD	0.0346	0.0320	0.0011	0.0003	0.0003	**0.07**
SANTA BARBARA CO APCD	0.0728	0.0443	0.0013	0.0007	0.0019	**0.12**
SHASTA COUNTY AQMD	0.0222	0.0200	0.0013	0.0002	0.0004	**0.04**
SISKIYOU COUNTY APCD	0.0017	0.0118	0.0001	0.0006	<0.0001	**0.01**
SOUTH COAST AQMD	3.0406	0.7125	0.0480	0.0029	0.5433	**4.35**
TEHAMA COUNTY APCD	0.0008	0.0129	0.0002	0.0009	0.0001	**0.02**
TUOLUMNE COUNTY APCD	0.0008	0.0116	0.0003	<0.0001	0.0001	**0.01**
VENTURA COUNTY APCD	0.0891	0.1020	0.0115	0.0010	0.1024	**0.31**
YOLO/SOLANO AQMD	0.0035	0.0480	0.0005	0.0034	0.0001	**0.06**
Statewide	**5.84**	**2.46**	**0.10**	**0.19**	**8.21**	**16.81**

Table 28: Fine Particulate Matter (PM2.5) Emissions by Air District (tpd) for CY 2022

Air District	Commercial	General Aviation	Rotorcraft	Aerial Applicator	Military	Total
AMADOR COUNTY APCD	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	**<0.01**
ANTELOPE VALLEY AQMD	0.0003	0.0008	<0.0001	<0.0001	0.0021	**<0.01**
BAY AREA AQMD	0.1526	0.0164	0.0003	<0.0001	0.1264	**0.30**
BUTTE COUNTY AQMD	0.0001	0.0011	0.0001	0.0002	<0.0001	**<0.01**
CALAVERAS COUNTY APCD	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	**<0.01**
COLUSA COUNTY APCD	<0.0001	0.0004	<0.0001	0.0002	<0.0001	**<0.01**
EASTERN KERN APCD	0.0005	0.0019	<0.0001	<0.0001	0.1261	**0.13**
EL DORADO COUNTY APCD	0.0002	0.0017	<0.0001	<0.0001	<0.0001	**<0.01**
FEATHER RIVER AQMD	<0.0001	0.0007	<0.0001	0.0001	0.0831	**0.08**
GLENN COUNTY APCD	<0.0001	0.0005	<0.0001	0.0002	<0.0001	**<0.01**
GREAT BASIN UNIFIED APCD	0.0004	0.0005	<0.0001	<0.0001	<0.0001	**<0.01**
IMPERIAL COUNTY APCD	0.0001	0.0002	<0.0001	0.0004	0.0230	**0.02**
LAKE COUNTY AQMD	<0.0001	0.0009	<0.0001	<0.0001	<0.0001	**<0.01**
LASSEN COUNTY APCD	<0.0001	0.0002	<0.0001	<0.0001	<0.0001	**<0.01**
MARIPOSA COUNTY APCD	<0.0001	0.0001	<0.0001	<0.0001	<0.0001	**<0.01**
MENDOCINO COUNTY AQMD	<0.0001	0.0004	<0.0001	<0.0001	<0.0001	**<0.01**
MODOC COUNTY APCD	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	**<0.01**
MOJAVE DESERT AQMD	0.0004	0.0023	0.0001	<0.0001	<0.0001	**<0.01**
MONTEREY BAY UNI APCD	0.0035	0.0032	<0.0001	0.0002	<0.0001	**0.01**
NORTH COAST UNI AQMD	0.0011	0.0015	<0.0001	<0.0001	<0.0001	**<0.01**
NORTH SONOMA CTY APCD	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	**<0.01**
NORTHERN SIERRA AQMD	0.0005	0.0016	<0.0001	<0.0001	<0.0001	**<0.01**
PLACER COUNTY APCD	<0.0001	0.0019	0.0001	<0.0001	<0.0001	**<0.01**
SACRAMENTO AQMD	0.0236	0.0029	0.0002	<0.0001	0.0002	**0.03**
SAN DIEGO COUNTY APCD	0.0400	0.0096	0.0003	<0.0001	0.3216	**0.37**
SAN JOAQUIN VALLEY APCD	0.0093	0.0107	0.0002	0.0019	0.4700	**0.49**
SAN LUIS OBISPO CO APCD	0.0028	0.0013	<0.0001	<0.0001	<0.0001	**<0.01**
SANTA BARBARA CO APCD	0.0045	0.0019	0.0001	<0.0001	<0.0001	**0.01**
SHASTA COUNTY AQMD	0.0013	0.0008	0.0001	<0.0001	<0.0001	**<0.01**
SISKIYOU COUNTY APCD	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	**<0.01**
SOUTH COAST AQMD	0.2626	0.0322	0.0013	0.0001	0.2383	**0.53**
TEHAMA COUNTY APCD	<0.0001	0.0005	<0.0001	<0.0001	<0.0001	**<0.01**
TUOLUMNE COUNTY APCD	<0.0001	0.0007	<0.0001	<0.0001	<0.0001	**<0.01**
VENTURA COUNTY APCD	0.0017	0.0041	0.0001	<0.0001	0.0094	**0.02**
YOLO/SOLANO AQMD	<0.0001	0.0023	<0.0001	0.0001	<0.0001	**<0.01**
Statewide	**0.51**	**0.11**	**0.00**	**0.00**	**1.40**	**2.02**