Recreational Marine Vessels Emissions Inventory (RMV2026)

Air Quality Planning & Science Division
California Air Resources Board

April 1, 2026

Workshop Questions

- Please include slide numbers in questions
- Questions can be added to the “chat "in Zoom during the presentation
- Following the presentation, questions can be asked by “raising your hand” in Zoom
- On phone:
    - #2 to “Raise Hand”
    - *6 to Mute/Unmute
- Additional questions may be submitted after the workshop to: msei@arb.ca.gov

Workshop Instructions

- Telephone Call - In: (855) 758-1310
  - Meeting ID: 864 2722 8003
  - Passcode: 095077
- Workshop is being recorded
- Slides and recording will be available on our website:
  - CARB's Off-Road Conferences and Workshops

Emission Reduction Strategies

- This Workshop is **not** intended to update on spark ignition marine engine emission reduction strategies introduced in the 2022 State SIP Strategy[1]

1. https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf

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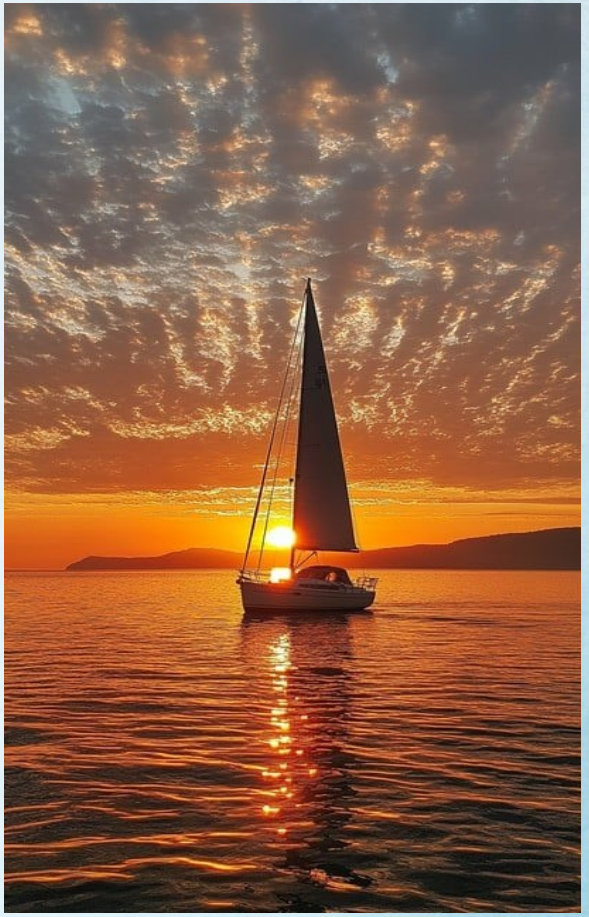
Outline

- Background
- 2022 RMV Survey
- Population & Growth
- Emission Results
- Next Steps



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Recreational Marine Vessels

- RMVs are primarily gasoline-powered and include six categories of vessels according to DMV registration
- The last emission inventory was released in 2014
- RMV engine manufacturers are subject to exhaust standards (amended 2011) and evaporative emission standards (amended 2015)


Inboard


Sterndrive


Outboard


Jet


Personal Watercraft (PWC)


Auxiliary & Sail

Understanding the Emission Inventory

- The emission inventory characterizes:
  - **Population**, age, fuel type, and horsepower of RMV
  - **Activity** or how often each vessel is used every year, and in which months they operate
  - **Emissions** produced per hour from each vessel
  - Where RMV are stored and operate
- When combined, these data show total emissions and where and when the emissions happen = **Emission Inventory**

Summary of Updated Input Data Sources

- RMV Survey 2022
- DMV Registration (2006-2021)
- U.S.C.G.[2] 2020: Baseline population adjustment
- 2022 UCLA 10-Year Economic Report
- SIME[3] (2006-2021) & PLT[4] (2008-2021)

[2] United States Coast Guard
[3] Spark Ignition Marine Engine Database
[4] Production Line Test Report

2022 RMV Survey Methodology & Background

- Contractor: Social Science Research Center (SSRC) at California State University (CSU), Fullerton
- Recipients: RMV owners, identified using DMV registration data.
- Survey Design: Beta-test was developed and refined with input from 18 participants in December 2020.
- Pilot Survey: Conducted in July 2021.
- Main Survey Period: Ran from January to July 2022.
- Mailing and Response Rate:
  - 85,691 surveys were mailed.
  - 2,857 responses were received.
  - This gives a response rate of approximately 3.33%.

Sample Size & Confidence

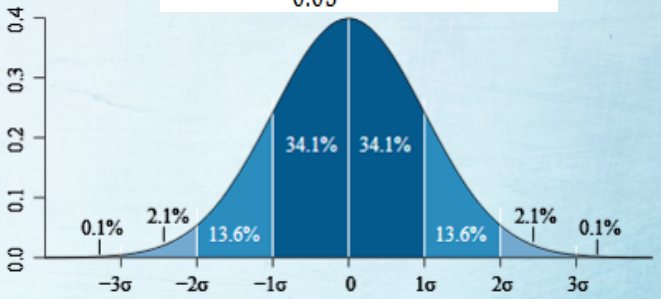
- What is an appropriate sample size for a survey to accurately represent a population >100,000?
- **384** responses is needed for have a +/- 5% margin of error
- The RMV survey had **2,857** responses

Equation for Sample Size with +/-5% Confidence

$$n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

$$n = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = 384.16$$

Recommended Sample Size	Confidence Level	Margin of Error	
270	90%	±5%	
384	**95%**	**±5%**	**Typical**
666	99%	±5%	
2,475	**99%**	**±2%**	**More Precise**



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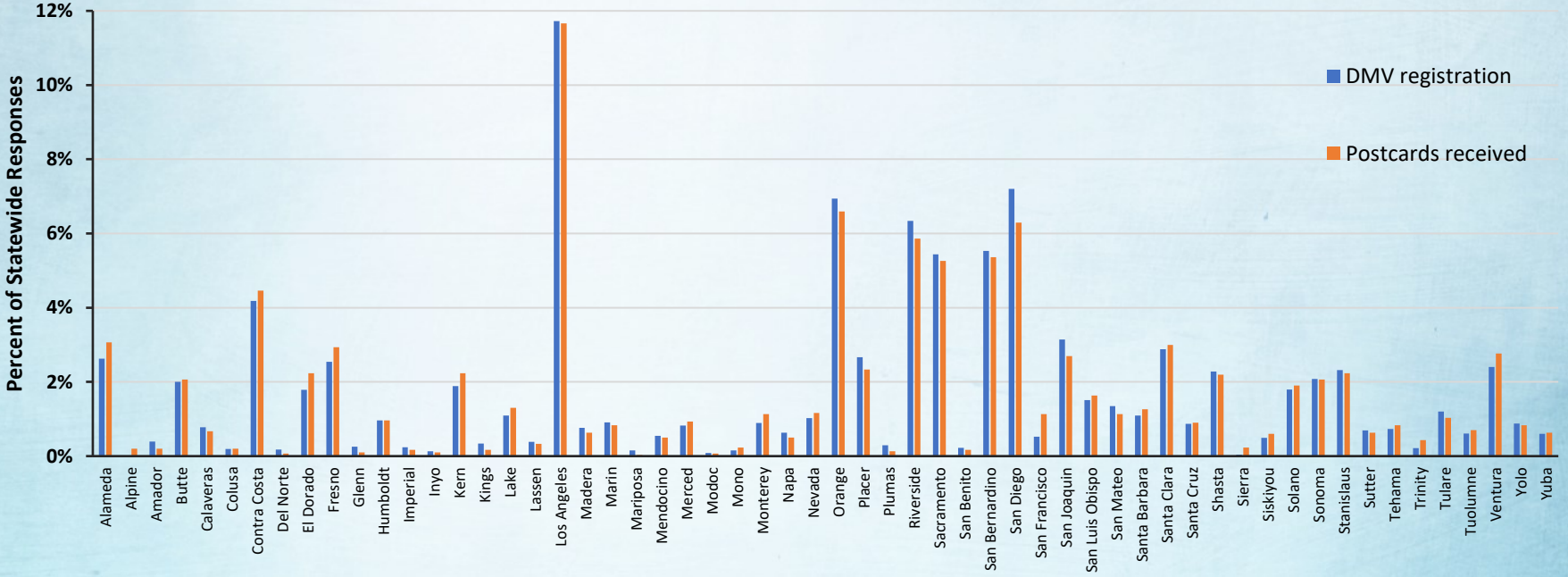
Geographic Representation: Survey vs. Reality

