Draft California Recreational Marine Vessels

Emissions Inventory (RMV2026) Technical Documentation

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Table of Contents

List of Figures

List of Tables

List of Appendices

Statewide California Recreational Marine Vessels Emissions Inventory (RMV2026) Technical Documentation

I. Executive Summary

Recreational Marine Vessels (RMV) represent a broad category of watercraft that are primarily powered by internal combustion engines and used for leisure activities. Nearly 800,000 RMV are operating in California, and they are an important source of reactive organic gas (ROG) and oxides of nitrogen (NOx) emissions. As shown in Figure 1, RMV accounts for about 6% of statewide NOx emissions from off-road mobile sources[1] in the summer of 2025. By 2037, this contribution increases to 7% of total off-road emissions. This percentage increase does not reflect higher emissions from this category, but rather a reduction in total off-road emissions resulting from emission control measures and technological improvements in other off-road equipment categories, such as farm equipment, trains, and all other off-road equipment.

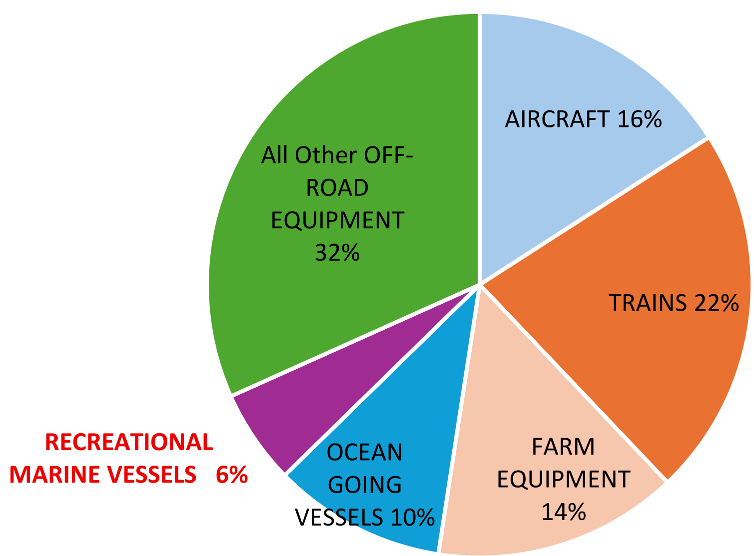

Figure 1: Statewide NOx from Off-Road Mobile Sources, Summer 2025

[1] Mobile source emissions are based on the most recent CARB California Emission Projection Analysis Model (CEPAM), with a base year of 2017, and do not include inventory updates or amendments developed in 2021 and later. Thus, the current CEPAM version is based on the outputs from PC2014. The data is available online at *https://ww2.arb.ca.gov/cepam*

The RMV2026 model is a revised emissions inventory developed to estimate emissions from Spark-Ignition Marine Engine and Watercraft (SIME/SIMW) across California. It builds upon the previous PC2014 model by incorporating updated data. Key updates include:

- Vessel Population & Growth Projections: Updated to reflect current trends in vessel population growth and survival rates.
- Activity Data: Estimated hours of vessel use were developed from a two-year survey conducted by California State University, Fullerton (CSUF) on behalf of California Air Resources Board (CARB).
- Emissions Data: Zero-hour (ZH) exhaust emission rates and deterioration factors (DF) of NOx and HC were updated using data from the SIME and Production Line Testing (PLT) databases, submitted regularly by marine engine manufacturers to CARB.
- Technology Shift Considerations: The model accounts for the ongoing transition from carbureted (CB) to fuel-injected (FI) engines, and from 2-stroke (G2) to 4-stroke (G4) gasoline engines, as well as changes in the ratio between diesel and gasoline engines.
- Storage Allocation: Vessel population profiles were mapped by region and category using data from vessel registrations in the California Department of Motor Vehicles (DMV) as of 2021.
- Operational Allocation: Locations of vessel operation were obtained from the CSUF survey, providing a more accurate spatial representation.
- RVP updates were also included to account for localized temperature impact on evaporative emissions. The temperature/RVP correction factors were updated using RVP measurements on fuels that were recently incorporated into EMFAC2025[2].
- Total hydrocarbon (THC) conversion factors were updated to align with the most recent speciation profiles (OG2309, OG2310[3], OG2311[4]) for off-road equipment and exempt compound lists.

[2] California's emissions inventories of on-road mobile sources. *https://arb.ca.gov/emfac*

[3] *https://ww2.arb.ca.gov/sites/default/files/classic/speciation/reference/96-ohrvexhaust_og2309%262310.pdf*

[4] *https://ww2.arb.ca.gov/sites/default/files/classic/speciation/reference/97-ohrvevap_og2311.pdf*

Figures 2 through 4 summarize the current statewide summer NOx, ROG, and fine PM (PM2.5) emissions from RMVs in California quantified by the previous RMV model, Pleasurecraft2014 (PC2014)[5] compared to the updated model, RMV2026.

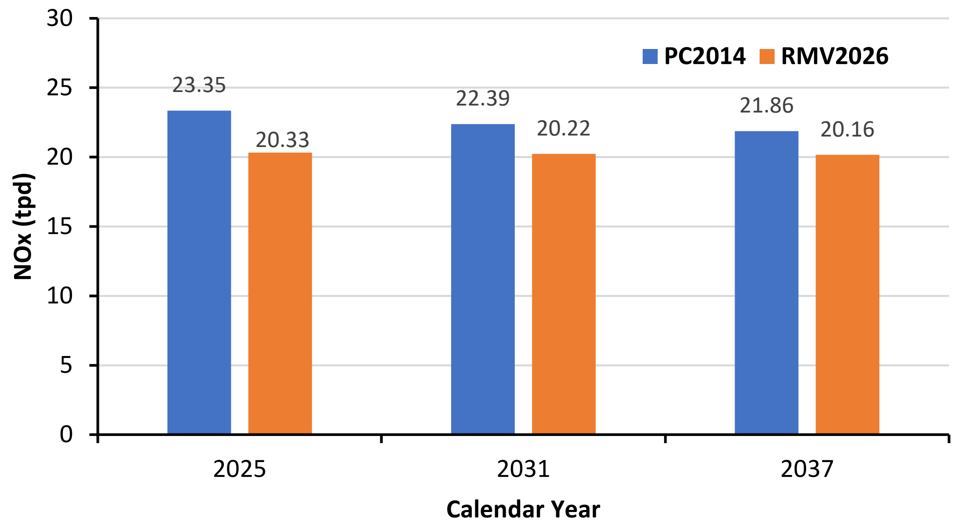

Figure 2: Summer Statewide NOx RMV Emissions (tpd)

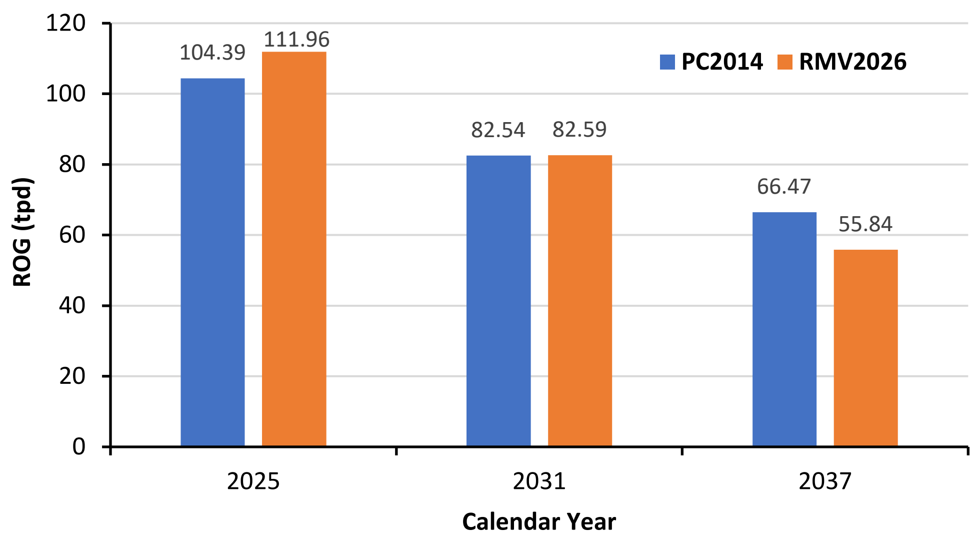

Figure 3: Summer Statewide ROG RMV Emissions (tpd)

[5] The emissions from the previous model (PC2014) were pulled from CARB's 2022 California Emissions Projection Analysis Model (CEPAM2022) *https://ww2.arb.ca.gov/applications/cepam2019v103-standard-emission-tool,%202022*

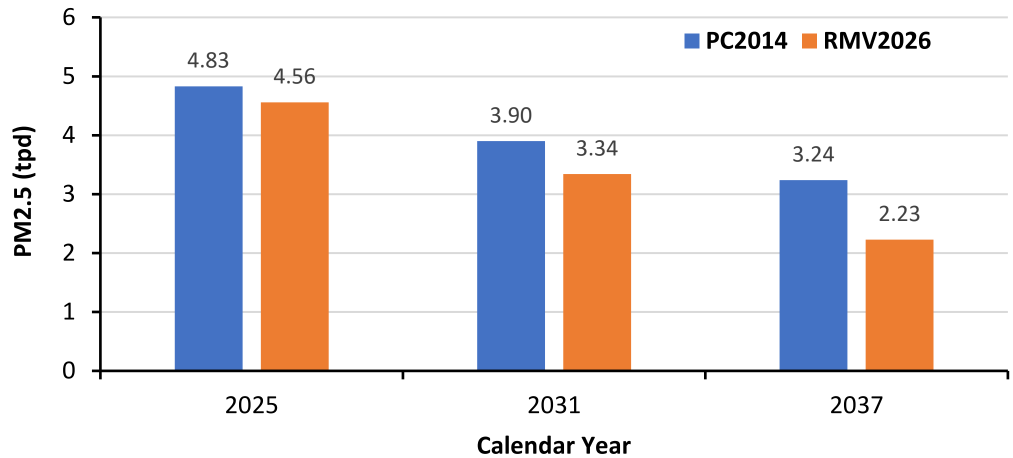

Figure 4: Summer Statewide PM2.5 RMV Emissions (tpd)

Figure 5 compares the projected summer emissions of ROG from various types of RMVs in California for the year 2031 based on models RMV2026 and PC2014, broken down by exhaust and evaporative emissions. The graph shows that Outboards and PWCs remain the dominant contributors in both models, with RMV2026 consistently producing higher exhaust estimates primarily due to updated ZH-HC exhaust emission factors and the inclusion of DFs. The largest differences occur in high-population categories such as Outboards and PWCs, while Auxiliary & Sail and Jet contribute very little to either model. Evaporative emissions are comparatively small but appear lower in RMV2026, mainly due to updated RVP temperature correction factors, which lowered HC emissions from diurnal and resting-losses when RMVs are stored. Overall, RMV2026 shifts exhaust ROG emissions upward slightly while preserving the relative ranking of vessel types, indicating that PC2014 underrepresented exhaust ROG contributions from high-population vessel categories.

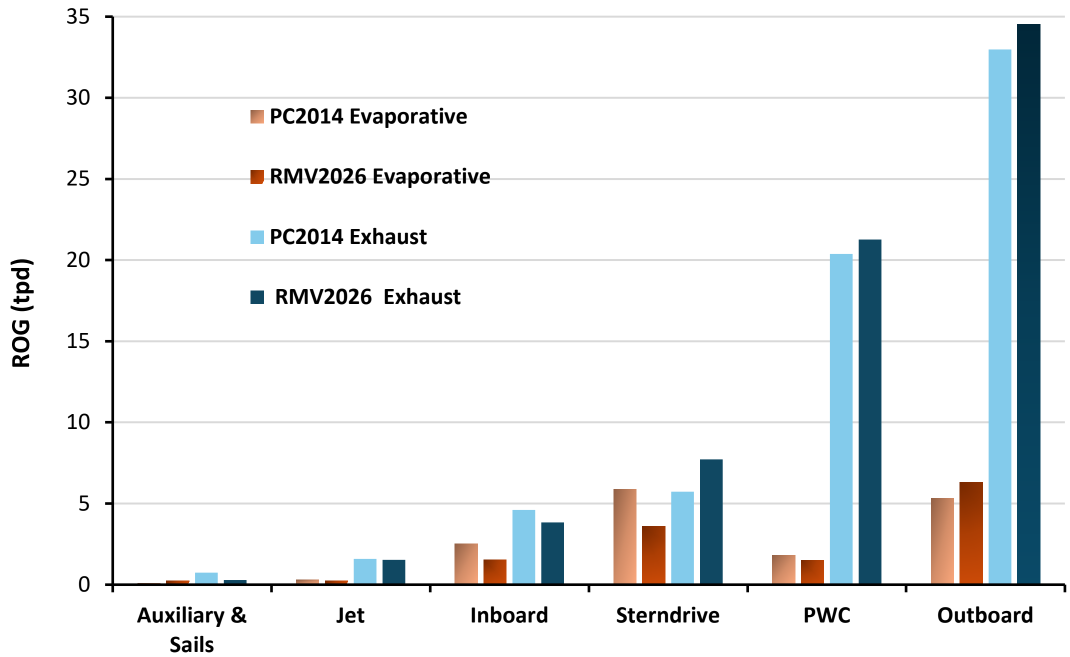

Figure 5: Projected Summer ROG Emissions by RMV Category in Calendar Year 2031

II. Background

Emissions from RMV are a major source of ROG and NOx emissions, which are key precursors to the formation of ground-level ozone. Reducing ROG and NOx emissions from this sector is critical for California to meet its ambient air quality standards for ambient ozone and particulate matter. This document outlines the data sources, methodologies, and key assumptions used in developing the RMV2026 emissions inventory model.

