WORKING PAPER

Fuel flexibility + cleaner cars

Mitigating air pollution from fuel changes with a vehicle replacement program

Abstract

The EPA MOVES model was used to analyze the tailpipe pollution implications of allowing the use in California of gasoline that meets federal specifications for conventional gasoline (CG) or reformulated gasoline (RFG) in place of California Phase 3 Reformulated Gasoline (CaRFG3), subject to a fee used to fund a vehicle replacement program modeled on Clean Cars 4 All, which would help low income consumers replace pre-2004 passenger vehicles with electric vehicles. A voluntary program would allow the sale of CG or RFG in place of CaRFG3 subject to a 25 cent per gallon mitigation fee. We find that the pollution reduction benefits of the vehicle replacement program were larger than the pollution increases from the fuel changes because the difference between Ca-RFG3 and CG or RFG have narrowed over time, and modern vehicles are not very sensitive to small changes in fuel properties. Accelerating the replacement of older vehicles has pollution reduction and public health benefits that are concentrated in the areas where older vehicles are driven and also reduces the economic burden of gasoline price spikes on low income households that are more likely to drive older cars. Thus, the program would help address significant disparities in air pollution and economic burdens.

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https://files.ucs.org/2026/fuel-flexibility-mitigation.pdf

Union of Concerned Scientists

Introduction

As California transitions to a transportation system powered by clean electricity, it must phase out the existing supply chain for petroleum fuels in an orderly process—one that protects communities, workers, and consumers (Martin 2024). That process is well underway, and recent announcements of refinery closures at the Phillips 66 refinery in Los Angeles in 2025 and the Valero refinery in Benicia in 2026 underscore the challenges attendant in managing the transition(Grubert and Hastings-Simon 2022). California has historically refined the vast majority of the gasoline it consumed in-state, operating as a self-contained "fuel island" in which linkages to other domestic and global refined product markets through trade were of secondary importance. But circumstances are changing, and moving forward California's gasoline market will be served by a mix of in-state production and refined product imports, with a balance that is likely to change over time. The state is evaluating policy measures to ensure that California drivers have reliable access to the transportation fuel they need without compromising progress on air quality and climate initiatives essential to protecting public health and the environment.

As California's gasoline market changes, some of the state's regulations may need to change to suit evolving market conditions. California's unique gasoline regulations were essential to its progress addressing air pollution, and when the state functioned as a largely self-sufficient fuel island with a competitive market within its borders, the fact that California used a different specification of fuel was manageable. But as the market consolidates, the regulations limit the state's ability to import gasoline from other states and countries and create barriers to the flexible use of gasoline already produced in California that does not meet California standards. The result is decreased flexibility, reduced competition, increased costs and delays in securing imported gasoline, which contributes to price spikes when unforeseen disruptions in gasoline production arise.

California adopted stringent fuel regulations in the 1990s and early 2000s to address air pollution from gasoline vehicles. The third and final phase of these regulations were proposed in 1999, adopted in 2000 and amended several times between adoption and the last amendments in 2013. When these regulations were adopted, California's regulations were much more stringent than those in the rest of the US. In the last two decades, however, gasoline regulations outside of California have largely caught up, dramatically reducing the differences between gasoline used in California and other states. The most dramatic and significant change was the reduction of sulfur levels. In 1999, California adopted a sulfur standard of 20 ppm as part of Phase 3 California Reformulated Gasoline (CaRFG3) regulations that went into effect in 2004 (CARB n.d.-a). The CaRFG3 regulations incorporate a predictive model, which considers the effect of many fuel properties on pollution and allows refiners flexibility on individual fuel parameters so long as the model predicts the overall requirements are satisfied. Under this regulation, the sulfur levels in California gasoline have fallen significantly below the flat 20 ppm specification. We have not been able to find public data on California gasoline sulfur levels over time. EPA reported that California gasoline sulfur levels were at 10 ppm by 2014 (EPA 2014), and recent data in the MOVES model database suggests sulfur levels were approximately 6 ppm in 2021-2023 (EPA 2024).