- Survey responses closely correlated to DMV registration, not biased by any one region



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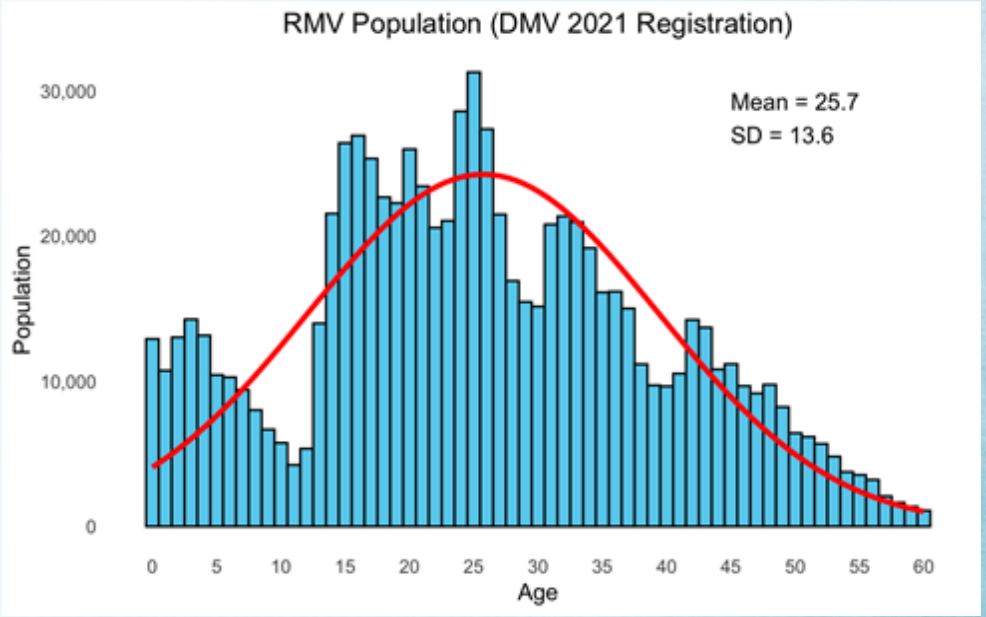
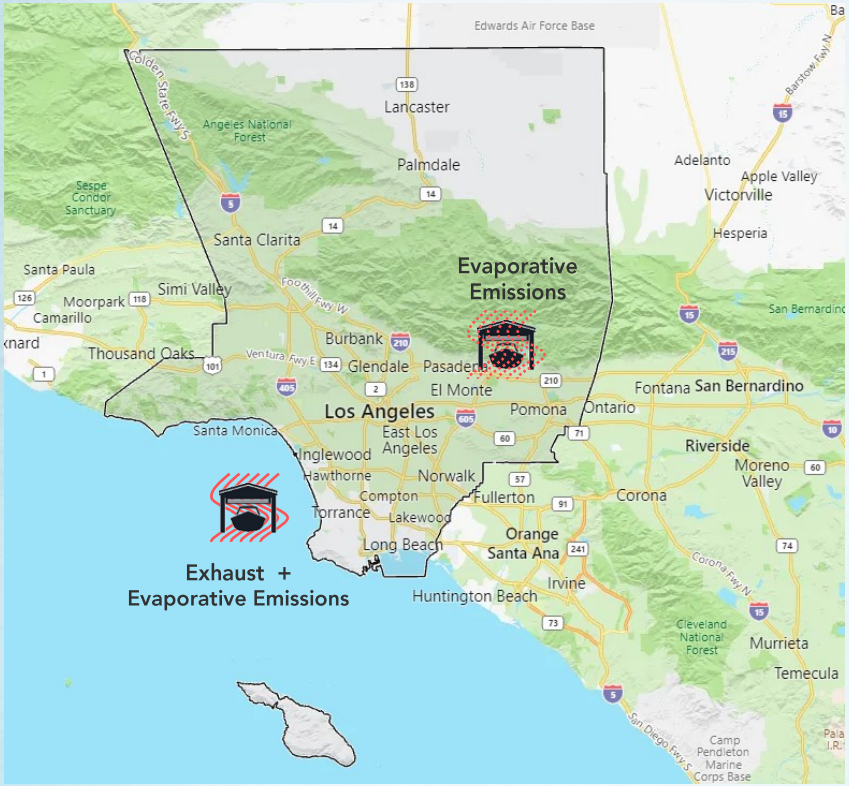
Engine Repower/Rebuild/Replacement

- Survey asked if owners repowered, rebuilt or replaced engines separately from vessel
- Sample size= 4,865
  - No = 89%
  - Yes = 11%
- CARB chose not to reflect any difference in engine year vs vessel year in emission inventory.





Storage allocation

- Residential areas & marina slips
- Active & inactive population
- Evaporative Emissions
  - Diurnal
  - Resting loss

Operational allocation

- Lakes & coastal areas
- Active population
- Exhaust Emissions
- Evaporative Emissions
  - Hot soak
  - Running loss