In RMV2026, vessels are classified into six types and two fuel-technology groups, as detailed in Table 1.

Table 1: RMV Types and Fuel Combinations

Vessel Type	Gasoline	Diesel
Outboard	X	
Inboard	X	X
Sterndrive	X	X
Personal Watercraft (PWC)	X	
Jet Boat	X	

Auxiliary & Sail	X	X

III. Summary of Updated Data Inputs

This section outlines the data input files used in developing the RMV2026 emissions inventory.

a. Base Year Population and Model Year (MY) Distribution

The base calendar year (CY) for the RMV2026 emissions inventory is 2022. Updated California Department of Motor Vehicles (DMV) registration data provided detailed information on the total vessel population and model year (MY) distribution for each calendar year from 2006 through 2022. Based on existing DMV data, RMV2026 includes estimates for both active and inactive vessels. This distinction is important because inactive vessels, while not producing running exhaust emissions, often still contribute to evaporative emissions.

In addition to the DMV, recreational marine vessels (RMV) can be registered with the United States Coast Guard (USCG). Owners are not required to register vessels with both agencies. Staff compared the January 2020 vessel registration data from the USCG USCG's Merchant Vessels of the United States[6], with the corresponding 2021 California DMV registration. The comparison revealed that a portion of specific vessel types operating in California are registered solely with the USCG and not captured in DMV records. To account for the population only found in USCG records, an adjustment factor was developed to increase the DMV-registered population. This adjustment is incorporated into RMV2026 and ensures that emissions estimations more accurately reflect the total in-use fleet. The USCG population adjustment correction factors are provided in Table 2 below. The adjustment factors were applied directly to the DMV population. For example, for every auxiliary sail engine registered with the DMV, RMV2026 reflects 1.70 auxiliary & sail engines in service in California.

Table 2: USCG Population Adjustment and RMV

Vessel Type	Adjustment Factor
Auxiliary & Sail	1.70
Inboard	1.13
Sterndrive	1.03

The above described analysis was performed at a time when the most recent available DMV data was from CY 2021. More recent DMV data is available but prior to the release

[6] *https://unitedstatesvessel.us/uscg-vessel-database/*

of RMV2026, the scaled annual vessel reports from the DMV gave a trend that aligned with the RMV2026 statewide vessel population projection out to January of 2026. For this reason, it was not necessary to update the base year of RMV2026 before its release.

One of the primary reasons certain RMVs are registered with the USCG is that USCG registrations are internationally recognized, allowing for smoother customs clearance in foreign ports. In contrast, DMV-only registrations are not recognized outside the United States. Due to this, most USCG documented vessels are physically larger, exceeding 5 net tons and often longer than 30 feet, while California DMV registered vessels in general are smaller and fall below these thresholds. As a result, USCG registrations are dominated by Inboard, Sterndrive, and Auxiliary & Sail vessels, which are larger vessels capable of longer-range, offshore travel.

The USCG population adjustment had little to no effect on Outboards, PWCs, and Jet boats because these vessels are generally smaller than those typically registered with the USCG.

b. Forecasting RMV Populations and Age Distributions (2023 to 2050)

Staff used California DMV registration data to reassess the projected lifespan of each RMV type. This analysis was used to estimate the expected total life, useful life, and year-to-year survival ratios for each vessel category. These estimates support more accurate modeling of fleet turnover, emissions deterioration, and long-term emissions projections within RMV2026.

c. Forecasting Annual RMV Sales

To estimate near-term annual sales of RMV for the years 2023 to 2027, staff relied on economic projections from the 2022 UCLA 10-Year Economic Forecast[7]. For the long-term sales forecast spanning 2028 to 2050, staff used California's projected annual human population growth as a surrogate indicator.

d. Technology Shifts

California's shift from G2 to G4 marine engines is primarily driven by CARB's emission regulations. G2 engines emit significantly more pollution, releasing unburned fuel into the air and water than cleaner, more efficient G4 engines. In 1998, CARB targeted these high-emission engines and, by 2001, implemented stricter exhaust standards that were more stringent than federal EPA requirements. These rules, along with CARB's engine labeling program, encouraged manufacturers and consumers to adopt cleaner technologies. Staff used the updated CARB Spark Ignition Marine Engine (SIME) database and Production Line Testing (PLT) reports to re-estimate the proportion of G2 and G4

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[7] https://www.anderson.ucla.edu/about/centers/ucla-anderson-forecast/research-and-reports

engines within the overall RMV population. Compared to the previous model, RMV2026 incorporates an updated base year and revised projections of G2/G4 ratios, reflecting a higher share of G4 engines in the fleet.

e. Emission Factors

PC2014 used CARB's SIME database to develop RMV exhaust emission factors. These emission factors were population-weighted, using projected engine production provided by marine engine manufacturers. For RMV2026, engine population values are sourced from the Production Line Testing (PLT) Report, which reflects the actual number of engines produced for California sales each year. Using verified production counts to replace projections increases the accuracy of the population weights used for HC and NOx's exhaust emission factors. In contrast, evaporative emissions factors remain consistent with those used in the PC2014 model, which are based on CARB's in-house testing of RMV.

f. Activity and Spatial Allocations

In 2020, CARB initiated a contract with California State University, Fullerton (CSUF) to conduct an online survey, which collected responses from over 2,800 RMV users. Staff used the results of this survey, disaggregated by county and vessel categories, to update activity in RMV2026.

Exhaust emissions and a portion of evaporative emissions, specifically running-loss and hot-soak, were allocated to areas of vessel operation. In contrast, diurnal and resting-loss emissions, which occur when vessels are not in use, were allocated to RMV storage locations.

Operational emission allocations were derived from the 2022 RMV Survey result, while storage allocations were derived from 2021 DMV registration data. This dual-source methodology supports a more accurate spatial representation of emissions throughout California.

IV. Emission Calculation Methodology

This section describes the methodology used to develop the RMV2026 emissions inventory. This emissions inventory begins with calculating statewide emissions by multiplying the vessel population with the emission factors specific to each model year and fuel technology type and horsepower group, the activity levels associated with each vessel category, and applicable load factors. Once statewide emissions are calculated, they are spatially distributed using allocation factors that reflect regional patterns of vessel use and storage. Finally, Reid Vapor Pressure (RVP) correction factors are applied to adjust evaporative emissions based on localized temperature conditions.

a. Exhaust Emissions

Exhaust emissions are estimated for the criteria pollutants: Reactive Organic Gases (ROG), Total Organic Gases (TOG), Hydrocarbons (HC), Oxides of Nitrogen (NOx), Carbon Monoxide (CO), Carbon Dioxide (CO_2), and Particulate Matter (PM). Emissions are calculated by RMV type, engine age (vintage), and calendar year (CY) using the following equation:

$$P_{i,y} = \sum Pop_{i,v} * EF_{i,v} * Hrs_{i,v} * Avg.\ Hp * Load\ Factor$$

Where:

- P = pollutant (HC, CO, NOx, PM, CO2)
- Pop = engine population
- EF = emissions factor (grams/bhp-hr)
- Hrs = annual average use hours (hours/year)
- Avg. Hp = the average of the rated horsepower within the horsepower group
- Load factor = load factor (unitless)
- y = scenario year (2000-2050)
- i = equipment type
- v = vintage (age of equipment, years) for scenario year y

b. Evaporative Emissions

RMV2026 retains the same evaporative emission factors as the PC2014 model. Evaporative emissions are separated into four distinct processes as summarized in Table 3 below:

Table 3: Evaporative Emission Types

Type	When It Occurs	Cause	Equipment Status
Diurnal	During the 24-hour daily cycle of temperature fluctuation excluding resting-losses	Vapor expansion + permeation due to heating of fuel system components	Not operating
Resting-Loss	During the nighttime temperature cooling	Permeation through rubber/plastic fuel system parts	Not operating
Hot Soak	Immediately after shutdown	Vapor release from residual heat post-operation	Just shut off
Running-Loss	While the engine is running, separate from the exhaust	Ongoing vaporization from the fuel system at elevated temperatures	Operating

Please note that the definition of diurnal in a regulatory context represents the sum of the diurnal and resting loss processes output from our model. In RMV2026, staff separated the two evaporative processes for more granular emission calculation.

The basic equations for estimating evaporative emissions are provided below:

$$\text{Diurnal/Resting-Loss} = \text{Population} * EF_{\text{Diurnal/Resting-Loss}} * RVP_{\text{Correction}}$$

$$\text{Hot-Soak} = \text{Population} * \text{Daily Engine Starts} * EF_{\text{Hot-Soak}} * RVP_{\text{Correction}}$$

$$\text{Running-Loss} = \text{Population} * EF_{\text{Running-Loss}} * \text{Activity} * RVP_{\text{Correction}}$$

Where:

- EF Diurnal/Resting-Loss = Emission factors of Diurnal and Resting-Loss (grams/day)
- EF Hot-Soak = Emission factor of Hot-Soak (gram/event)
- EF Running-Loss = Emission factor of Running-Loss (grams/hour)
- Activity = usage of hours (hours/year)
- RVP Correction = RVP correction factor (region-specific, unitless)

V. Population and Forecasting

To maintain temporal consistency, base-year population data from the DMV2021 dataset were used, with adjustments from the 2020 USCG Merchant Vessel Database applied during development of the RMV2026 population file. The RMV2026 population also requires accounting for the number of engines installed on each vessel.

a. Engine Population

To update the RMV population, staff used vessel registration from 2006 to 2021 to determine fleet retirement trends. DMV assigns specific registration codes to indicate vessel usage status. Based on these codes, staff categorized the RMV population into two groups: active and inactive vessels.

- **Active** RMVs are those registered with codes "C" (currently registered), "E" (evidence of use), or "S" (pending).
- **Inactive** RMVs include those registered with codes "N" (not currently registered), "P" (planned non-operational), or "R" (prior history).

RMVs tend to remain in Active status in the years following their purchase date, a pattern reflected in DMV registration data. This phenomenon is evident as active vessels gradually transition to inactive status with increasing age. On average, approximately 85 percent of the registered RMV fleet population is classified as active, with the remaining 15 percent considered inactive. This active/inactive split ratio was also applied to the addition of the USCG population. For emissions modeling, staff assumed that inactive vessels were not in use. As a result, only evaporative emissions of ROG, specifically diurnal and resting-loss emissions, are attributed to inactive RMVs in the inventory.

While DMV registration data is instrumental in quantifying the RMV population in California, it does not provide information on the number of engines per vessel. To address this limitation, staff supplemented the DMV data with the survey information from California State University, Fullerton (CSUF), which was used to estimate the average number of engines per vessel for each RMV category.

These engine-to-vessel ratios were applied to both active and inactive vessel populations to determine the corresponding engine populations. As shown in Table 4.

Table 4: Engine-to-RMV ratio per RMV type

Vessel Type	The Survey Result					Avg. Engine-to-Vessel Ratio
	One Engine	Two Engines	>=3 Engines	Total Vessels	Total engines	
Boat with electric engine(s)	46	1	-	47	48	1.02
Inboard	821	27	8	856	899	1.05
Jet	269	7	-	276	283	1.03
Outboard	1,960	51	-	2,011	2,062	1.03
PWC	935	-	-	935	935	1.00
Auxiliary & Sail	230	1	-	231	232	1.00
Sterndrive	629	13	-	642	655	1.02

b. Forecasting Population

Population growth for RMVs is based on the incoming population (estimated via new RMV annual sales) and the outgoing population (estimated via survival rate):