EPA regulations have also reduced US average gasoline sulfur content dramatically, although a few years behind California. The Tier 2 standards that were finalized in 2000 required that by 2004 most refiners meet an average sulfur standard of 120 ppm, which was lowered to 30 by

2006 (EPA 2000). Tier 3 standards finalized in 2014 lowered the average sulfur standard to 10 ppm starting in 2017 (EPA 2014). Figures 1 and 2 compare the US levels for sulfur and benzene for conventional and reformulated (RFG) gasoline over time to the CA-RFG2 and CA-RFG3 specs (based on a daily averaging limit).

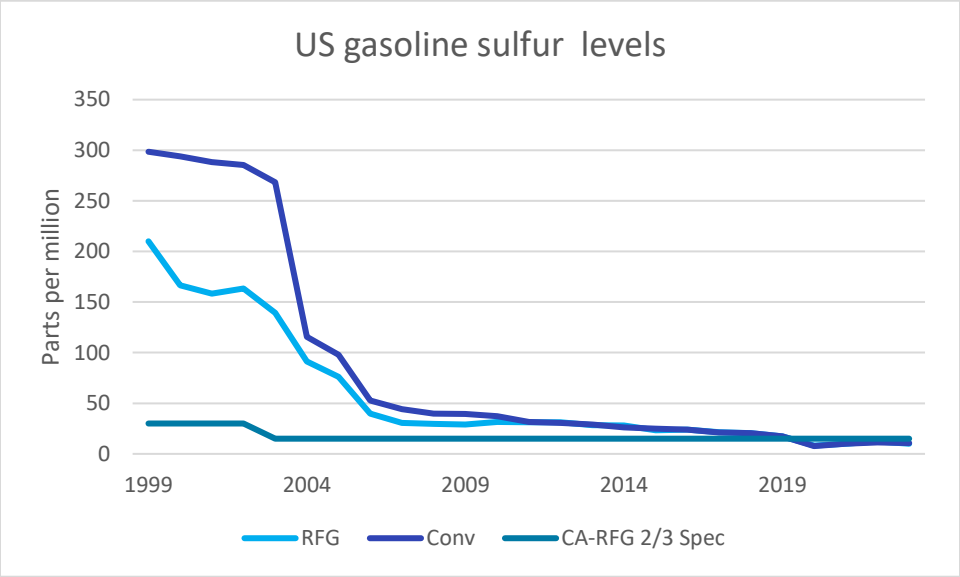


Figure 1: US gasoline sulfur Levels over time and CA-RFG2 and Ca-RFG3 specifications. Source EPA n.d. and CARB n.d.-a.