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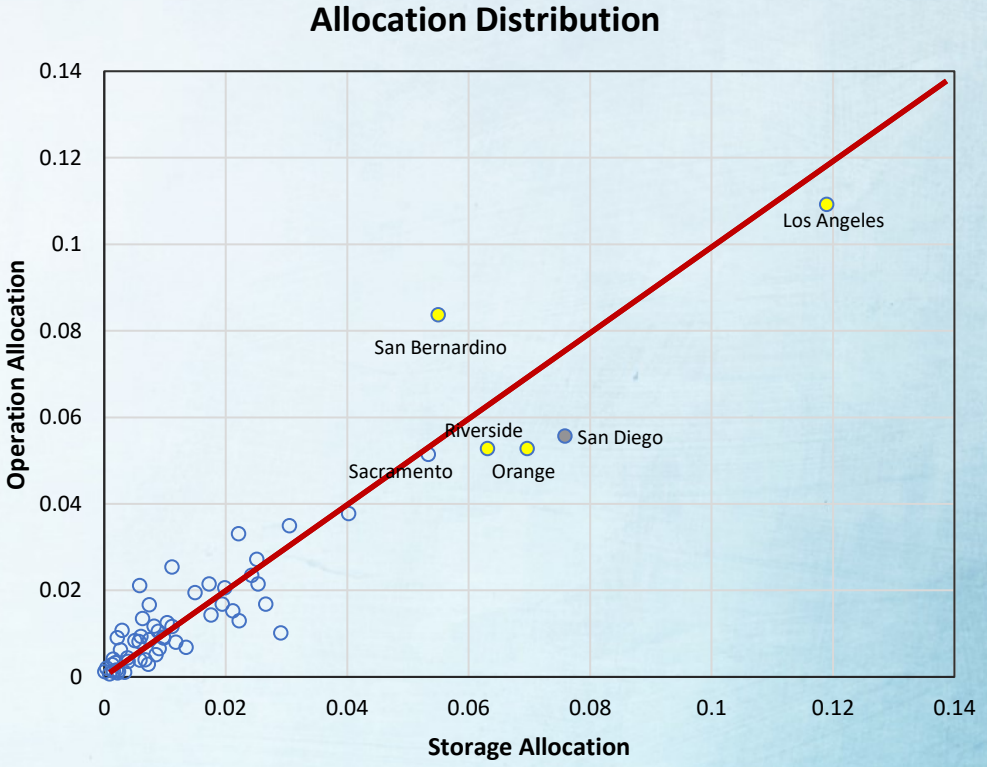
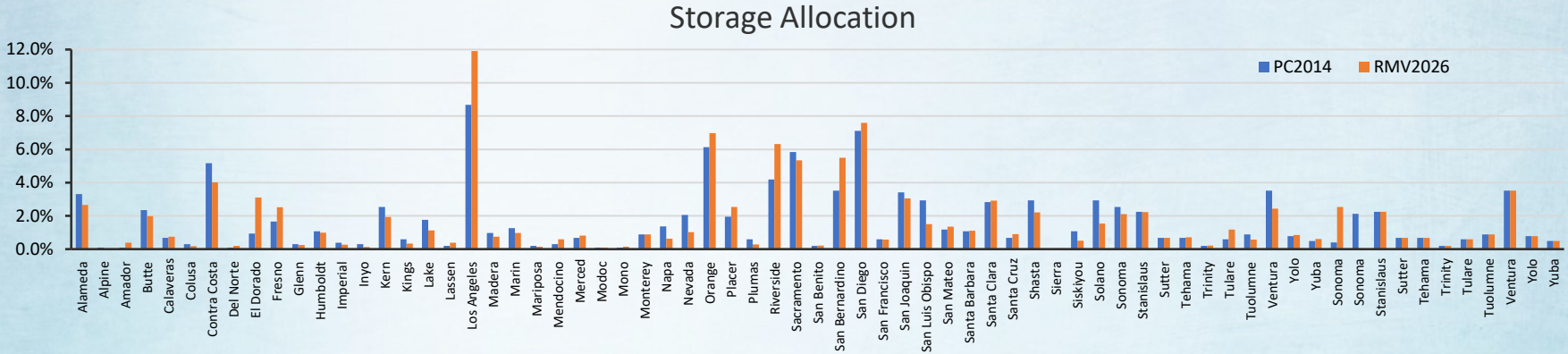
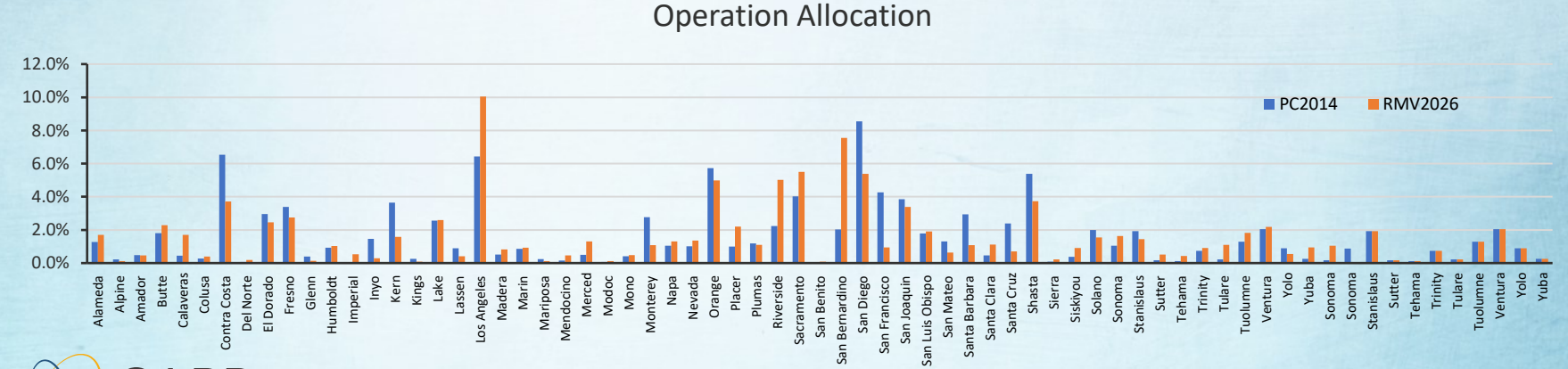
Allocation: Storage and Operational

- 78% of RMVs are stored and operated in the same county
- San Bernardino has the largest excess of operation over storage, suggesting it's a deployment-heavy area
- San Diego has much higher storage than operation, possibly serving as fleet storage or servicing centers



Changes in Storage and Operation Allocations





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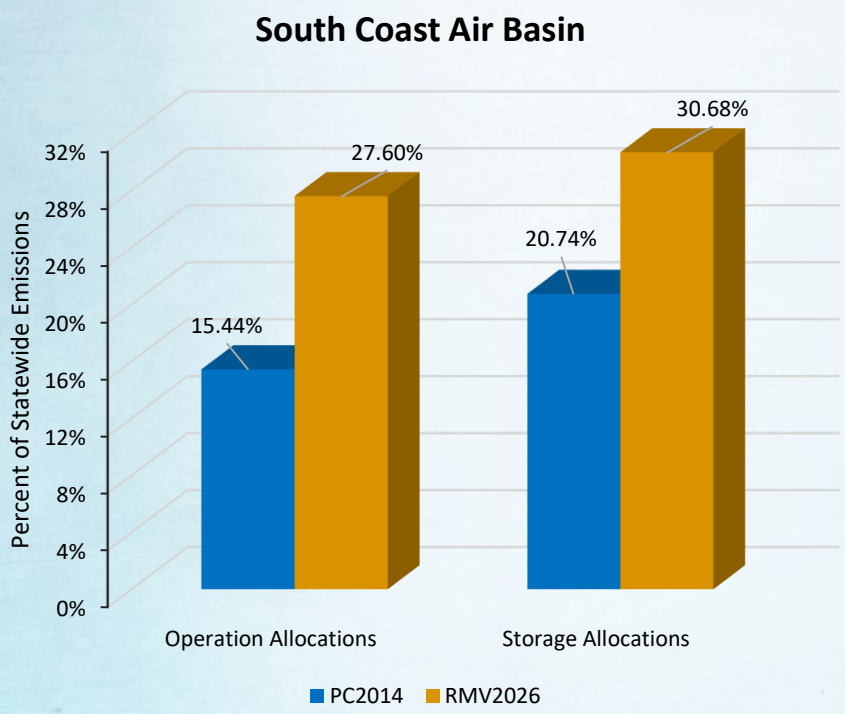
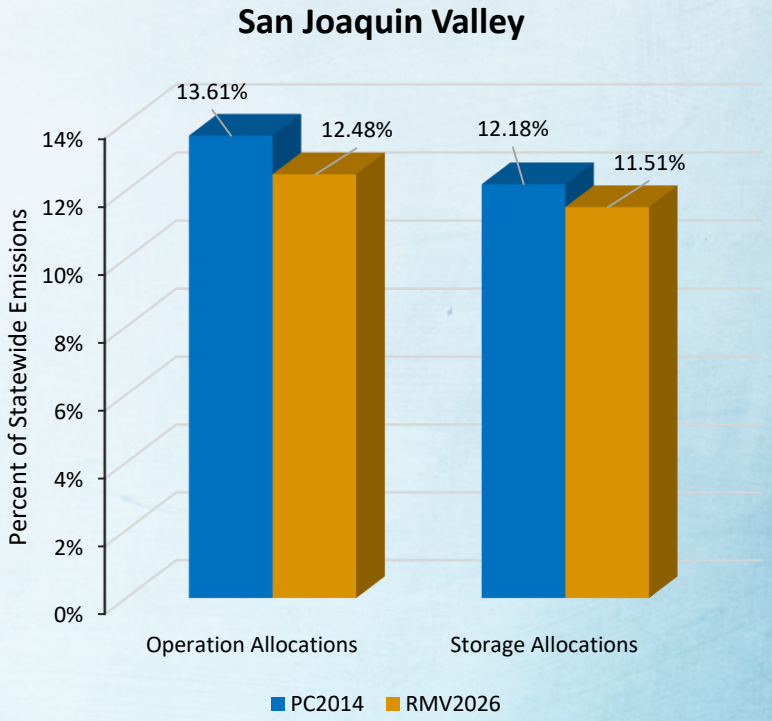
Regional Emissions Allocation Updates