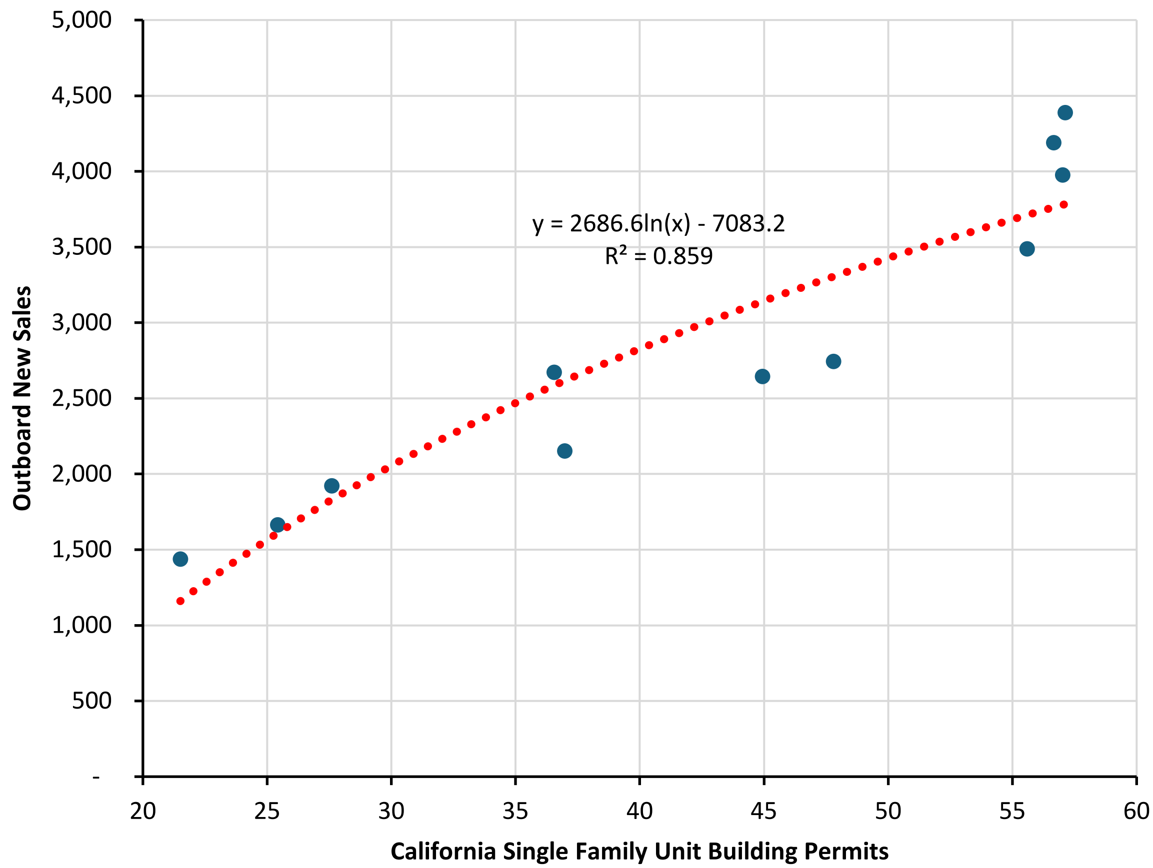
$$Population_{t} = New\ RMV\ sales_{t} + (Population_{t-1} * S)$$

Where:

- Population t = Population at year t
- New RMV sales t = New RMV annual sales (incoming population at year t)
- Population t-1 = Population at previous year (t-1)
- S = Survival rate

c. Annual Sales

CARB used the UCLA Anderson School of Management (UCLA) economic forecast to aid in forecasting the annual sales of RMV. Based on the published 2022 UCLA 10-year Economic Forecast Report[8] (UCLA, 2022), CARB staff found that in the years 2009-2019, California's RMV annual sales correlated well with California Building Permits of Residential Single-Family Units. Outboard vessels were used as an example because they account for over 30% of the total RMV fleet and consistently dominate new vessel sales compared to other vessel types. As shown in Figure 6, there is a strong correlation between past California Single-Family Unit Permits and historical annual sales of outboard, with an R^2 of 0.859. Since the UCLA Economic Forecast Report also projects the future California Building Permits, staff used it as a surrogate to project the near future (year 2023-2027). For 2028 and beyond, the RMV annual sales forecast assumes a 0.3% yearly growth rate, consistent with the California Department of Finance's projections of the human population[9].



[8] https://www.anderson.ucla.edu/about/centers/ucla-anderson-forecast/research-and-reports

[9] https://dof.ca.gov/forecasting/demographics/projections/

Figure 6: Correlation of Outboard Engine Sales with Building Permits

In PC2014, the near-term projection of new vessel sales was based on the Nationwide Housing-Start Index from UCLA's 2010 10-year economic forecast, which served as a surrogate growth factor. Beyond that period, the long-term annual sales forecast (2020 and beyond) is based on the historical annual growth rate of the California human population (1.2 % yearly growth rate at the time of the PC2014 model development). Note that the Nationwide Housing-start index, used in PC2014, and California Building Permits of Residential Single-Family Units, used in RMV2026, are two distinct economic metrics. Each was chosen for use in its respective model simply due to its high correlation to new vessel sales at the time the models were being developed.

Figure 7 compares RMV2026 new sales to PC2014 new sales. In this figure, PC2014 values have been corrected with USCG adjustment factors based on 2020 data to provide a more direct comparison. PC2014 overestimated RMV new vessel sales for each year starting with 2014 through 2022. While RMV2026 uses actual DMV registration data from 2014 to 2022, the new sales figures shown for PC2014 were based on projections.

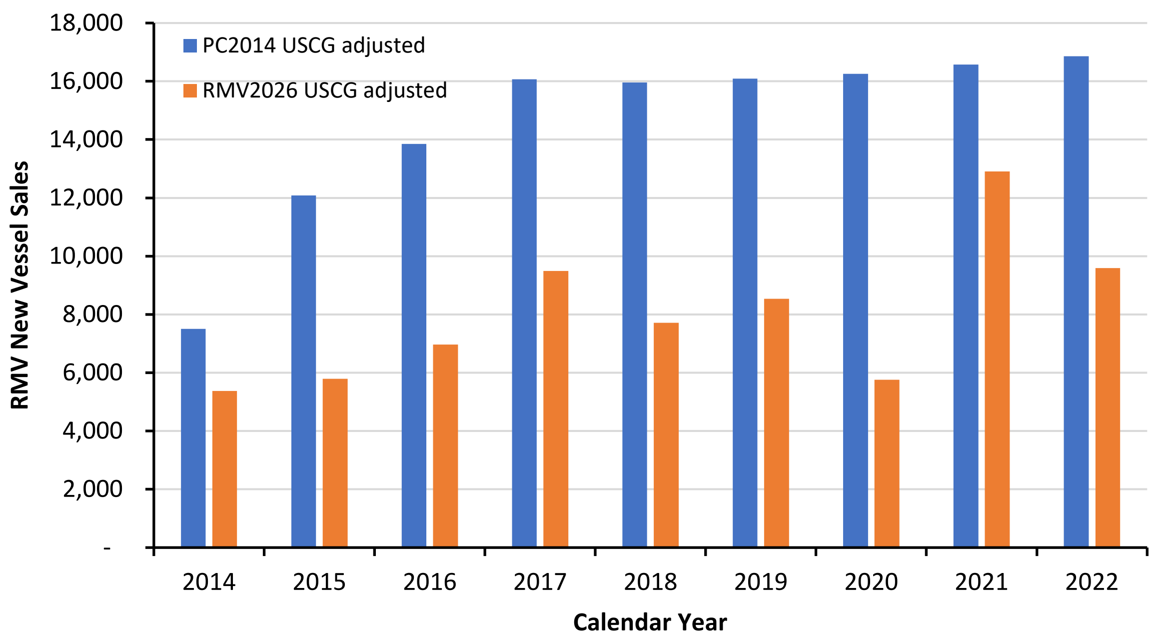


Figure 7: RMV New Sales Comparison

d. Survival Rate

The survival rate is used to estimate year-to-year changes in the RMV population. Each year, a portion of the RMV fleet is removed due to accidents, attrition, sales to other states or countries, or being permanently taken out of service for other reasons. To calculate these changes, staff analyzed DMV registration data to estimate the survival rate for each RMV category at every vessel age. For example, the number of outboard engines that were retired between age 10 and 11, then between the ages of 11 and 12, and so on. These retirement rates are then applied to determine the survival ratio between two consecutive age groups.

In many inventories, the survival rate begins to decline immediately after a vessel or vehicle is sold. However, for discretionary items such as RMVs and other recreational vehicles, the population often initially increases before it declines. For RMVs, this early increase in the survival rate is attributed to the fact that newly manufactured units are often sold over several years, rather than all in the year of manufacture. This trend is reflected in the estimated survival rates.

Figure 8 below illustrates an example of a survival curve comparison for the outboard category. In PC2014, staff had access to only six years of DMV registration data (2007–2012). As a result, the survival curve was manually constructed by estimating fleet population levels at key thresholds, such as 100%, 75%, 50%, and 25%, and then connecting these points. In contrast, RMV2026 has an additional ten years of DMV registration data (2013–2022). The extended dataset reveals that RMVs tend to remain in the fleet longer than originally estimated in PC2014.

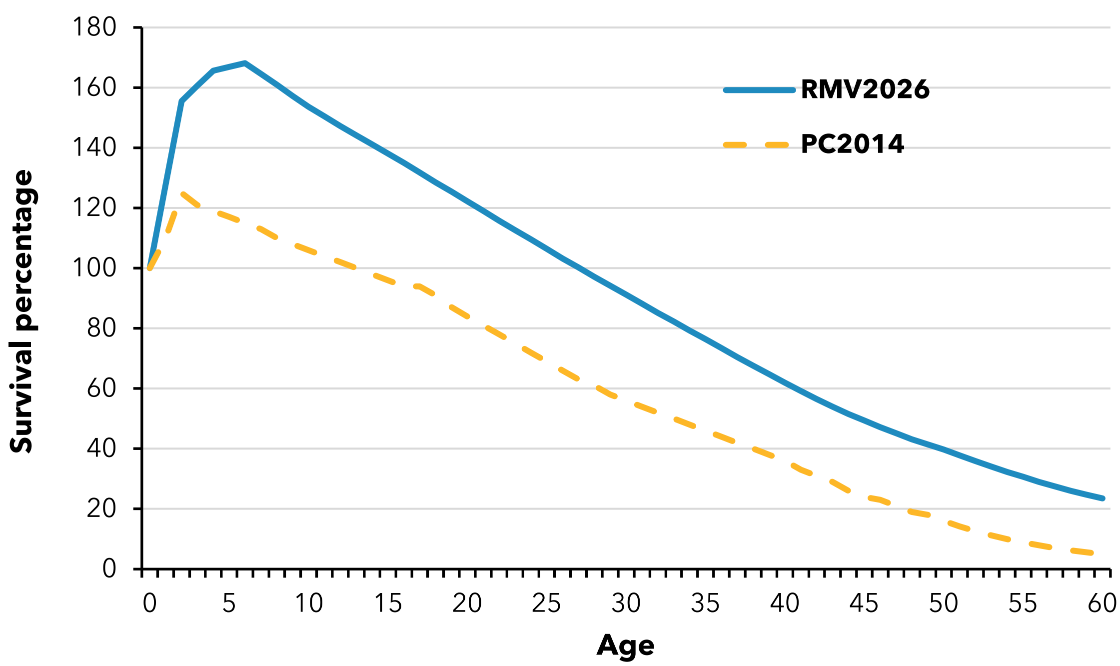


Figure 8: Outboard Survival Curve

e. Age Distribution

Age distributions were obtained from the annual DMV registration records, which include information about the vessel model year. By analyzing data from multiple years, CARB staff identified trends in the age distribution of the entire fleet. Since outboard vessels have become the dominant vessel type within the RMV new sales in recent years, staff used the calendar year 2021 outboard population profile as an example to demonstrate the age distribution concept.

Figure 9 compares the age distribution projected in PC2014 with the historical age distribution derived from RMV2026's actual DMV registration data for outboard vessels in calendar year 2021. The age distribution of outboard vessels in CY 2021 shows clear differences between the PC2014 projections and the historical RMV2026 data. PC2014 overestimated the number of newer vessels for ages 0 through 10 while underestimating the population of vessels age 34 and older, compared to the historical RMV2026 data. This indicates that the actual fleet contained more long-lived, older vessels than PC2014 anticipated.

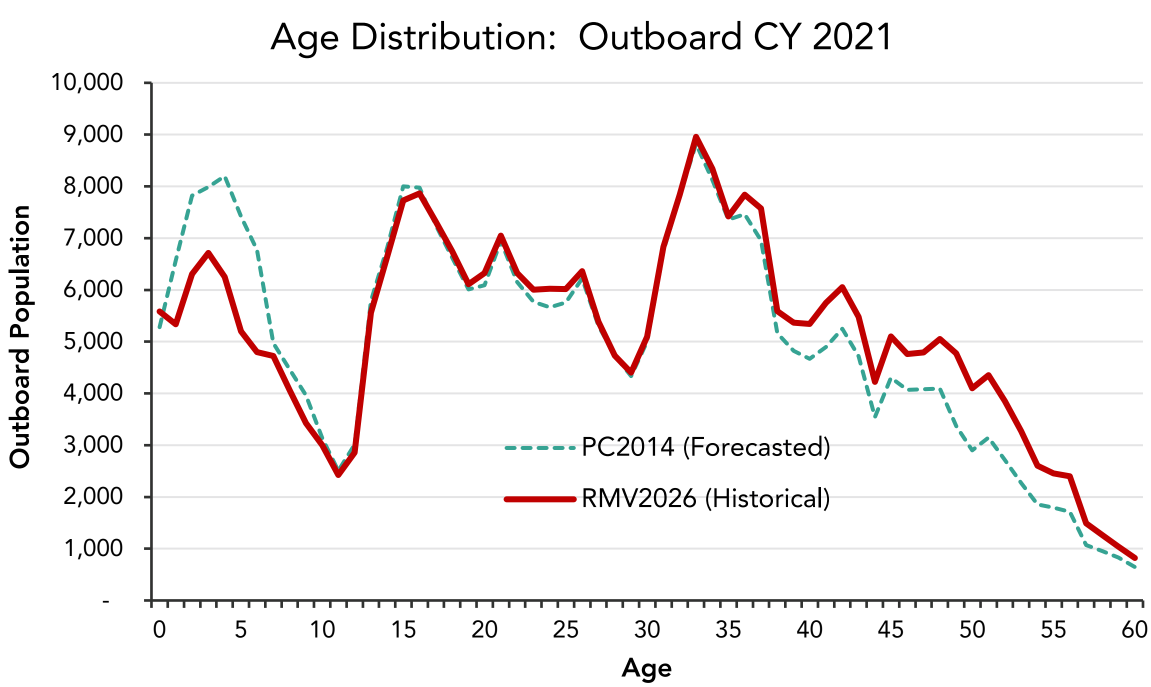
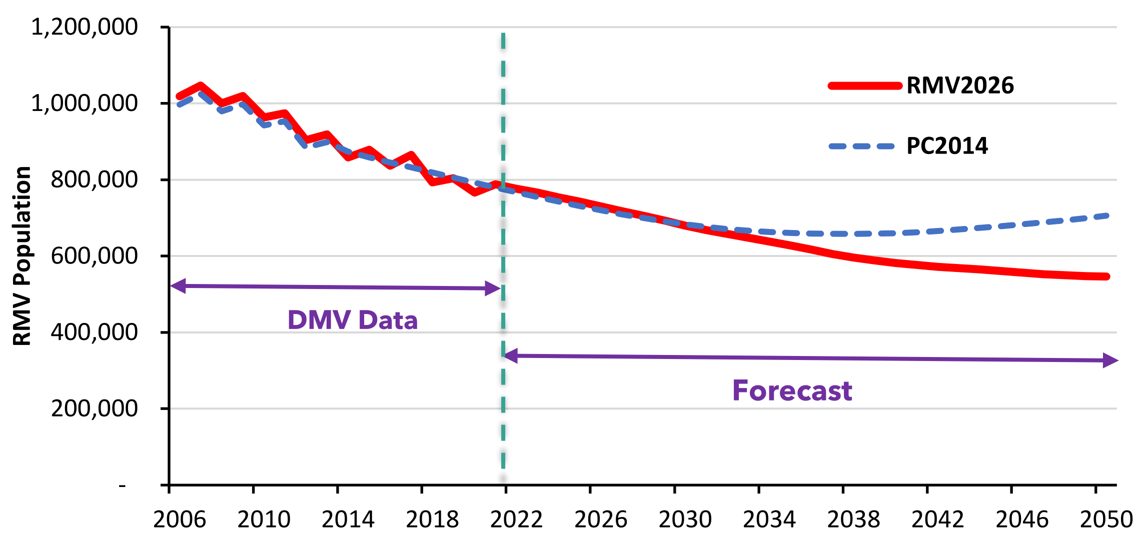