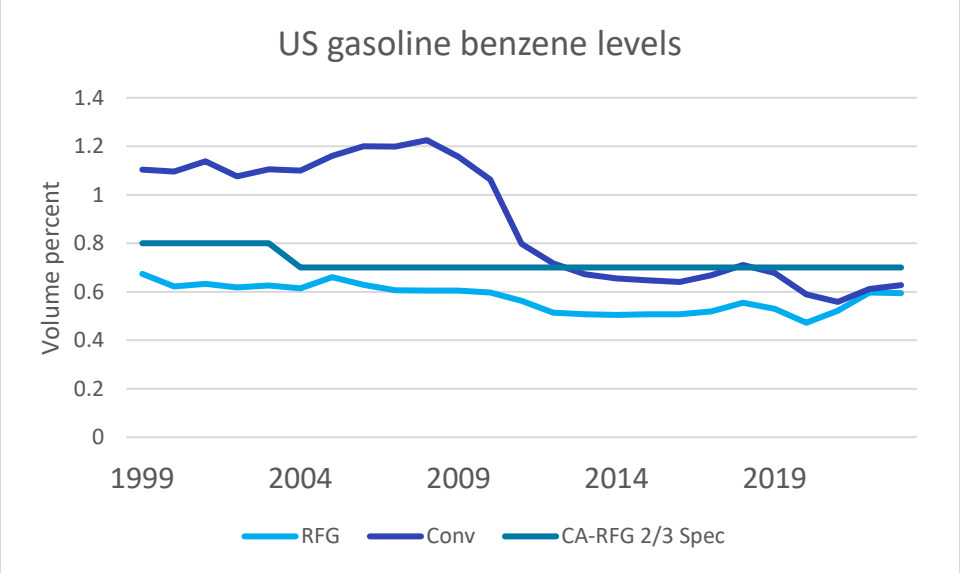


Figure 2: US gasoline benzene levels over time. Source EPA n.d.

Tighter sulfur standards dramatically lower VOC, NOx, air toxics, and particulate matter emissions by improving the efficiency of the catalytic converter in the exhaust emissions control systems of gasoline vehicles. Note that the specs don't tell the whole story, as recent survey data summarized by EPA in the MOVES model shows that between 2021 and 2023 US average gasoline has an average sulfur content of about 10 ppm, versus below 6 ppm in

California. Sulfur was not the only change in fuel properties. EPA gasoline regulations also lowered benzene concentration, particularly in conventional gasoline.

The most complete dataset we were able to find comparing California gasoline to US reformulated gasoline (RFG) and US average gasoline (US-Avg) are the survey data that are reported in the MOVES5 model database (EPA 2024). Key properties including sulfur content, Reid Vapor Pressure (RVP), a measure of volatility, and benzene content are summarized in Table 1 below. Sulfur content is the most dramatic difference, for while sulfur content outside California have fallen dramatically, California gasoline still has 40 percent lower sulfur content than the rest of the country.

Table 1. Gasoline formulation data from MOVES5 database from survey data for 2021-2023

	Summer			Winter		
Property	Sulfur (ppm)	RVP (psi)	Benzene (v%)	Sulfur (ppm)	RVP (psi)	Benzene (v%)
CA	5.7	7.2	0.56	6.2	12.7	0.53
US-Avg	10.3	8.2	0.70	10.2	13.6	0.57
US-RFG	10.1	7.2	0.63	10.8	13.8	0.56

Even more dramatic than the changes to fuel properties are the changes to emissions control technology in cars. Modern cars are much less polluting overall and have technology that makes them much less sensitive to differences in fuel properties (Machiele 2025a, 2025b). EPA Tier 2 standards for new passenger cars and light-duty trucks, implemented in 2004, and Tier 3 standards for light- and medium-duty vehicles, implemented in 2017, have steadily reduced emissions per mile of nitrogen oxides (NOx), volatile organic compounds (VOCs), particulate matter (PM) and other toxic pollutants, as shown below in Figure 3 below.

Hypothesis and study design

With this context, the Union of Concerned Scientists (UCS) began exploring whether modernizing California's gasoline regulations could make the state's gasoline market more resilient against disruptions while at the same time continuing to protect public health. Our hypothesis is that any air pollution increases associated with relaxation of the CA-RFG requirements could be cost effectively mitigated by investing in a program to accelerate the retirement of older cars. Previous analyses UCS conducted with The Greenlining Institute showed that pre-2004 cars are responsible for a disproportionate share of pollution, indicating that early retirement could produce significant air pollution reductions (Beyer et al. 2023).

UCS used the EPA MOVES model (EPA 2024) to analyze the tailpipe pollution implications of allowing the use in California of conventional US gasoline, as proposed in the Transportation Fuels Assessment as a Non CARBOB Fee Allowance (CEC 2024).[1] Specifically, we compared