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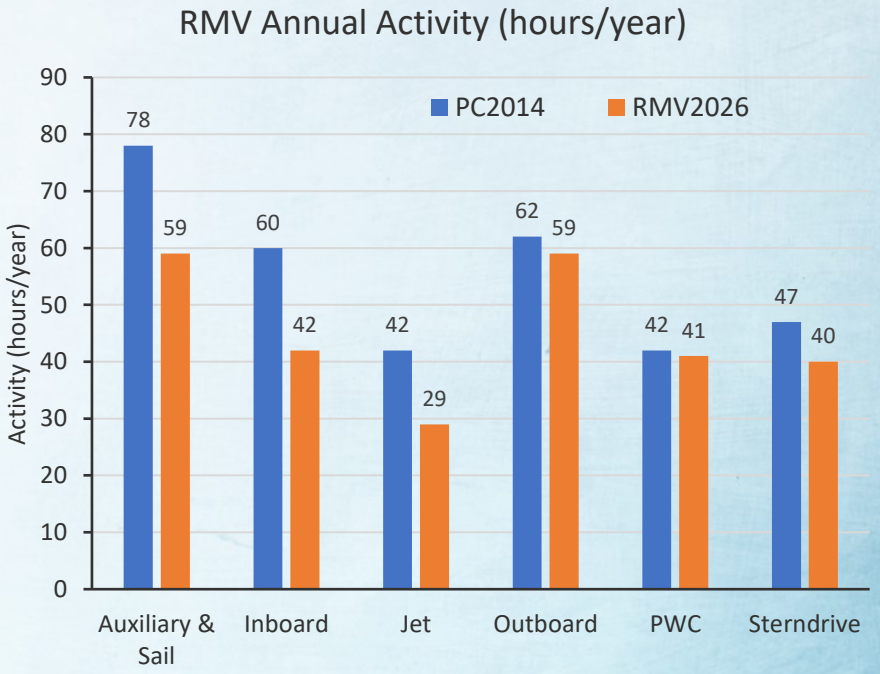
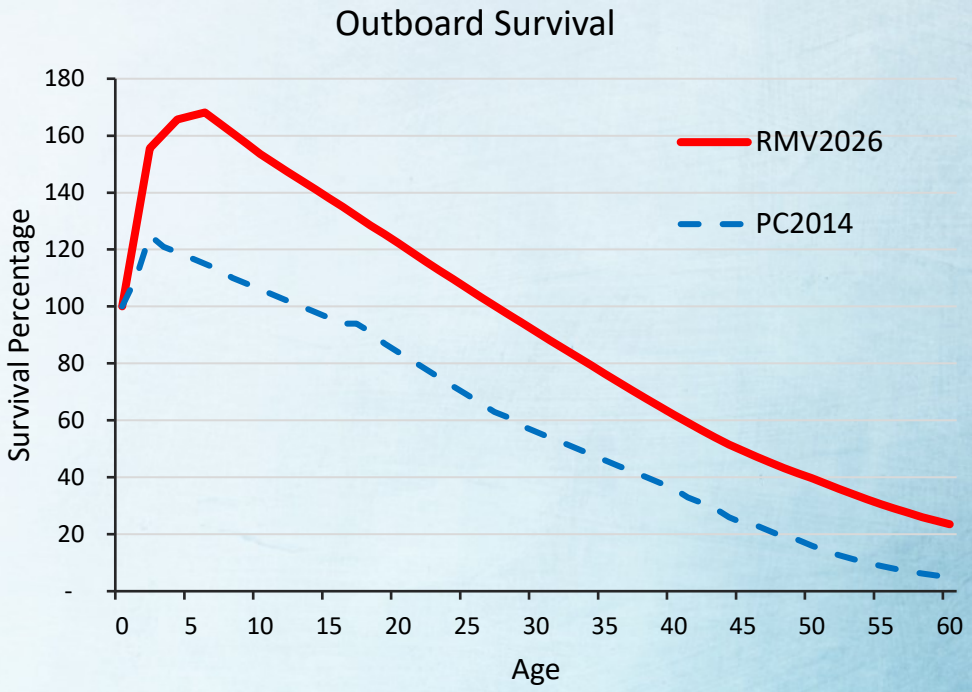
Change in Activity

- The survey assessed vessel usage for the period before the COVID-19 pandemic.
- The overall activity level is 22% lower than that used in the PC2014 emission inventory.



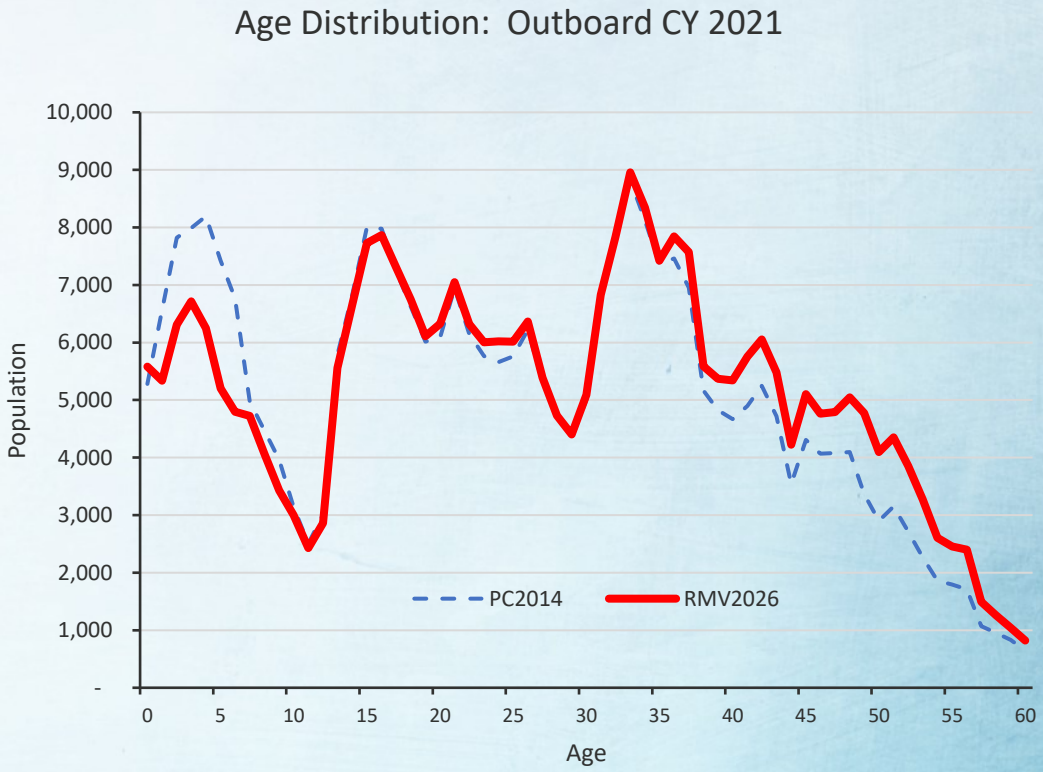
Vessel Longevity: The Survival Curve

- The survival curve reflects average year-to-year differences between 2006 and 2021
- RMV2026 survival was adjusted to reflect longer vessel ownership durations



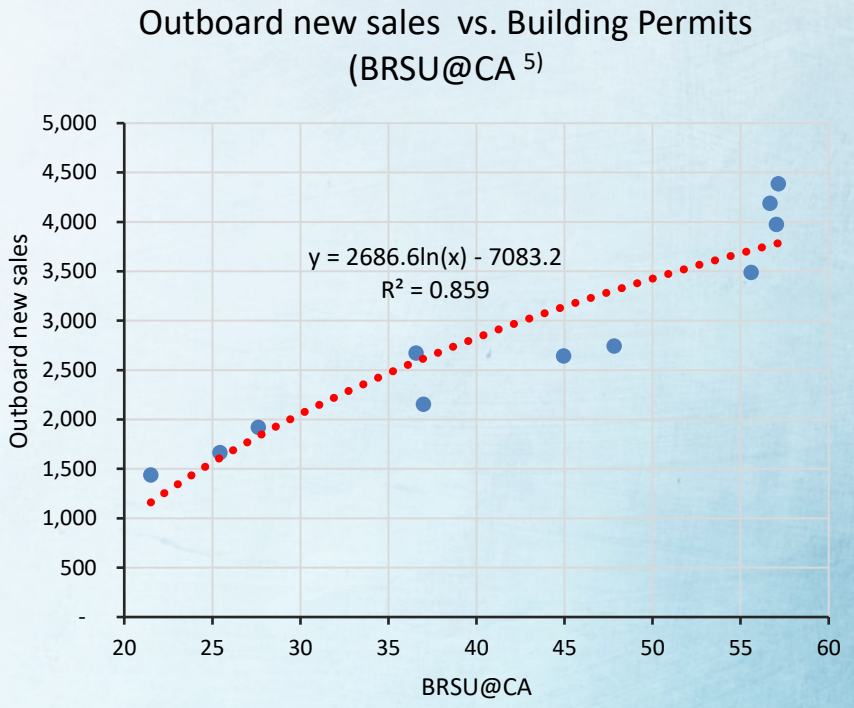
DMV Registration 2006-2021

- DMV population and survival data have been updated
- RMV2026 shows actual DMV registration in CY 2021
- PC2014 overestimated annual sales in the forecast