Figure 9: Outboard Engine Age Distribution for 2021

f. Population Updates Summary:

After implementing all population-related updates described above, the RMV2026 fleet population profile is shown in Figure 10. Vessel populations in RMV2026 from 2006 to 2022 are slightly higher than actual DMV registration data, due to adjustments based on USCG registration corrections. Projections for new sales for 2023 to 2027 are based on UCLA's 10-year economic forecast indicator: California Building Permits of Residential Single-Family Units. Beginning in 2027, annual sales projections will rely on the California Department of Finance's[10] (DOF) 2021 population growth forecast, which assumes an average annual growth ratio of 0.3%. Just before the release of RMV2026, an updated DOF forecast was released, but since recent monthly DMV reports through January of 2026 align well with the projections based on DOF2021, staff chose not to consider the DOF2025 forecast until the next update to the RMV inventory.

While PC2014 overestimated new vessel sales following its base year of 2011, resulting in a greater low-age population than what RMV2026's historical data show, the effect does not persist in the middle and higher ages of the population. This is due to RMV2026 having a higher survival rate than PC2014, causing RMV2026's overall fleet distribution to shift to higher ages, and ultimately resulting in a similar total population as PC2014. However, the long-term projections diverge because PC2014 applied an average historical population growth rate of 1.2 % annually, whereas RMV2026 uses a more conservative long-term growth assumption of 0.3%. Given that projection uncertainty increases with time, the actual long-term fleet population will ultimately need to be verified as new data becomes available.



[10] https://dof.ca.gov/forecasting/demographics/projections/

Figure 10: RMV Fleet Population Comparison

VI. Exhaust and Evaporative Emission Factors

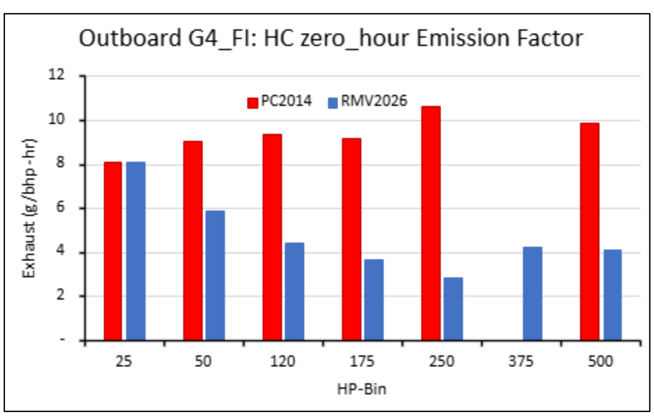
The emission factors can be categorized into two main types: exhaust emission factors and evaporative emission factors. They are influenced by the engine's horsepower and can change over time.

a. Exhaust Emission Factors

Since 2001, all marine engine manufacturers have been required to certify compliance with exhaust emissions standards with CARB. This compliance is tracked in the SIME database, which has documented HC and NOx emissions factors from 2001 to 2021. These exhaust emission factors used in PC2014 were derived based on the SIME database.

Starting in 2008, manufacturers have also submitted quarterly production line testing (PLT) reports that provide actual production volume for California sales, unlike the estimated production volume submitted in the SIME database. By using PLT data for calculating population-weighted HC and NOx exhaust emission factors, staff were able to weigh the emission rates for each engine by its actual production volume. This makes engines with higher production volume have a greater influence on the average emission factor, thus improving the accuracy of the HC and NOx exhaust emission factors for RMV2026.

Figure 11 demonstrates the differences in emission factors for the MY 2018 G4-FI engine in the outboard category. The RMV2026 zero-hour emission factors for HC are noticeably lower than those of PC2014 across all horsepower (HP) groups except the 25HP group, indicating that the actual engine population used in the calculations affects the exhaust emission factors. In contrast, other than the 25 HP group, the zero-hour emission factors for NOx are noticeably higher than those of the previous model. Since HC and NOx are combined under a single emission standard when certified by CARB, the emission thresholds for the engines are still met.



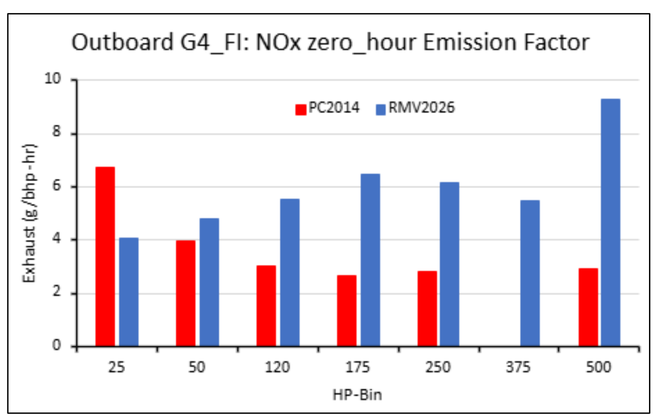


Figure 11: Example of MY 2018 Zero Hour Emission Rates for HC and NOx Comparison for Outboard G4-FI

b. Deterioration Factors

Deterioration factors (DF) were set to zero for PC2014 due to a lack of data on engine deterioration at the time the emission inventory was developed. In RMV2026, when multiple years of PLT data became available, along with the SIME database, staff were able to derive DF data for the engine HP and fuel-tech groups. Since not every fuel-tech group has DF information from the PLT database, the staff used the closest available DF as surrogates.

Figure 12 illustrates the relationship between cumulative lifetime engine usage hours and exhaust emission levels for marine vessels. The solid blue region represents baseline zero-hour emissions used in PC2014. The orange shaded region shows emission increases from deterioration incorporated in RMV2026. The horizontal red dashed line denotes the applicable HC + NOx emission standard. The orange dotted line represents DF, which calculates emissions as zero-hour levels plus the DF multiplied by hours of operation. Although this relationship is theoretically linear, real-world data suggests exhaust emissions plateau once engines reach a certain portion of their useful life. The useful life assumptions in RMV2026 remain consistent with PC2014: most vessels have a 60-year useful life, except jet engines have 50 years and PWCs have 40 years. After evaluating useful life, half-life, median life, and the average fleet age across vessel categories and horsepower groups, staff determined that 1,000 hours of accumulated usage is representative of the median age for most RMV categories and horsepower classes. Staff therefore capped deterioration at 1,000 hours, meaning that beyond this point, exhaust emission factors stabilize.

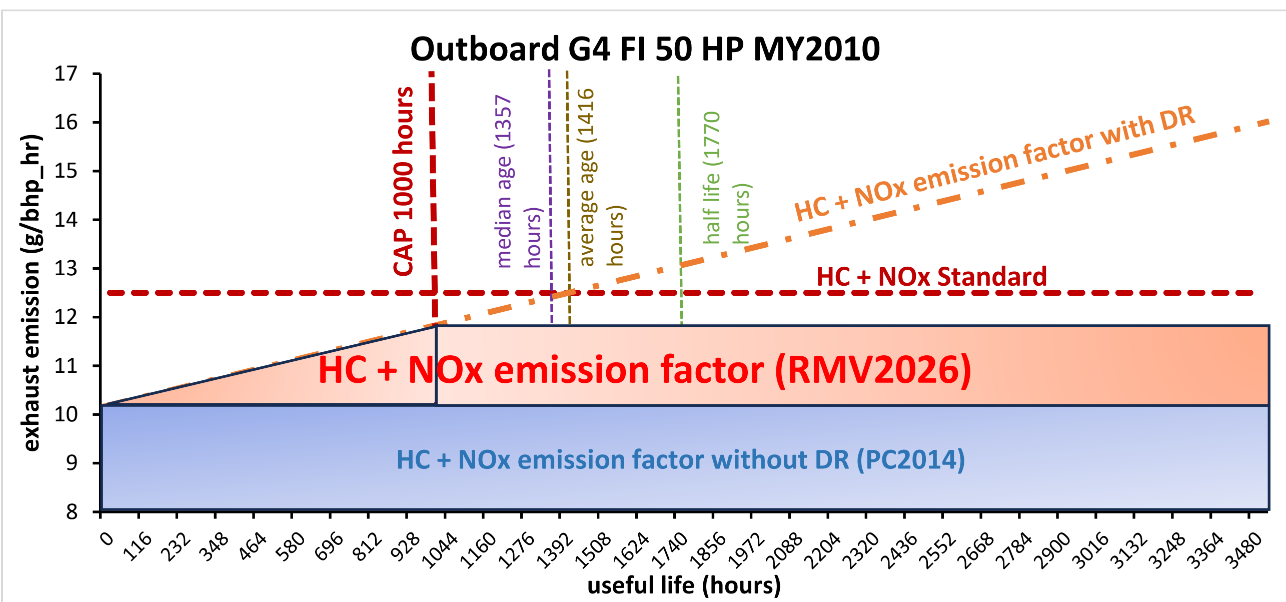


Figure 12: Deterioration Rates for Outboard Engines.

Table 5 compares zero-hour and deterioration emission factors for outboard marine engines across horsepower groups ranging from 15 to 500 HP. In RMV2026, both HC and NOx factors include a deterioration component (expressed in g/bhp-hr²) to account for emissions increase over engine life.

For HC emissions, RMV2026 generally shows lower zero-hour emission levels than PC2014, reflecting updated baseline performance data, but introduces small positive deterioration rates. Similarly, for NOx emissions, RMV2026 zero-hour values are somewhat higher across most horsepower groups, again incorporating deterioration effects that more realistically represent in-use engine aging. For complete sets of emission factor tables, please refer to the *Emitest-{RMVtype}.csv* input tables in the RMV2026 model, where *{RMVtype}* refers to each of the six RMV types.

Table 5: Comparison of Outboard Gasoline 4-stroke Fuel-Injection Engine MY 2018 HC and NOx Exhaust Emission Factors between RMV2026 and PC2014

Outboard G4-FI MY2018 Hydrocarbon (HC) exhaust emission factors				
	PC2014		RMV2026	
Horsepower Group	zero-hour (g/bhp-hr)	Deterioration (g/bhp-hr²)	zero-hour (g/bhp-hr)	Deterioration (g/bhp-hr²)
15	15.35	0	9.80	0.00007
25	8.07	0	8.12	0.00301
50	9.06	0	5.86	0.00026
120	9.34	0	4.42	0.00015
175	9.16	0	3.69	0.00031
250	10.65	0	2.86	0.00003
375[11]	---	---	4.23	0.00003
500	9.87	0	4.12	0.00001
Outboard G4-FI MY2018 Nitrogen Oxide (NOx) exhaust emission factors				
	PC2014		RMV2026	
Horsepower Group	zero-hour (g/bhp-hr)	Deterioration (g/bhp-hr^2)	zero-hour (g/bhp-hr)	Deterioration (g/bhp-hr^2)
15	4.25	0	4.14	0.00003
25	6.73	0	4.07	0.00171

[11] 375 Horsepower group is newly created in the RMV2026 model.