[1] *MOVES5 is the latest version available. However, it only incorporates gasoline property emission effect data from Tier2 vehicles. As discussed in Machiele 2025a it is likely that Tier3 and newer vehicles are even less sensitive to fuel property changes, which would cause MOVES to show even smaller emission inventory changes.*

the statewide average emissions in California using gasoline formulations based on the MOVES fuel regions: California reformulated gasoline (CA-RFG, based on EPA survey data of California and Phoenix-area counties using gasoline produced by California refineries) and US Average RFG (US-RFG averaged across EPA fuel regions using RFG) and gasoline reflecting the US national average properties (US-Avg averaged across all 24 MOVES fuel regions). We also evaluated the impact of a vehicle retirement program modeled on Clean Cars for All (CARB n.d.-b), removing 500,000 pre-2004 light duty passenger cars and replacing 90 percent of these with electric vehicles (EVs). We modeled these changes in both 2023, based on most recent real-world data, and a projection to 2030. We also examined results for Los Angeles County, comparing the same fuel changes to a vehicle retirement program removing and replacing 125,000 pre-2004 vehicles (reflecting the share of the California fleet in LA County).

Results

Pollution impact of fuel changes

Results are shown in Table 2a, b, c for weekday emissions from gasoline-powered passenger cars and passenger light-duty trucks for 6 key pollutants: oxides of nitrogen (NOx); volatile organic compounds (VOCs); primary exhaust particulate matter with a diameter of 2.5 micrometers or less (PM2.5); a potency weighted toxics index that includes Benzene, Formaldehyde, 1-3 Butadiene and Acetaldehyde[2]. Three scenarios are compared California Statewide fleet in 2023 (1a) and 2030 (1b) and Los Angeles County in 2030 (1c) and in each case using CA-RFG, US-RFG or US-Avg gasoline.

Table 2a. California statewide emissions in 2023 from gasoline powered passenger cars and trucks in grams per mile driven

	Summer			Winter		
Pollutant	CA-RFG	US-Avg	US-RFG	CA-RFG	US-Avg	US-RFG
NOx	0.186	0.198	0.196	0.203	0.212	0.212
VOCs	0.287	0.290	0.292	0.289	0.297	0.297
PM2.5	0.00417	0.00443	0.00449	0.00479	0.00509	0.00495
Toxics	0.00132	0.00141	0.00147	0.00130	0.00140	0.00136

Table 2b. California statewide emissions in 2030 from gasoline powered passenger cars and trucks in grams per mile driven

	Summer	Winter

[2] *We adopted the potency weighted toxics approach used by the California Air Resources Board in relevant fuel regulations (CARB 2012). The specific weights are Benzene 0.170; 1,3-Butadiene 1.000; Formaldehyde 0.035; Acetaldehyde 0.016.*

Pollutant	CA-RFG	US-Avg	US-RFG	CA-RFG	US-Avg	US-RFG
NOx	0.130	0.137	0.136	0.145	0.150	0.149
VOCs	0.315	0.318	0.319	0.319	0.327	0.317
PM2.5	0.00406	0.00439	0.00449	0.00486	0.00529	0.00511
Toxics	0.00117	0.00126	0.00131	0.00119	0.00129	0.00125

Table 2c. Los Angeles County emissions in 2030 from gasoline powered passenger cars and trucks in grams per mile driven						
	Summer			Winter		
Pollutant	CA-RFG	US-Avg	US-RFG	CA-RFG	US-Avg	US-RFG
NOx	0.101	0.107	0.106	0.114	0.118	0.117
VOCs	0.263	0.262	0.263	0.276	0.282	0.280
PM2.5	0.00380	0.00411	0.00418	0.00413	0.00449	0.00431
Toxics	0.00093	0.00100	0.00103	0.00089	0.00096	0.00093

Table 3a, b, c shows the percentage change relative to CA-RFG.