Population Forecast & Economic Indicators

- Annual RMV sales have historically shown a strong correlation with building permits for single-family units
- A UCLA forecast of single-family unit permits is being used to project near-future RMV sales from 2023 to 2027
- For 2028-2050, projections are based on the Department of Finance's population forecast



[5] California Building Permits of Residential Single-Family Units

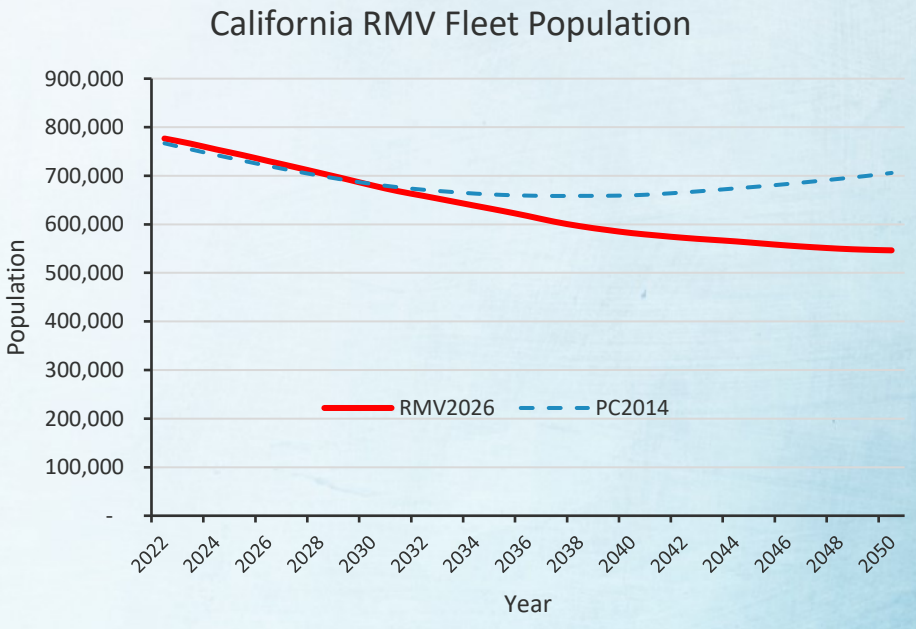
Incorporating RMVs Registered only with USCG

- CARB compared DMV 2021 and USCG 2022 downloads
  - USCG: 23,123 vessels in California for recreational purposes
  - Vessels with a weight over 5 tons & over 30 feet are considered diesel engines
  - 546 duplicate with DMV registration, 0.067% of DMV registration
- Population adjusted up to include the USCG only registration.
  - For example, for every 100 auxiliary sailboats in the DMV, 170 are reflected in the inventory
- The fuel split ratio in RMV2026 reflects the USCG's addition

DMV2022 with USCG adjustment	*Fuel Split Ratio*		*Population*
	diesel	gasoline	increase factor
Auxiliary Sailboat	62%	38%	**70.03%**
Inboard	16%	84%	**13.34%**
Sterndrive	3%	97%	**2.72%**

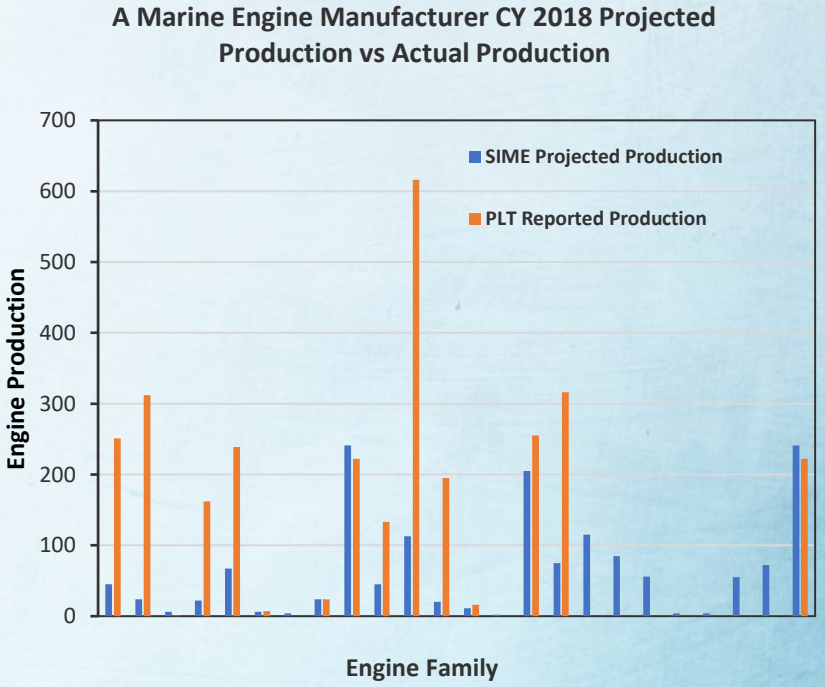
RMV Fleet Population Projections

- From 2022 to approximately 2028, both models show a similar downward trend
- PC2014 projected a population "bottoming out" around 2036 before beginning a steady increase through 2050
- The updated RMV2026 projects a sustained decline in total vessel population over the next two decades



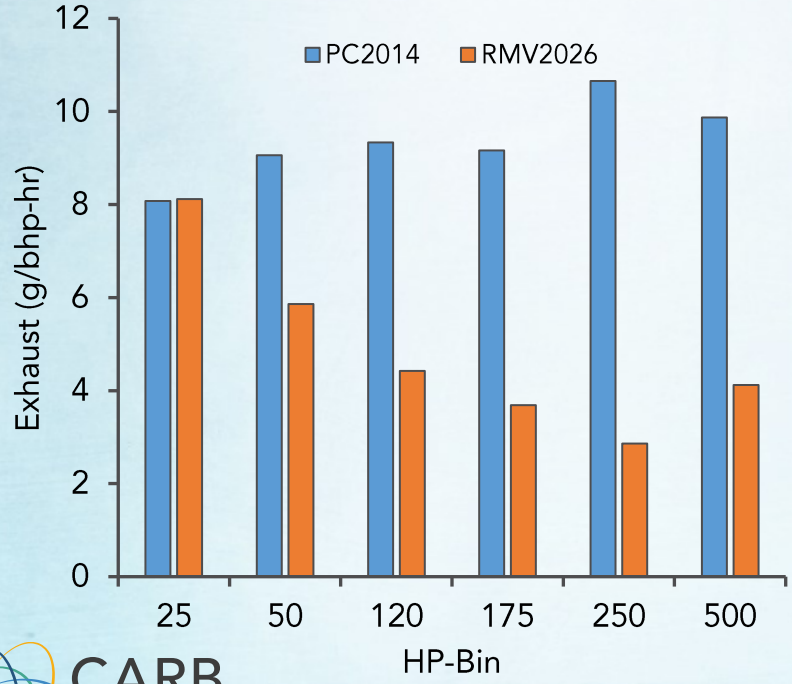
Exhaust Emission Factors Update

- Based on engine certification data provided by manufacturers for all RMV engines
- Result of thousands of hours of testing by all manufacturers
- Weighted by population
  - *PC2014*: Used projected Production with Spark Ignition Marine Engine (SIME) Database
  - *RMV2026*: Uses Engine Production Line Testing (PLT) Database showing actual production of the specific engine models in that calendar year
  - Noticeable difference between projected and reported sales volumes