50	3.95	0	4.78	0.00069
120	3.05	0	5.51	0.00056
175	2.65	0	6.46	0.00066
250	2.83	0	6.17	0.00013
375	---	---	5.49	0.00127
500	2.95	0	9.27	0.00002

c. Fuel-Technology and Horsepower Split

RMV2026 has also introduced new horsepower categories in response to a request from the National Marine Engine Manufacturers Association (NMMA). A new category of 375 HP has been added between the existing 250 to 500 HP range in PC2014. Additionally, the new second high-horsepower category is now set at 650 HP, replacing the previous highest category of 750 HP. Note that the horsepower values in Table 5 and Table 6 represent the upper bound of each horsepower group. For example, the horsepower group "25 hp" represents all engines > 15 hp and ≤ 25hp.

Table 6: Updated HP Groups of RMV2026

PC2014 HP Group	RMV2026 HP Group
15 hp	15 hp
25 hp	25 hp
50 hp	50 hp
120 hp	120 hp
175 hp	175 hp
250 hp	250 hp
500 hp	**375 hp**
	500 hp
750 hp	**650 hp**
	> **650 hp**

Using data gathered from the SIME and PLT databases, the staff compiled the technology and horsepower distribution by model year for each RMV type in PC2014 and RMV2026. The analysis revealed a technological shift from G2 to G4 engines around the early 1990s. This comparison confirms a transition in the marine engine industry from G2 CB to G4 FI engines, which represent a cleaner technological advancement for marine engines. Furthermore, changes in the horsepower group distribution ratio have been noted with the updated PLT database. Table 7 and Table 8 below are examples to illustrate these changes. In addition, diesel engines make up a smaller portion of the RMV fleet in RMV2026 (13%), compared to PC2014 (17%), a 4% decrease. Table 9 below shows the comparison of diesel and gasoline split ratios between RMV2026 and PC2014.

Table 7: Population Comparison by Fuel and Technology Type

Equipment	Model Year	PC2014				RMV2026			
		G2-CB	G2-FI	G4-CB	G4-FI	G2-CB	G2-FI	G4-CB	G4-FI
Outboard	1995	78%	9%	13%	0%	78%	9%	13%	0%
	2000	25%	14%	61%	0%	25%	14%	61%	0%
	2005	0%	19%	37%	44%	0%	19%	37%	44%
	2010	0%	19%	29%	52%	0%	6%	72%	22%
	2015	0%	19%	29%	52%	0%	6%	45%	49%
	2020	0%	19%	29%	52%	0%	4%	42%	54%
	2025	0%	19%	29%	52%	0%	4%	42%	54%

Table 8: Population Comparison by Horsepower Bin

Source	Model Year	Horsepower (HP) Group							
		15	25	50	120	175	250	375	500
RMV2026 (Outboard G4_FI)	2005	0%	0%	12%	43%	20%	21%	3%	0%
	2010	0%	0%	33%	39%	11%	10%	7%	0%
	2015	3%	2%	25%	17%	28%	12%	10%	1%
	2020	2%	3%	17%	22%	27%	20%	6%	3%
	2025	2%	3%	17%	22%	27%	20%	6%	3%
PC2014 (Outboard G4_FI)	2005	0%	0%	12%	43%	20%	21%		3%
	2010	0%	0%	20%	51%	12%	4%		14%
	2015	0%	0%	20%	51%	12%	4%		14%
	2020	0%	0%	20%	51%	12%	4%		14%
	2025	0%	0%	20%	51%	12%	4%		14%

Table 9: Fuel Type Split Ratio Comparison

RMV Type	Diesel		Gasoline	
	PC2014	RMV2026	PC2014	RMV2026
Auxiliary & Sails	72%	62%	28%	38%
Inboard	32%	16%	68%	84%
Jet	0%	0%	100%	100%
Outboard	0%	0%	100%	100%
PWC	0%	0%	100%	100%

Sterndrive	0%	3%	100%	97%
Total	**17%**	**13%**	**83%**	**87%**

d. Evaporative Emission Factors

The evaporative emission factors remain the same as those for PC2014. These factors were generated through CARB's SHED testing at the Haagen-Smit Laboratory in El Monte, California. Separately, the RVP correction factors were updated to account for the vapor pressures of recent fuels used in California and the impacts that they have on evaporative emissions. For details on the RVP correction factor, see section XIII, part b.

e. Load Factors

The load factors used for RMV2026 are identical to those used for PC2014[12], as staff did not conduct any studies on the load factors for the current RMV inventory update.

VII. Activity and Seasonality

The activity values used in PC2014 were obtained from a phone survey conducted by Cal State Sacramento (CSUS) in 2009. This survey included 1,127 randomly selected registered owners of registered RMV in California. Given that more than a decade has passed since the survey, CARB staff believe these activity values no longer accurately represent current RMV usage in California. This is one of the main reasons for conducting the updated survey in 2022 by the Social Science Research Center (SSRC) at California State University, Fullerton (CSUF).[13]

a. Activity

The RMV2022 Survey project collected the annual activity for each type of watercraft used in California, based on how many hours per year each RMV was used. The survey collected data on winter and summer uses, impacts of the COVID pandemic, seasonality, and locations.

The survey was conducted during the COVID-19 pandemic, spanning the years 2020 through 2022. The activity section of the survey specifically asked respondents whether their boating activity was affected by the pandemic and, if so, to what extent compared to pre-pandemic levels. Following a detailed analysis of the responses, staff derived updated estimates of RMV boating activity levels in California, broken down by winter and summer seasons, and adjusted to reflect conditions and activity levels prior to the beginning of the COVID-19 pandemic.

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[12] https://ww2.arb.ca.gov/sites/default/files/2023-08/pc2014_technical_document.pdf

[13] https://ww2.arb.ca.gov/sites/default/files/2026-03/carb_rmv_survey_results_final_report_v2_050925.pdf

Below is Table 10 comparing the annual boating activity values (in hours per year) between the updated RMV2026 estimates and those from PC2014.

Table 10: RMV Activity (hours/year) by Vessel Type

Vessel Type	PC2014	RMV2026
Outboard	62	59
Inboard	60	42
Sterndrive	47	40
PWC	42	41
Jet	42	29
Auxiliary & Sail	78	59

The survey results indicated that the activity level of RMV was lower compared to PC2014. Some vessel owners reported that their vessel activity was impacted by lower waterway levels coincident with the timing of the last survey conducted.

b. Seasonality

The survey asked vessel operators whether their boating activity varied between California's winter season (November to April) and summer season (May to October). The results indicate only a slight change in seasonal boating activity compared to the patterns observed in PC2014. After normalizing the values against total annual activity, the seasonality adjustment is presented below in Table 11.

Table 11: Seasonality Adjustment Comparison: RMV2026 vs PC2014

Seasonality	PC2014	RMV2026
Annual	1	1
Summer	1.46	1.48
Winter	0.54	0.52

The results show that seasonal boating activity patterns have remained relatively stable over time. In both RMV2026 and PC2014, boating activity is significantly higher in the summer season, with monthly activity being nearly one and a half times the annual average. Conversely, winter activity is lower, with monthly activity comprising roughly half the annual average. The slight differences, such as a minor increase in the summer-to-winter ratio in RMV2026, suggest consistent seasonality with only marginal shifts over the past decade.

c. Spatial Allocation

Allocating emissions spatially is necessary for creating an accurate emissions inventory for RMVs because different types of emissions occur in various locations. Operating emissions (exhaust, hot-soak, and running-loss) are directly related to the vessel's activity and are assigned to specific areas such as lakes, rivers, or coastal waters. This approach ensures that emissions are appropriately associated with the air quality of the counties in which these waterways are located. In contrast, storage emissions (diurnal and resting-loss), which are evaporative emissions occurring when the vessel is not in use, are assigned to the storage location, often a residential area (for trailered boats) or a marina slip (for larger, non-trailered vessels).

1. Operational Allocation Factor

The operational allocation factor, identifying how much of the statewide activity occurs in each area, was derived using data from the 2022 RMV survey. This factor distributes emissions geographically based on reported boating activity and is calculated using the following formula, which weighs emissions according to where respondents reported operating their RMV:

$$AF_{OP,i} = \frac{\sum_j D_j \times H_j \times PT_{i,j}}{\sum_i \sum_j D_j \times H_j \times PT_{i,j}}$$

Where,

- $AF_{OP,I}$ = the operation allocation factor for county i
- D_j = days of RMV operation for respondent j per year
- H_j = hours of operation per day for respondent j
- $PT_{i,j}$ = percent of time respondent j operate the RMV in the county

The survey asked participants where they operate their vessels. Of the 5,126 total number of engines counts of the survey, 78% (3,982 engines) indicated that their vessels are operated within the same county as their DMV registration county; 22% (1,144 engines) reported operating their vessels in multiple counties.

Based on the latest survey result, RMV operational activity across California shifted notably toward Southern and inland regions compared with that from PC2014. Southern California counties, particularly Los Angeles, San Bernardino, and Riverside saw the largest growth. In contrast, several coastal and Bay Area counties, including San Francisco, Contra Costa, and San Diego, experienced some declines. In Northern California, moderate growth occurred around the Sacramento region, with Sacramento, Placer, and Butte all slightly rising, while more rural northern and coastal counties such as Shasta and Humboldt remained flat or declined slightly. Overall, the trend points to a clear inland shift in operational concentration, with Southern California and the Sacramento area emerging as the key growth regions by 2025.

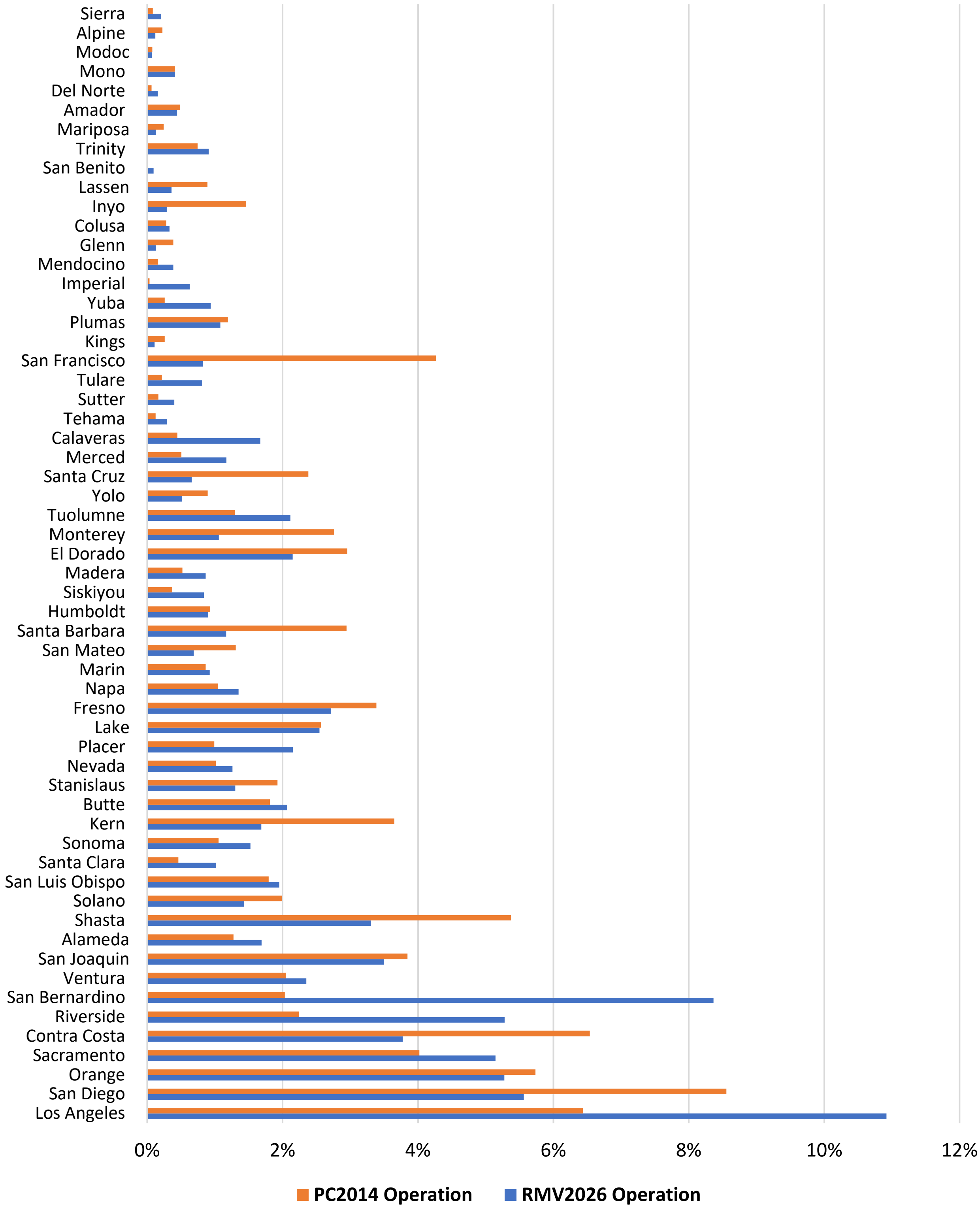

Figure 13: Operation Allocation Factors Comparison

2. Storage Allocation

RMV storage locations may differ from the owner's or operator's DMV registration address, which is typically their residence. In PC2014, the storage allocation was determined using data from the 2009 CSUS survey. The 2022 RMV survey included a specific question about where respondents typically store their RMVs. The results revealed that 73% (3,109 out of 4,277 engines) were stored at home, while 12% (522 engines) were stored at a marina. Only 54 of these 522 (1.2%) were located more than 50 miles away from the registered owners' address, potentially placing them in a different county. Since these survey results suggest storage rarely occurs far from home, CARB is aligning the storage location for RMVs with their DMV registration for RMV2026. In contrast, the storage allocation factors were derived from the 2009 survey results in PC2014. The storage allocation of RMV2026 follows the same overall trend as the operation allocation data. Both show a clear shift of activity toward Southern California and inland regions. Specifically, Los Angeles, San Bernardino, and Riverside counties show a larger share of storage increase compared to PC2014. Meanwhile, Bay Area counties such as Contra Costa, Alameda, and San Francisco, along with some northern coastal regions, have seen their shares decline. In the Sacramento area, counties like Sacramento, Placer, and the nearby Central Valley regions show moderate growth. Northern counties remain relatively small contributors, with minimal change.