Table 3a. Emissions change from replacing CA-RFG with non-California gasoline in 2023 fleet				
	Summer		Winter	
Pollutant	US-Avg	US-RFG	US-Avg	US-RFG
NOx	6.44%	5.42%	4.60%	4.54%
VOCs	0.94%	1.59%	2.50%	2.61%
PM2.5	6.28%	7.72%	6.13%	3.33%
Toxics	7.16%	11.60%	7.32%	4.71%

Table 3b. Emissions change from replacing CA-RFG with non-California gasoline in 2030 Fleet				
	Summer		Winter	
Pollutant	US-Avg	US-RFG	US-Avg	US-RFG
NOx	5.55%	4.73%	3.51%	3.15%
VOCs	0.77%	1.20%	2.39%	2.50%
PM2.5	8.06%	10.61%	8.96%	5.13%
Toxics	7.25%	11.95%	8.01%	5.11%

Table 3c. Los Angeles County emissions change from replacing CA-RFG with non-California gasoline in 2030 fleet				
	Summer		Winter	
Pollutant	US-Avg	US-RFG	US-Avg	US-RFG
NOx	5.38%	4.36%	3.44%	2.85%
VOCs	0.48%	0.23%	2.36%	1.66%
PM2.5	8.17%	10.16%	8.59%	4.37%
Toxics	7.27%	10.89%	7.76%	3.93%

Changing from CA-RFG to US-Avg or US-RFG gasoline statewide or in Los Angeles County would significantly increase pollution. The extent of the increases varies by pollutant, season and depends on when the fuel change is made. NOx pollution would increase from 3-6 percent, VOCs would increase by up to 3 percent, Primary PM2.5 by 3 to 11 percent and toxics between 4 and 12 percent. These changes reflect the impact of changing all of California's gasoline. These levels of increased pollution from non-California gasoline use suggest that California fuel regulations continue to provide important emission reductions, and mitigation measures would be required to provide similar levels of health protections compared to existing requirements. It is important to note that the voluntary flexibility program considered in this study is designed to be used only when CA-RFG is not readily available and would likely account for less than 10 percent of the fuel so the pollution increases would be proportionally smaller.

Emissions rates and sensitivity to fuel changes were similar for Los Angeles County as California as a whole. Emissions rates in 2023 were higher, especially for NOx. The higher emissions rates in 2023 are because a larger share of the driving is done by older vehicles with less effective emission controls, as discussed in the next section. The sensitivity of pollution to changes in fuel properties in 2023 was similar to 2030.

Emissions by model year

Our hypothesis is that pollution increases associated with using conventional or reformulated US gasoline in place of Ca-RFG3 could be mitigated with a program that replaces pre-2004 cars with battery electric vehicles. The reason retiring older vehicles is expected to be an effective mitigation strategy is that newer vehicles are certified to more stringent emission standards

and because older vehicles tend to have faulty emission control systems that do not operate properly.

Figure 3 below shows emissions per mile of driving of the pollutants examined above in the 2023 fleet broken down by model year of the vehicles normalized by the value in 1984.