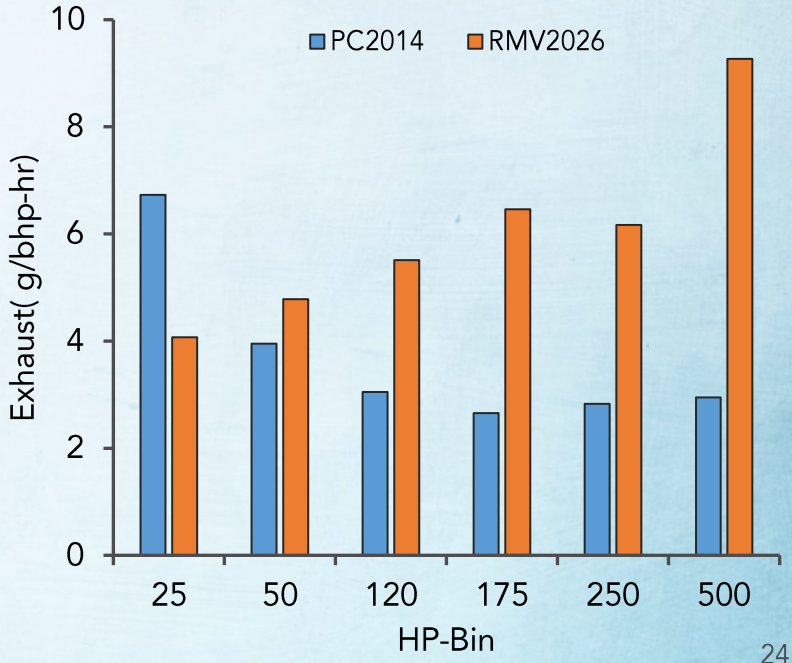


The PLT Advantage: Correcting Emission Factors via Actual Production Data

G4 FI: HC Zero-hour Emission Factor



G4 FI: NOx Zero-hour Emission Factor



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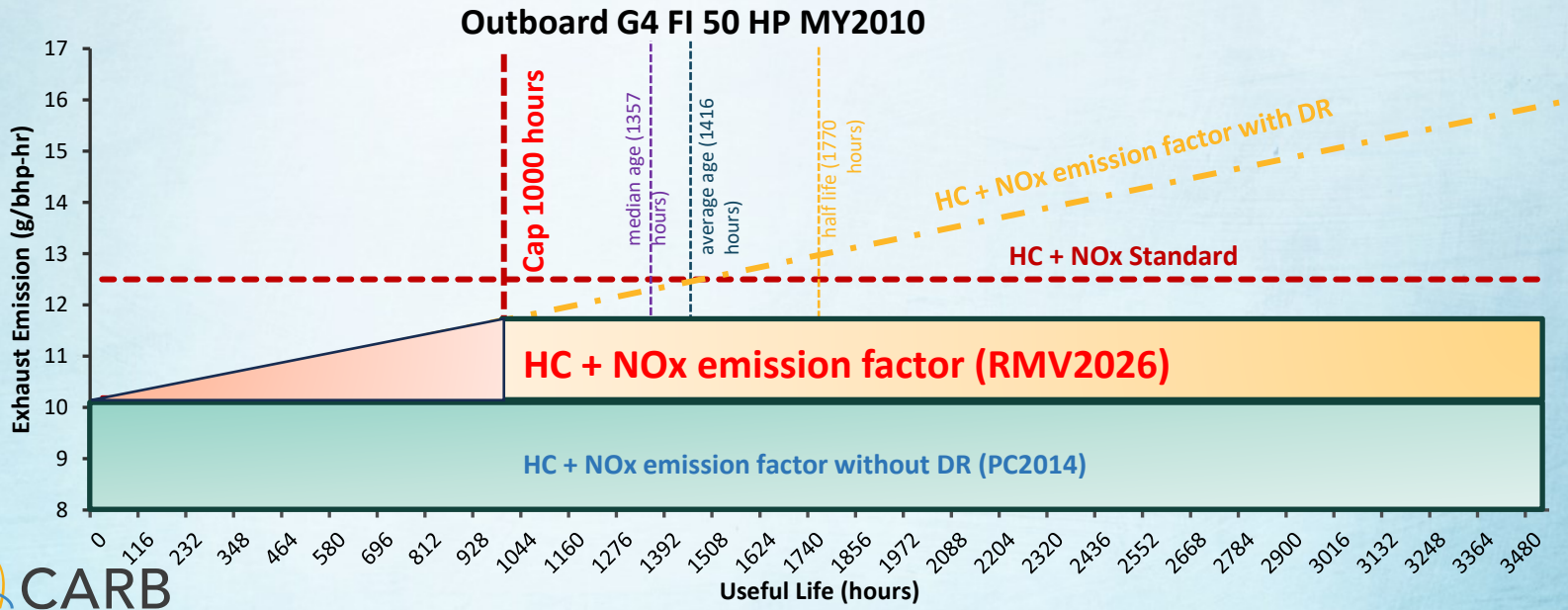
Accounting for Engine Aging: Deterioration Factors & the 1000 hours Cap

- Deterioration was capped at the average median age of the six categories of RMV
- Activity levels generally decline as vessels age



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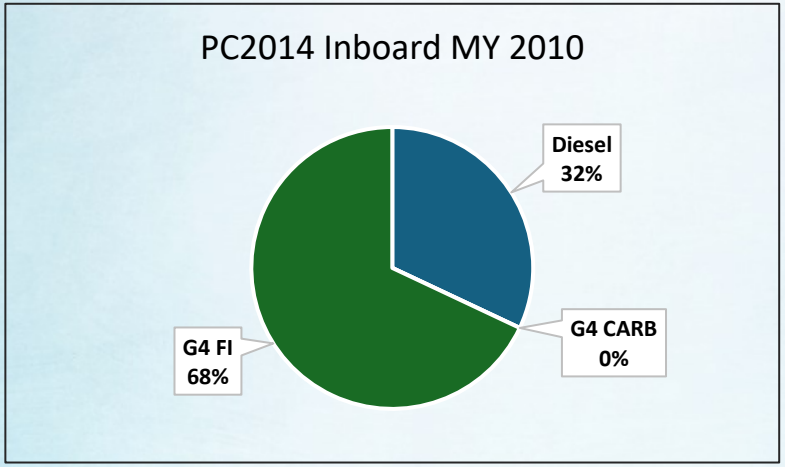
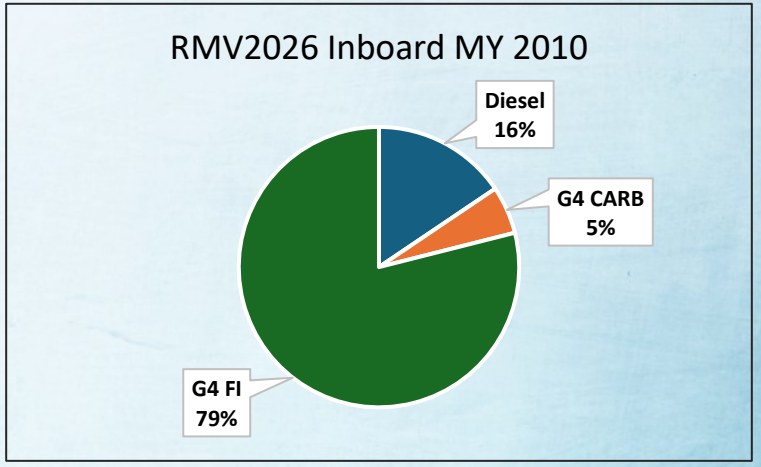
Updates in Fuel and Engine-Technology Split Ratio

- Actual engine production data from the PLT dataset was used to reevaluate the fuel and engine-technology ratios for all model years of the population