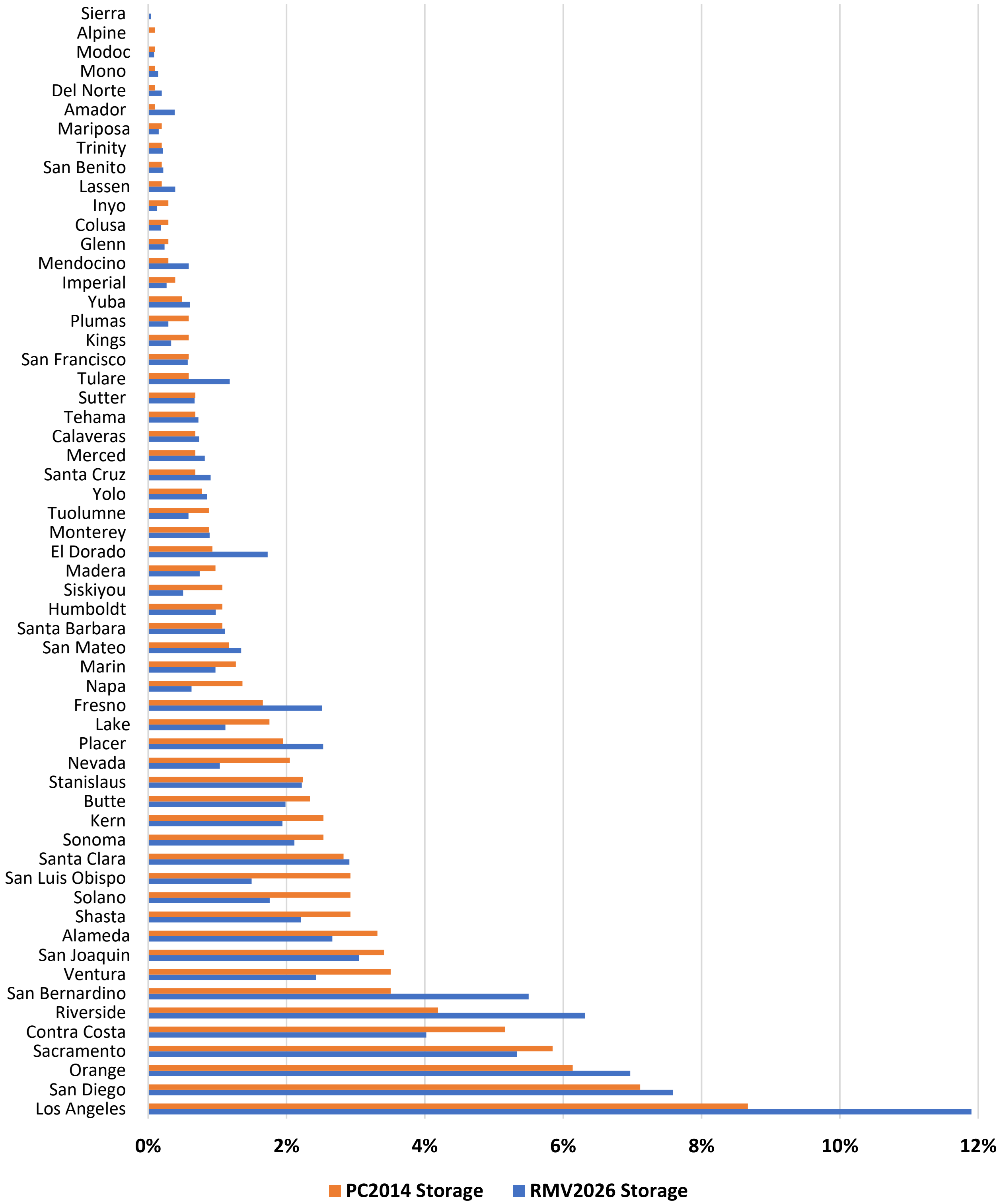

Figure 14: Storage Allocation Factors Comparison

VIII. Survey Results Validation

The survey was carefully designed so that the final sample size reflects the vessel composition reported in DMV registration data across all 58 counties in California. This sampling approach was implemented to ensure that the survey results are unbiased and well-balanced, providing a representative and accurate profile of RMV activity throughout the state.

As mentioned earlier, the survey results revealed that 78% of the vessels are operated within the same county as their DMV registration, and 73% of the vessels are stored at the registered address. Figure 15 shows the relationship between storage and operation allocations across California counties of RMV2026. Each point represents a county, while the red diagonal line indicates where storage and operation allocations are equal. Most points cluster closely along the red line, demonstrating that storage and operation allocations are strongly correlated; counties with higher operational shares also tend to have higher storage shares. A few counties above the line suggest counties where operational activity slightly exceeds storage allocation, while points below the line indicate the reverse. Overall, the chart visually confirms that RMV2026 storage and operation patterns follow nearly similar trends and reinforces the previously observed trend of the southern and inland region's dominance of RMV activities.

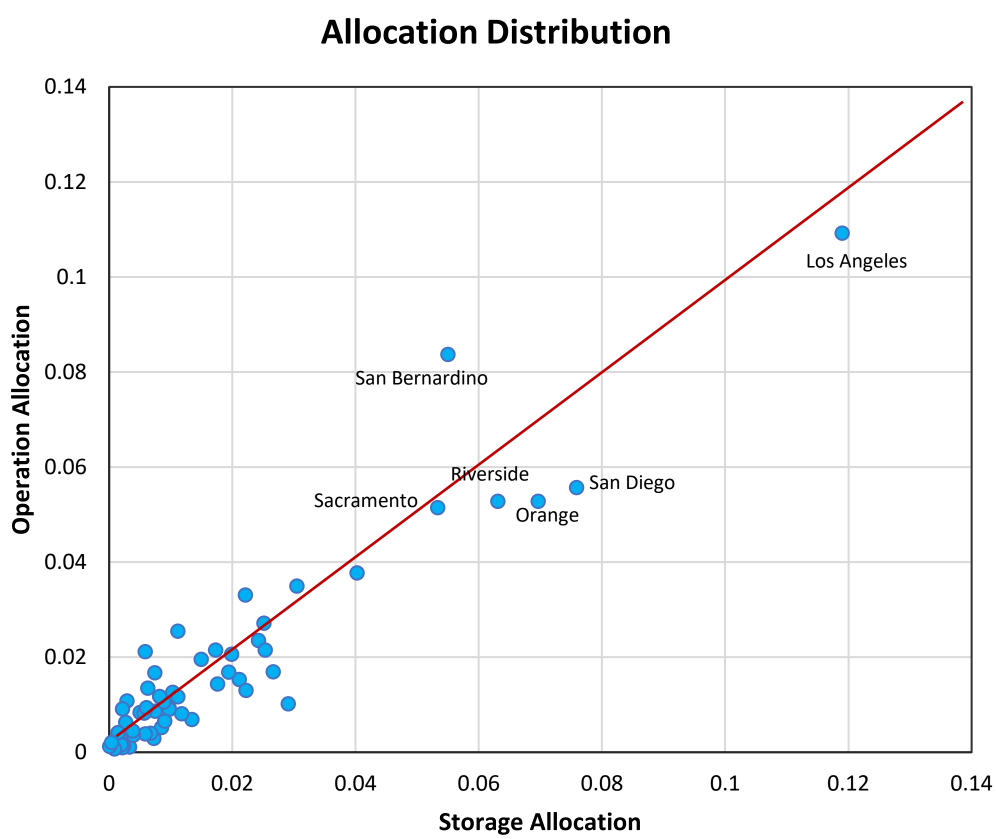

Figure 15: 2025 DMV Allocation Distribution

a. Regional Differences

The operation and storage allocation values used in PC2014 were based on a 2009 phone survey conducted by CSUS, which included 1,127 randomly selected California RMV-registered owners. Due to various limitations at the time, the survey sample did not proportionally represent all vessel types from all 58 counties based on DMV registration data. As a result, PC2014 relied on a single set of operation and storage allocation files that applied uniformly across all six RMV types.

In contrast, the updated RMV survey conducted by CSUF in 2020 through 2022 employed a stratified sampling approach that accounted for both the 58 counties and 6 vessel types, resulting in 348 homogeneous groups (strata) designed to closely reflect actual DMV registration patterns. With over 2,800 completed survey responses, a more granular operation allocation profile for RMVs in California was developed. Appendix 1 in the Appendix shows the updated allocation profile for RMV2026, which includes distinct operational allocation values for each of the six RMV types across all 58 counties.

The revised allocation factors in RMV2026 reveal significant regional shifts when compared to PC2014, particularly in the South Coast Air Basin and the San Joaquin Valley Air Basin. In the South Coast, the operation allocation increased from 15.4% in PC2014 to 27.6% in RMV2026, while the storage allocation rose from 20.7% to 30.7%. This reflects a substantial increase in both boating activity and vessel storage presence in the region.

Conversely, the San Joaquin Valley saw a modest decrease in both metrics. The operation allocation declined slightly from 13.61% in PC2014 to 12.48% in RMV2026, and the storage allocation dropped from 12.18% to 11.51%. These changes may be based on the change in methodology and increasing the number of participants in the survey or could reflect that RMV activity and storage in the San Joaquin Valley changed between 2009 and 2022. Figure 16 shows the updated allocation factors for these two key regions.

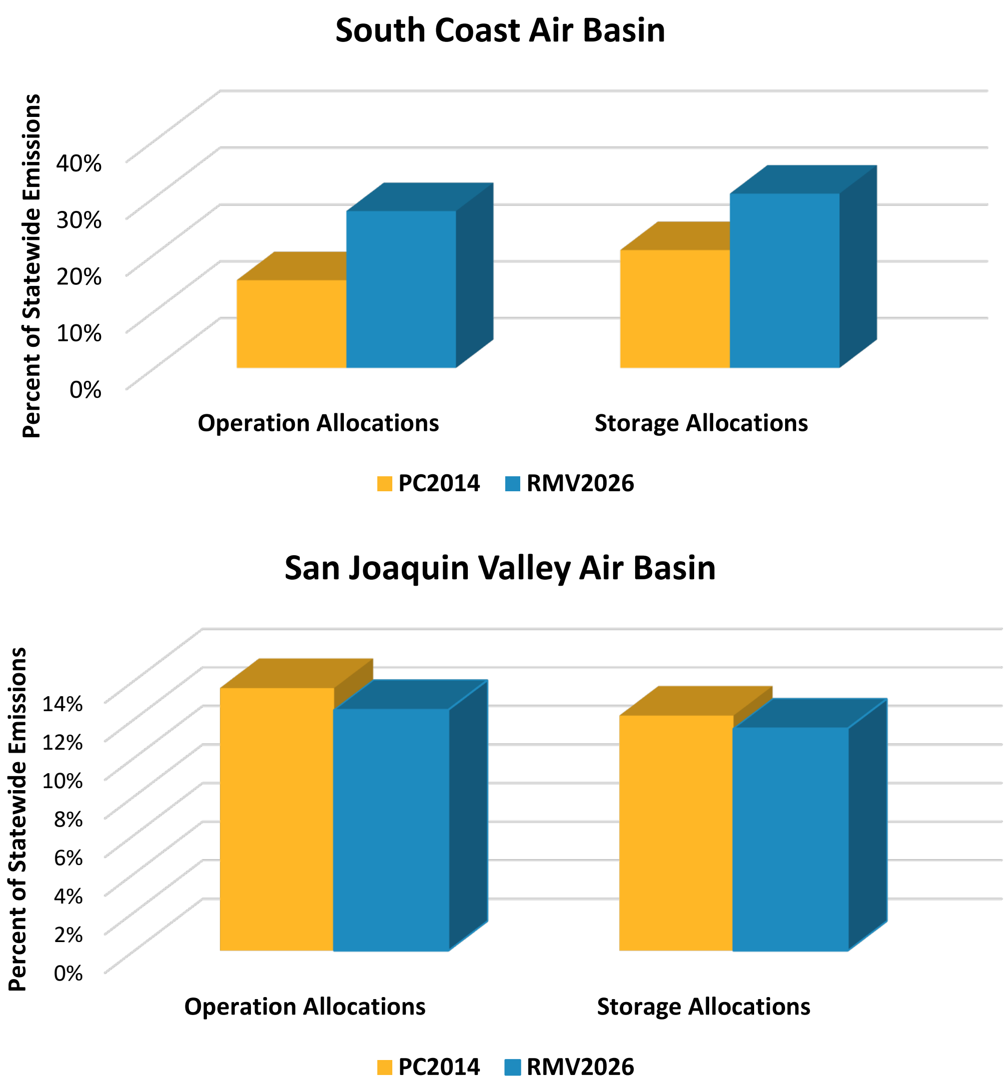

Figure 16: South Coast and San Joaquin Valley Operation and Storage Allocation

b. Correction Factors

Fuel correction factors, temperature and humidity correction factors, and pollutant conversion factors in RMV2026 remain unchanged from those used in PC2014. The temperature/RVP correction factors were updated using RVP measurements on fuels that were recently incorporated into EMFAC2025.[14] The RVP values were incorporated into the Reddy Equation[15] along with regional ambient temperatures that were used in

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[14] *https://www.arb.ca.gov/emfac2025-model-and-documentation*

[15] Reddy, S. Raguma.Prediction of Fuel Vapor Generation from a Vehicle Fuel Tank as a Function of Fuel RVP and Temperature.SAE Technical Paper 1989-09-01 .1989.DOI: 10.4271/892089.

PC2014 to determine necessary correction factors. The same process explained in the PC2014 technical documentation, section VI, part E, was used to determine the RVP correction factors.[16]

Some total hydrocarbon (THC) conversion factors (in red in Table 12) were updated to align with the most recent speciation profiles (OG2309, OG2310[17], OG2311[18]) for off-road equipment and exempt compound lists. Given the RMV fleet composition of approximately 35% gasoline 2-stroke (G2) and 53% gasoline 4-stroke (G4) engines, applying the updated THC to TOG/ROG conversion factors for 2004 and subsequent years, with engine type differentiation, leads to an approximate 2% reduction in TOG emissions and a 1% increase in ROG emissions relative to estimates without the updated THC conversion factors.

Table 12: Updated THC to TOG and ROG Conversion Factors

CY	Process	PC2014		RMV2026	
		TOG	ROG	TOG	ROG
< 1996	Exhaust (G2)	THC*1.015	THC*0.920	THC*1.015	THC*0.920
	Exhaust (G4)	THC*1.038	THC*0.890	THC*1.038	THC*0.890
	Evaporative	THC*1.040	THC*1.040	THC*1.040	THC*1.040
1996-2003	Exhaust	THC*1.090	THC*1.000	THC*1.090	THC*1.000
	Evaporative	THC*1.120	THC*1.120	THC*1.120	THC*1.120
>= 2004	Exhaust (G2)	THC*1.100	THC*1.010	THC*1.060	THC*1.038
	Exhaust (G4)	THC*1.100	THC*1.010	THC*1.090	THC*0.981
	Evaporative	THC*1.140	THC*1.140	THC*1.142	THC*1.140

IX. Emissions Results

Table 13 presents the statewide summer emissions estimates of RMV2026 and PC2014. Both models show consistent differences across all three pollutants, NOx, ROG, and PM2.5, over the 2025 to 2037 period.

Table 13: Statewide Summer Emissions (tons per day)

Year	NOx		ROG		PM2.5	
	PC2014	RMV2026	PC2014	RMV2026	PC2014	RMV2026

[16] *https://ww2.arb.ca.gov/sites/default/files/2023-08/pc2014_technical_document.pdf*

[17] *https://ww2.arb.ca.gov/sites/default/files/classic/speciation/reference/96-ohrvexhaust_og2309%262310.pdf*

[18] *https://ww2.arb.ca.gov/sites/default/files/classic/speciation/reference/97-ohrvevap_og2311.pdf*

2025	23.35	20.33	104.39	111.96	4.83	4.56
2026	23.14	20.31	100.13	106.71	4.64	4.34
2027	22.96	20.30	96.23	101.75	4.47	4.13
2028	22.80	20.29	92.58	96.87	4.32	3.93
2029	22.64	20.27	89.14	92.11	4.17	3.73
2030	22.50	20.24	85.76	87.29	4.03	3.54
2031	22.39	20.23	82.54	82.59	3.90	3.34
2032	22.30	20.23	79.80	78.40	3.78	3.17
2033	22.20	20.22	77.08	74.14	3.67	3.00
2034	22.10	20.21	74.46	69.93	3.56	2.82
2035	22.01	20.19	71.87	65.63	3.46	2.64
2036	21.93	20.18	69.20	60.90	3.35	2.45
2037	21.86	20.16	66.47	55.84	3.24	2.23

For NOx, RMV2026 estimates remain nearly flat at approximately 20.30 tons per day. This pattern is driven by the updated survival rates, which retain a larger share of older and typically higher-emitting engines in the fleet, combined with updated NOx emission factors and the addition of the deterioration rate, all having an increasing effect on NOx emissions. However, the declining population over time offsets the previous effects, resulting in NOx emissions remaining relatively stable in RMV2026. In contrast, PC2014 projects a gradual decline in NOx emissions from 23.35 to 21.86 tons per day. Because PC2014 had lower survival rates, dirtier engines turned over faster, resulting in a net decrease in NOx emissions over time, relative to RMV2026.

For ROG, the two models show the largest differences in both magnitude and trend. RMV2026 begins the projection period with higher ROG emissions than PC2014 (111.96 vs. 104.39 tons per day in 2025). This is primarily driven by the addition of deterioration rate emissions. Higher survival rates also play a role in the higher ROG estimation than that of PC2014. However, RMV2026 also shows a steeper decline in ROG emissions over time as older, higher-emitting vessels gradually retire. The updated temperature/RVP correction factors also contribute to reductions in diurnal and resting-loss evaporative emissions. By 2030, the gap between the two models narrows substantially, and RMV2026 eventually falls below PC2014 beginning around 2032. The long-term divergence is influenced by PC2014's higher population growth.

Despite the addition of the USCG population increase in RMV2026, PM2.5 emissions begin slightly lower than PC2014 in 2025 (4.56 vs. 4.83 tons per day), This is primarily due to the adjusted diesel/gasoline split ratio, with the diesel engine population share declining from 17% in PC2014 to 13% in RMV2026 across the entire RMV fleet, resulting in lower PM emissions. Reduced activity across the entire RMV population, which further contributes to the lower particulate matter estimates. By 2037, PM2.5 emissions in RMV2026 are approximately one ton per day lower (2.23 tons per day), representing a 31% reduction compared to PC2014 estimates.

Table 14 presents a comparison of summer ROG and NOx emissions for the South Coast Air Basin and the San Joaquin Valley Air Basin between PC2014 and RMV2026.

Table 14: South Coast and San Joaquin Summer Emissions

Emissions in Selected Air Basins (Summer)								
Year	ROG (tons/day)				NOx (tons/day)			
	South Coast Air Basin		San Joaquin Valley Air Basin		South Coast Air Basin		San Joaquin Valley Air Basin	
	PC2014	RMV2026	PC2014	RMV2026	PC2014	RMV2026	PC2014	RMV2026
2025	16.67	32.62	14.24	14.41	3.57	5.74	3.12	2.47
2026	16.01	31.02	13.65	13.73	3.54	5.74	3.09	2.48
2027	15.40	29.52	13.10	13.10	3.51	5.74	3.06	2.48
2028	14.83	28.04	12.59	12.47	3.49	5.73	3.04	2.48
2029	14.29	26.61	12.11	11.87	3.46	5.73	3.02	2.49
2030	13.77	25.14	11.64	11.25	3.44	5.73	3.00	2.49
2031	13.26	23.71	11.19	10.63	3.43	5.73	2.99	2.49
2032	12.84	22.45	10.81	10.09	3.41	5.73	2.97	2.50
2033	12.41	21.16	10.43	9.54	3.40	5.73	2.96	2.50
2034	12.00	19.88	10.06	8.99	3.38	5.73	2.95	2.50
2035	11.60	18.52	9.70	8.43	3.37	5.72	2.93	2.51
2036	11.19	16.95	9.32	7.80	3.36	5.72	2.92	2.51
2037	10.76	15.23	8.94	7.13	3.35	5.72	2.91	2.52

In most years in the South Coast and San Joaquin Valley Air Basins, ROG emissions in RMV2026 are higher than projections from PC2014. This difference is primarily due to the updated allocation factors used in RMV2026, which redistribute a greater portion of statewide emissions to this region. In contrast, except for 2025 and 2026, the San Joaquin Valley Air Basin shows lower ROG emissions in RMV2026 relative to PC2014, reflecting the effects of these revised allocations.

Despite the differences in magnitude, both models show a consistent downward trend in ROG emissions over time, driven by fleet turnover and cleaner engine technologies.

For NOx emissions, levels remain relatively stable in the South Coast Air Basin under RMV2026, while showing minor decreases under PC2014. The San Joaquin Valley exhibits minimal changes across years for both models, with PC2014 values slightly higher overall.

By 2037, both air basins show reduced ROG emissions and relatively stable NOx levels, indicating that updated modeling assumptions and fleet improvements, such as turnover from 2-stroke to cleaner 4-stroke engines, contribute to overall emission reductions, even as regional distribution patterns shift under RMV2026.

Appendix

Appendix 1: Comparison of RMV2026 and PC2014 Allocation Factors

GAI[1]	PC2014		RMV2026											
			Auxiliary & Sails		Inboard		Jet		Outboard		PWC		Sterndrive	
	Operation	Storage	Operation	Storage	Operation	Storage	Operation	Storage	Operation	Storage	Operation	Storage	Operation	Storage
1	0.01275	0.03312	0.00048	0.00006	0.00000	0.00004	0.00000	0.00008	0.00204	0.00012	0.00216	0.00003	0.00016	0.00006
2	0.00226	0.00097	0.00000	0.00091	0.00000	0.00096	0.00000	0.00083	0.00275	0.00191	0.00810	0.00088	0.00000	0.00090
3	0.00486	0.00097	0.00000	0.00091	0.00000	0.00136	0.00000	0.00098	0.00993	0.00231	0.00000	0.00086	0.00314	0.00067
4	0.01812	0.02338	0.00981	0.00946	0.02075	0.00877	0.01008	0.00874	0.02576	0.01220	0.03945	0.00903	0.02146	0.01255
5	0.00446	0.00682	0.00277	0.00461	0.00766	0.00561	0.00232	0.00289	0.00588	0.00508	0.00294	0.00263	0.01015	0.00601
6	0.00281	0.00292	0.00166	0.00091	0.00211	0.00238	0.00190	0.00132	0.00120	0.00195	0.00065	0.00130	0.00285	0.00198
7	0.06537	0.05163	0.00191	0.00194	0.00437	0.00251	0.00457	0.00289	0.00710	0.00570	0.00130	0.00190	0.00241	0.00356
8	0.00063	0.00097	0.00455	0.00309	0.02099	0.00671	0.00412	0.00563	0.01723	0.00967	0.02403	0.00494	0.01096	0.00719
9	0.00780	0.00245	0.00728	0.01213	0.02017	0.01476	0.00611	0.00761	0.01548	0.01337	0.00775	0.00692	0.02671	0.01582
10	0.02174	0.00684	0.00000	0.00103	0.00224	0.00117	0.00000	0.00083	0.00181	0.00216	0.00124	0.00075	0.00000	0.00145
11	0.03386	0.01656	0.00000	0.00843	0.01880	0.01279	0.00802	0.00791	0.01775	0.01256	0.00524	0.00418	0.00701	0.01089
12	0.00387	0.00292	0.00249	0.00136	0.00315	0.00356	0.00284	0.00197	0.00179	0.00293	0.00097	0.00195	0.00427	0.00297
13	0.00931	0.01072	0.00048	0.00121	0.01046	0.00189	0.00576	0.00188	0.01328	0.00447	0.00686	0.00127	0.01252	0.00222
14	0.00033	0.00390	0.00000	0.00036	0.00025	0.00024	0.00082	0.00011	0.00470	0.00063	0.00043	0.00012	0.00080	0.00026
15	0.01462	0.00292	0.00005	0.00291	0.01790	0.00469	0.01440	0.00263	0.02662	0.00843	0.01631	0.00323	0.02852	0.00509
16	0.00693	0.00481	0.00952	0.01504	0.00915	0.01223	0.01214	0.00506	0.01483	0.00906	0.00562	0.00614	0.00997	0.00944
17	0.02956	0.02052	0.00000	0.00109	0.00121	0.00315	0.00000	0.00139	0.00124	0.00215	0.00108	0.00153	0.00032	0.00269
18	0.00260	0.00584	0.03163	0.02487	0.00224	0.01073	0.00000	0.00304	0.00946	0.01077	0.00000	0.00402	0.00643	0.00742
19	0.02569	0.01753	0.00000	0.00079	0.00109	0.00137	0.00082	0.00338	0.00309	0.00301	0.00000	0.00049	0.00161	0.00169
20	0.00891	0.00195	0.00478	0.01007	0.00170	0.00634	0.00370	0.00754	0.01943	0.01492	0.00216	0.00417	0.00571	0.00745
21	0.00129	0.00173	0.00000	0.00576	0.00204	0.00455	0.00045	0.00266	0.00734	0.00794	0.00013	0.00270	0.00257	0.00562
22	0.06309	0.08497	0.00260	0.00342	0.00166	0.00365	0.00194	0.00206	0.00354	0.00400	0.00109	0.00202	0.00220	0.00357
23	0.00520	0.00974	0.00000	0.00055	0.01109	0.00132	0.00700	0.00139	0.01195	0.00339	0.00685	0.00092	0.00426	0.00193
24	0.00863	0.01266	0.00000	0.00109	0.00254	0.00267	0.00226	0.00293	0.00599	0.00575	0.00097	0.00216	0.00450	0.00319
25	0.00245	0.00195	0.00000	0.00012	0.00000	0.00031	0.00000	0.00060	0.00174	0.00159	0.00000	0.00025	0.00000	0.00051
26	0.00160	0.00292	0.00000	0.00212	0.00732	0.00253	0.00782	0.00394	0.01257	0.00865	0.00649	0.00121	0.00595	0.00365

[1] GAI is a refined numbering system used in CARB emission inventories to differentiate California counties, air basins, and air districts for emission modeling purposes. For more details on GAI, please refer to Appendix 2.