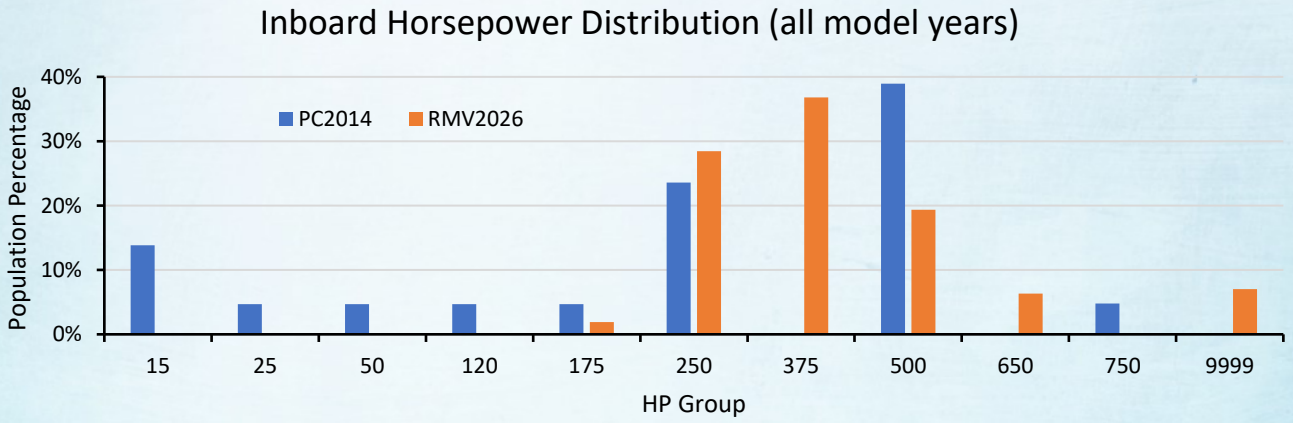




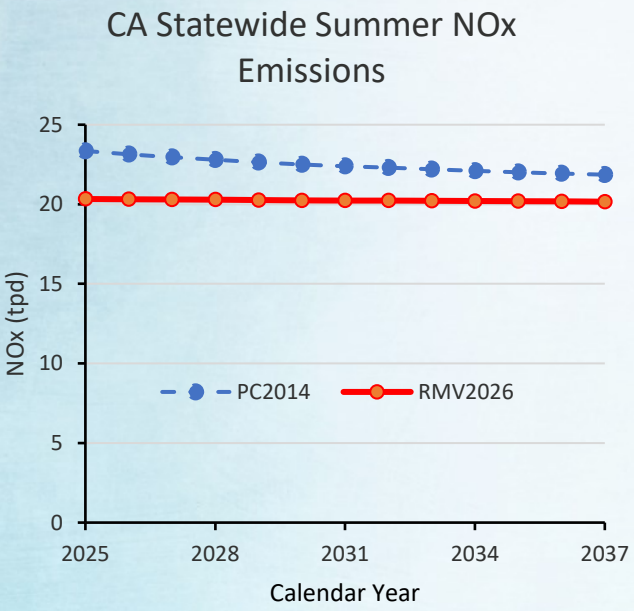
G4 CARB: 4-Stroke Gasoline Carburetor G4 FI: 4-Stroke Gasoline Fuel Injection

Shift in Engine Horsepower Distribution

- Actual California engine production data (PLT) provides a more accurate RMV horsepower distribution
- All Inboard engines are now larger than 175 HP

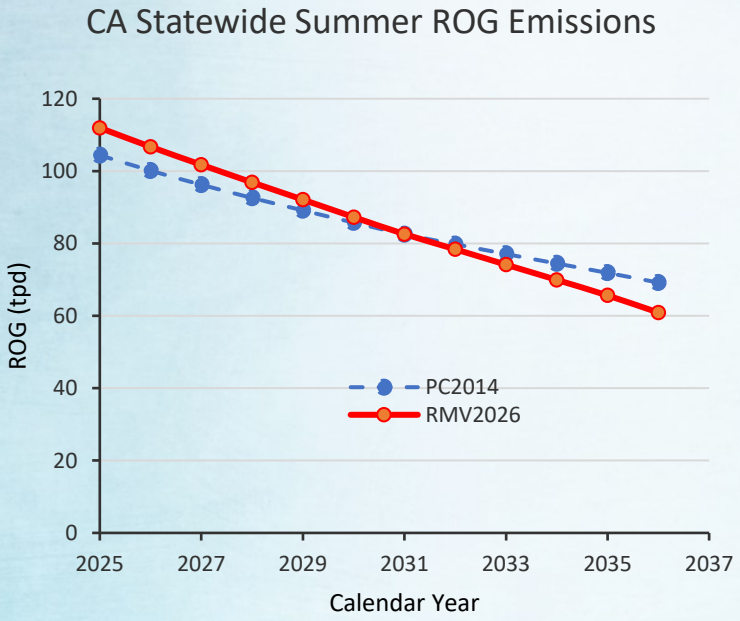


RMV NOx Emissions: Results of the RMV2026 Update



- RMV2026: NOx remains nearly flat (~20.3 tpd) as higher survival rates retain older, higher-emitting engines; updated emission factors and the addition of deterioration increase emissions, largely offset by declining vessel population
- PC2014: NOx declines from 23.4 tpd in 2025 to 21.9 tpd in 2037 due to lower survival rates, which accelerate turnover of higher-emitting engines, resulting in a gradual emission reduction over time
- The updated RMV2026 consistently reduces NOx estimates compared to PC2014, 13-8% lower across 2025 to 2037

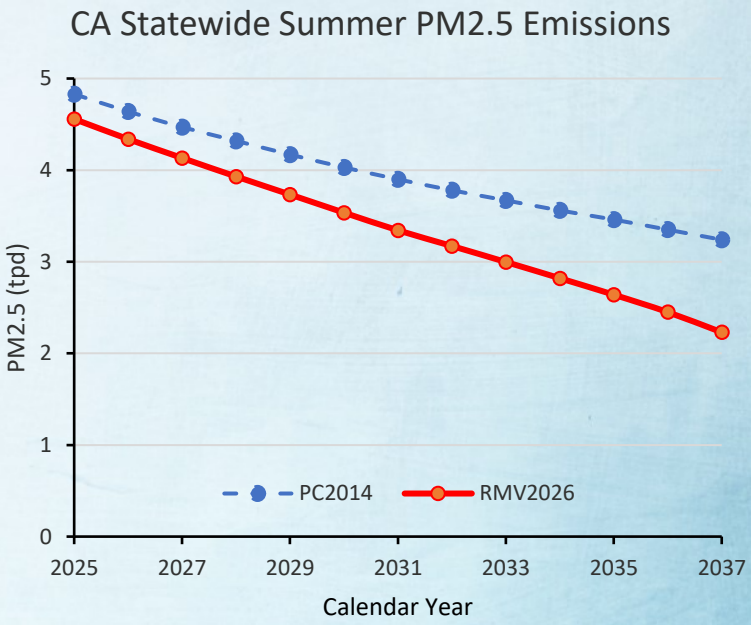
RMV ROG Emissions



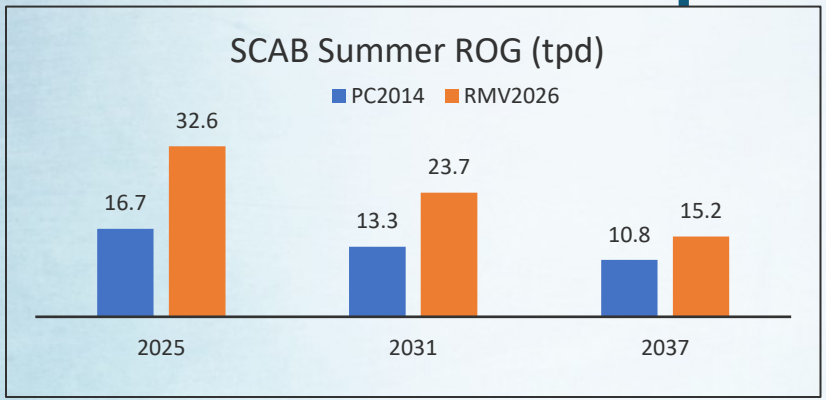
- RMV2026 starts higher than PC2014 in 2025 (112.0 vs. 104.4 tpd) due to added deterioration and higher survival rates
- RMV2026 declines more steeply from updated temperature/RVP factors and fleet turnover, falling below PC2014 around 2032
- Long-term divergence is influenced by PC2014's higher population growth