27	0.00505	0.00682	0.00239	0.00764	0.02105	0.01579	0.02947	0.02816	0.02438	0.02686	0.01096	0.01076	0.02524	0.01853
28	0.00076	0.00097	0.00478	0.00055	0.00024	0.00196	0.01214	0.00356	0.00440	0.00239	0.00140	0.00115	0.00169	0.00151
29	0.00413	0.00097	0.00000	0.00030	0.00266	0.00167	0.00864	0.00589	0.00098	0.00347	0.00022	0.00133	0.00000	0.00183
30	0.02760	0.00877	0.01906	0.01046	0.02419	0.02732	0.02180	0.01512	0.01375	0.02244	0.00741	0.01497	0.03272	0.02277
31	0.01045	0.01364	0.01603	0.02577	0.06163	0.04753	0.04185	0.03851	0.05608	0.06195	0.03715	0.04016	0.06486	0.05943
32	0.01014	0.02046	0.01435	0.00831	0.02711	0.01638	0.08189	0.02693	0.04032	0.02934	0.01253	0.01109	0.03915	0.02481
33	0.05734	0.06137	0.00925	0.00456	0.00402	0.00529	0.00157	0.00336	0.00482	0.00512	0.00184	0.00362	0.00387	0.00646
34	0.00069	0.00136	0.00000	0.00152	0.00042	0.00667	0.01502	0.01163	0.00566	0.00924	0.00432	0.00439	0.00161	0.00511
35	0.00109	0.00214	0.00000	0.00188	0.00018	0.00551	0.02346	0.01564	0.00421	0.01006	0.00000	0.00363	0.00000	0.00641
36	0.00811	0.01598	0.00144	0.00619	0.00212	0.00821	0.00535	0.00679	0.00820	0.01077	0.00162	0.00456	0.00847	0.00925
37	0.01193	0.00584	0.00024	0.00158	0.01366	0.00469	0.01399	0.00881	0.01072	0.00852	0.00335	0.00384	0.01214	0.00517
38	0.00022	0.00042	0.10789	0.12906	0.05040	0.06346	0.05144	0.07455	0.05902	0.07788	0.05486	0.08430	0.04317	0.05873
39	0.00022	0.00042	0.07665	0.06422	0.01239	0.03364	0.00016	0.01478	0.02296	0.02556	0.00659	0.02187	0.00704	0.02531
40	0.01749	0.03267	0.03455	0.03505	0.04762	0.05965	0.01564	0.02269	0.02842	0.03504	0.03575	0.03793	0.05466	0.04719
41	0.00448	0.00838	0.03211	0.03948	0.01030	0.01330	0.00000	0.00323	0.01195	0.01047	0.00335	0.00320	0.00653	0.00852
43	0.04021	0.05845	0.00718	0.00594	0.02372	0.00776	0.00823	0.00405	0.01496	0.00788	0.00907	0.00318	0.00764	0.00602
43	0.00005	0.00195	0.04813	0.03505	0.00861	0.00684	0.01235	0.00169	0.00912	0.00562	0.00022	0.00244	0.00211	0.00436
44	0.00386	0.00666	0.03278	0.03196	0.00877	0.02124	0.00000	0.00750	0.00809	0.01224	0.00000	0.01003	0.00498	0.01293
45	0.01648	0.02841	0.00048	0.03408	0.00774	0.03832	0.00823	0.01448	0.01095	0.02774	0.01091	0.02467	0.01289	0.03023
46	0.08555	0.07111	0.02357	0.01163	0.01023	0.01348	0.00399	0.00856	0.01229	0.01306	0.00469	0.00923	0.00987	0.01646
47	0.04268	0.00584	0.01343	0.01769	0.00857	0.01887	0.01004	0.01065	0.01831	0.02071	0.00566	0.01045	0.01139	0.01850
48	0.03845	0.03410	0.00718	0.01073	0.02358	0.02039	0.02757	0.02171	0.03145	0.03118	0.02944	0.01745	0.02141	0.02594
49	0.01793	0.02922	0.00777	0.00739	0.01772	0.01561	0.01170	0.01632	0.00872	0.01420	0.02160	0.01808	0.01273	0.01747
50	0.01309	0.01169	0.00000	0.00103	0.00091	0.00282	0.00000	0.00353	0.00063	0.00392	0.00227	0.00357	0.00177	0.00291
51	0.02945	0.01072	0.00239	0.00200	0.00931	0.00549	0.00412	0.00623	0.00843	0.00941	0.01199	0.00597	0.00804	0.00752
52	0.00459	0.02825	0.00167	0.00315	0.00810	0.00693	0.00494	0.00435	0.01682	0.01029	0.00729	0.00562	0.01270	0.00881
53	0.02382	0.00682	0.01469	0.01067	0.03859	0.03293	0.02078	0.01830	0.03213	0.03361	0.04595	0.02542	0.03505	0.03570
54	0.05374	0.02922	0.00072	0.00631	0.01360	0.02129	0.00494	0.01436	0.01350	0.02762	0.01501	0.01756	0.01458	0.02286
55	0.00083	0.00000	0.00000	0.00243	0.00937	0.01017	0.00823	0.01316	0.00709	0.01368	0.01058	0.00959	0.00506	0.01273
56	0.00371	0.01072	0.02297	0.01607	0.02288	0.01697	0.02222	0.01279	0.01614	0.01601	0.01971	0.01036	0.02556	0.01548
57	0.01433	0.02104	0.02847	0.02329	0.01479	0.01384	0.00535	0.00893	0.01170	0.01128	0.00400	0.00732	0.01174	0.01140
58	0.00557	0.00818	0.07153	0.03906	0.02778	0.03582	0.02922	0.02269	0.01727	0.02039	0.02030	0.02484	0.01857	0.02359
59	0.00168	0.00405	0.21010	0.16142	0.11753	0.10376	0.09444	0.13844	0.09566	0.08540	0.12663	0.17999	0.09342	0.11053
60	0.00885	0.02128	0.09325	0.07933	0.05756	0.08227	0.04239	0.08168	0.04811	0.05985	0.04606	0.08996	0.04373	0.05736
61	0.01923	0.02241	0.00470	0.01933	0.04524	0.04136	0.10568	0.10044	0.03616	0.03117	0.09081	0.08440	0.04566	0.05265
62	0.00167	0.00682	0.00674	0.01622	0.05576	0.03094	0.10674	0.07440	0.02843	0.02782	0.14430	0.07542	0.09043	0.05189
63	0.00124	0.00682	0.00000	0.00073	0.00435	0.00144	0.01893	0.00450	0.00410	0.00290	0.00889	0.00359	0.00941	0.00192

64	0.00744	0.00195	0.00000	0.00479	0.00000	0.01025	0.00000	0.02489	0.00000	0.00772	0.00000	0.02091	0.00000	0.01305
65	0.00216	0.00584	0.00180	0.00171	0.00410	0.00361	0.00271	0.00378	0.00202	0.00329	0.00500	0.00419	0.00295	0.00404
66	0.01295	0.00877	0.00009	0.00039	0.00083	0.00083	0.00194	0.00202	0.00066	0.00063	0.00166	0.00170	0.00084	0.00106
67	0.02048	0.03507	0.00000	0.00005	0.00000	0.00011	0.00000	0.00027	0.00000	0.00009	0.00000	0.00023	0.00000	0.00014
68	0.00893	0.00779	0.00000	0.00282	0.00000	0.00181	0.00000	0.00241	0.00000	0.00149	0.00000	0.00314	0.00000	0.00193
69	0.00258	0.00487	0.00163	0.00392	0.01346	0.00747	0.02577	0.01797	0.00686	0.00672	0.03484	0.01821	0.02184	0.01253

Appendix 2: GAI Cross Reference of California Counties, Air Basins, and Air Districts

GAI	County	Basin	Air Basin	District	Air District
1	Alpine	GBV	Great Basin Valleys	GBUAPCD	Great Basin Unified Air District
2	Inyo	GBV	Great Basin Valleys	GBUAPCD	Great Basin Unified Air District
3	Mono	GBV	Great Basin Valleys	GBUAPCD	Great Basin Unified Air District
4	Lake	LC	Lake County	LCAPCD	Lake Air District
5	El Dorado	LT	Lake Tahoe	EDCAPCD	El Dorado Air District
6	Placer	LT	Lake Tahoe	PCAPCD	Placer Air District
7	Amador	MC	Mountain Counties	ACAPCD	Amador Air District
8	Calaveras	MC	Mountain Counties	CACAPCD	Calaveras Air District
9	El Dorado	MC	Mountain Counties	EDCAPCD	El Dorado Air District
10	Mariposa	MC	Mountain Counties	MACAPCD	Mariposa Air District
11	Nevada	MC	Mountain Counties	NSAQMD	Northern Sierra Air District
12	Placer	MC	Mountain Counties	PCAPCD	Placer Air District
13	Plumas	MC	Mountain Counties	NSAQMD	Northern Sierra Air District
14	Sierra	MC	Mountain Counties	NSAQMD	Northern Sierra Air District
15	Tuolumne	MC	Mountain Counties	TUCAPCD	Tuolumne Air District
16	Monterey	NCC	North Central Coast	MBUAPCD	Monterey Bay Unified Air District
17	San Benito	NCC	North Central Coast	MBUAPCD	Monterey Bay Unified Air District
18	Santa Cruz	NCC	North Central Coast	MBUAPCD	Monterey Bay Unified Air District
19	Del Norte	NC	North Coast	NCUAPCD	North Coast Unified Air District
20	Humboldt	NC	North Coast	NCUAPCD	North Coast Unified Air District
21	Mendocino	NC	North Coast	MCAQMD	Mendocino Air District
22	Sonoma	NC	North Coast	NSCAPCD	Northern Sonoma Air District
23	Trinity	NC	North Coast	NCUAPCD	North Coast Unified Air District
24	Lassen	NEP	Northeast Plateau	LACAPCD	Lassen Air District
25	Modoc	NEP	Northeast Plateau	MCAPCD	Modoc Air District
26	Siskiyou	NEP	Northeast Plateau	SICAPCD	Siskiyou Air District
27	Butte	SV	Sacramento Valley	BCAPCD	Butte Air District
28	Colusa	SV	Sacramento Valley	CCAPCD	Colusa Air District
29	Glenn	SV	Sacramento Valley	GCAPCD	Glenn Air District
30	Placer	SV	Sacramento Valley	PCAPCD	Placer Air District
31	Sacramento	SV	Sacramento Valley	SMAQMD	Sacramento Air District
32	Shasta	SV	Sacramento Valley	SHCAQMD	Shasta Air District
33	Solano	SV	Sacramento Valley	YSAQMD	Yolo-Solano Air District
34	Sutter	SV	Sacramento Valley	FRAQMD	Feather River Air District
35	Tehama	SV	Sacramento Valley	TCAPCD	Tehama Air District
36	Yolo	SV	Sacramento Valley	YSAQMD	Yolo-Solano Air District
37	Yuba	SV	Sacramento Valley	FRAQMD	Feather River Air District
38	San Diego	SD	San Diego	SDCAPCD	San Diego Air District
39	Alameda	SF	San Francisco Bay Area	BAAQMD	San Diego Air District

40	Contra Costa	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
41	Marin	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
42	Napa	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
43	San Francisco	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
44	San Mateo	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
45	Santa Clara	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
46	Solano	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
47	Sonoma	SF	San Francisco Bay Area	BAAQMD	San Diego Air District
48	Fresno	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
49	Kern	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
50	Kings	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
51	Madera	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
52	Merced	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
53	San Joaquin	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
54	Stanislaus	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
55	Tulare	SJV	San Joaquin Valley	SJVUAPCD	San Joaquin Valley Unified Air District
56	San Luis Obispo	SCC	South Central Coast	SLOCAPCD	San Luis Obispo Air District
57	Santa Barbara	SCC	South Central Coast	SBCAPCD	Santa Barbara Air District
58	Ventura	SCC	South Central Coast	VCAPCD	Ventura Air District
59	Los Angeles	SC	South Coast	SCAQMD	South Coast Air District
60	Orange	SC	South Coast	SCAQMD	South Coast Air District
61	Riverside	SC	South Coast	SCAQMD	South Coast Air District
62	San Bernardino	SC	South Coast	SCAQMD	South Coast Air District
63	Imperial	SS	Salton Sea	ICAPCD	Imperial Air District
64	Riverside	SS	Salton Sea	SCAQMD	South Coast Air District
65	Kern	MD	Mojave Desert	KCAPCD	Kern Air District
66	Riverside	MD	Mojave Desert	MDAQMD	Mojave Desert Air District
67	Riverside	MD	Mojave Desert	SCAQMD	South Coast Air District
68	Los Angeles	MD	Mojave Desert	AVAPCD	Antelope Valley Air District
69	San Bernardino	MD	Mojave Desert	MDAQMD	Mojave Desert Air District