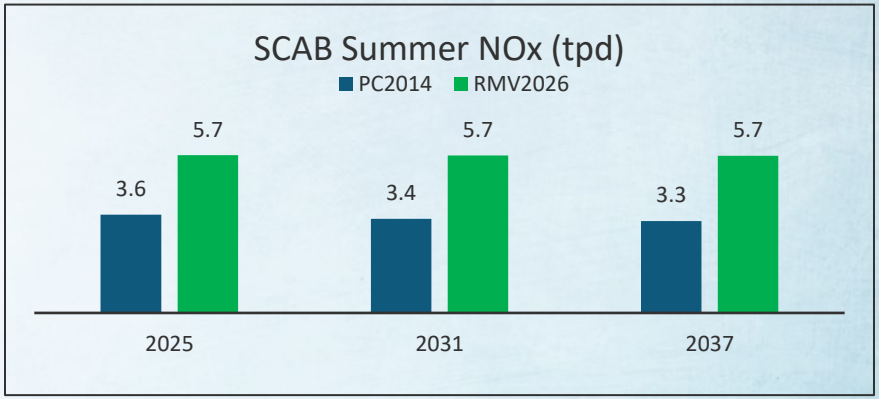
RMV PM2.5 Emissions

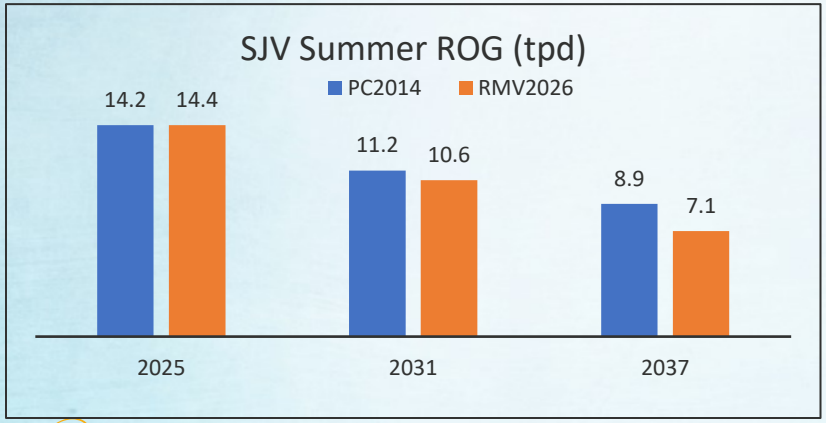
- Despite the USCG population increase, RMV2026 PM2.5 emissions begin lower than PC2014 (4.6 vs. 4.8 tpd), mainly due to the reduced diesel share (17% to13%), and lowered overall fleet activity
- By 2037, RMV2026 PM2.5 emissions are about 1 ton per day lower (2.2 tpd), representing approximately a 31% reduction compared to PC2014

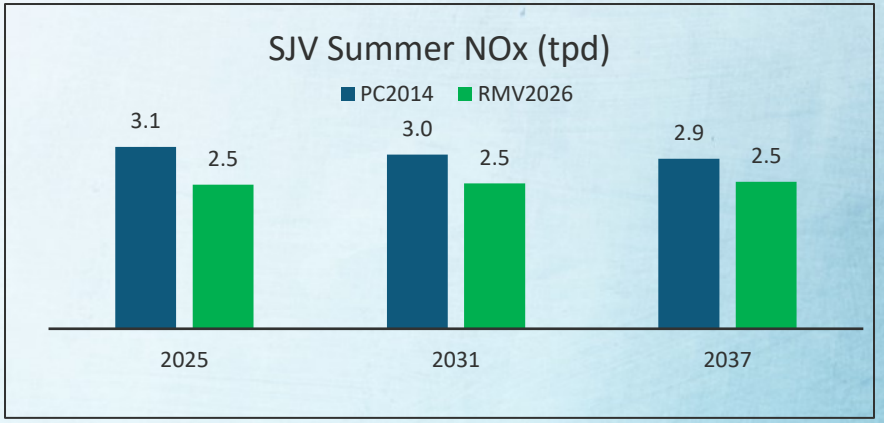


Emissions Update at the Local Level









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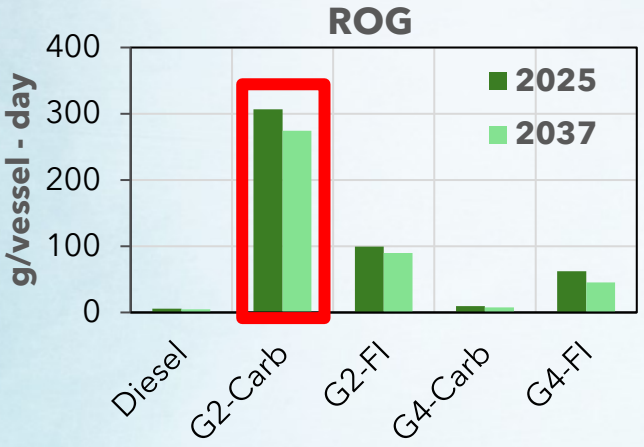
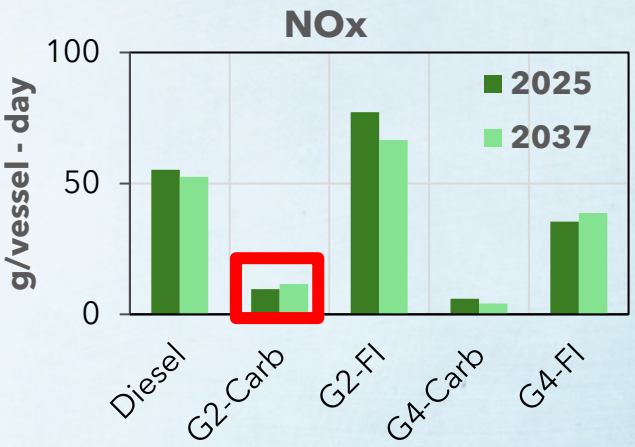
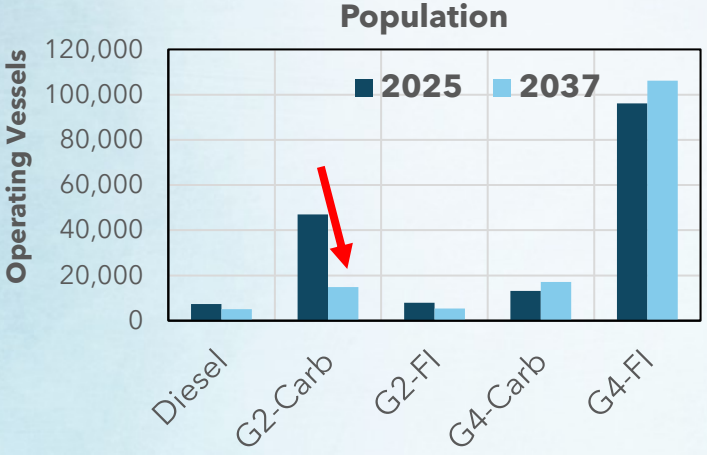
SCAB Pollutants by Tech-Group

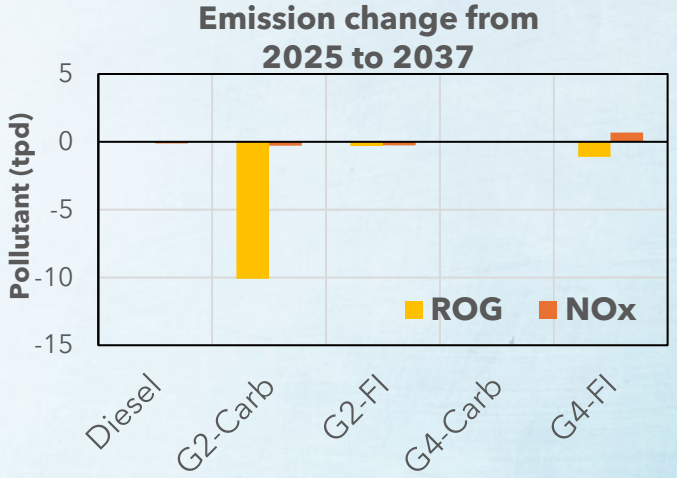




- The fleet-wide effective emission factors, EF, by tech-group do not change substantially between 2025 and 2037
- Note the high ROG and low NOx emissions of the G2-Carb (2-stroke, carburetor) tech-group

SCAB Pollutants by Tech-Group





- A substantial reduction in the G2-Carb population between 2025 and 2037 pulls down ROG emissions, while having little effect on NOx

Contacts

- Questions, comments, and feedback are encouraged and welcome
- To address comments and reflect any changes, please submit comments and any supporting data by **May 1st, 2026**

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Questions or Comments?

- Additional questions may be submitted after the workshop to: msei@arb.ca.gov
- Provide 30 days for informal written comments after the workshop.