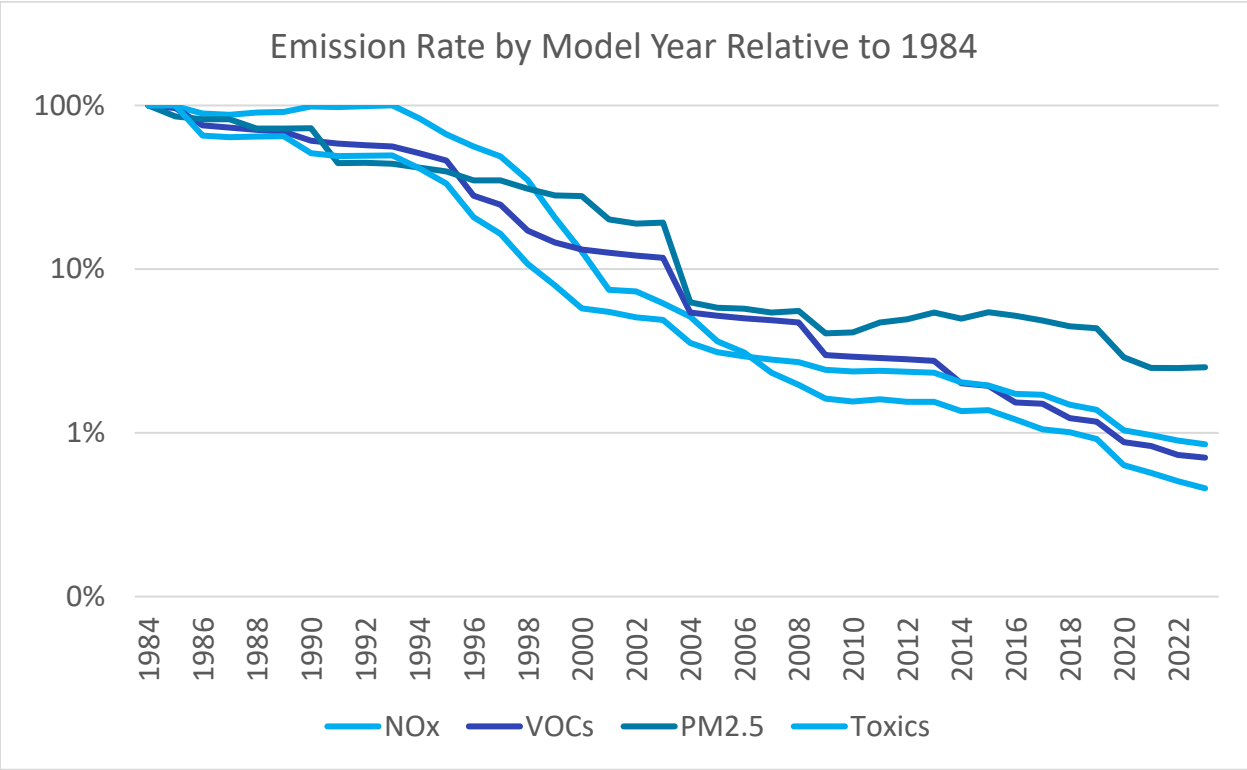


Figure 3: Emissions rate by model year. Source: UCS, MOVES, EMFAC.

However, while older cars are responsible for much more pollution per mile, they account for a relatively small share of total driving, as shown Figure 4.

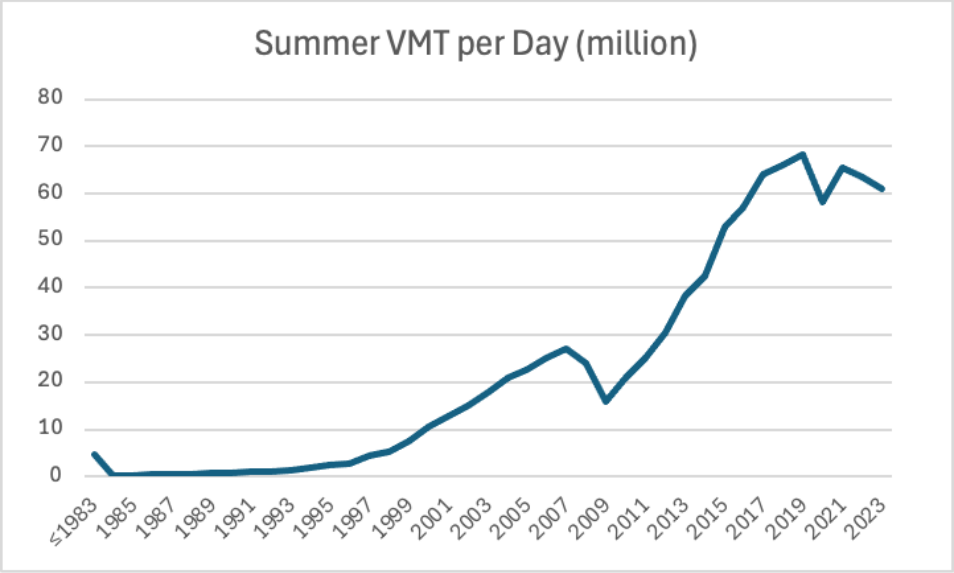


Figure 4. VMT by Model year. Source: UCS, MOVES, EMFAC.

For this reason, total pollution from more recent vehicles is still very significant, as shown in Figure 5, which shows total emissions by model year.

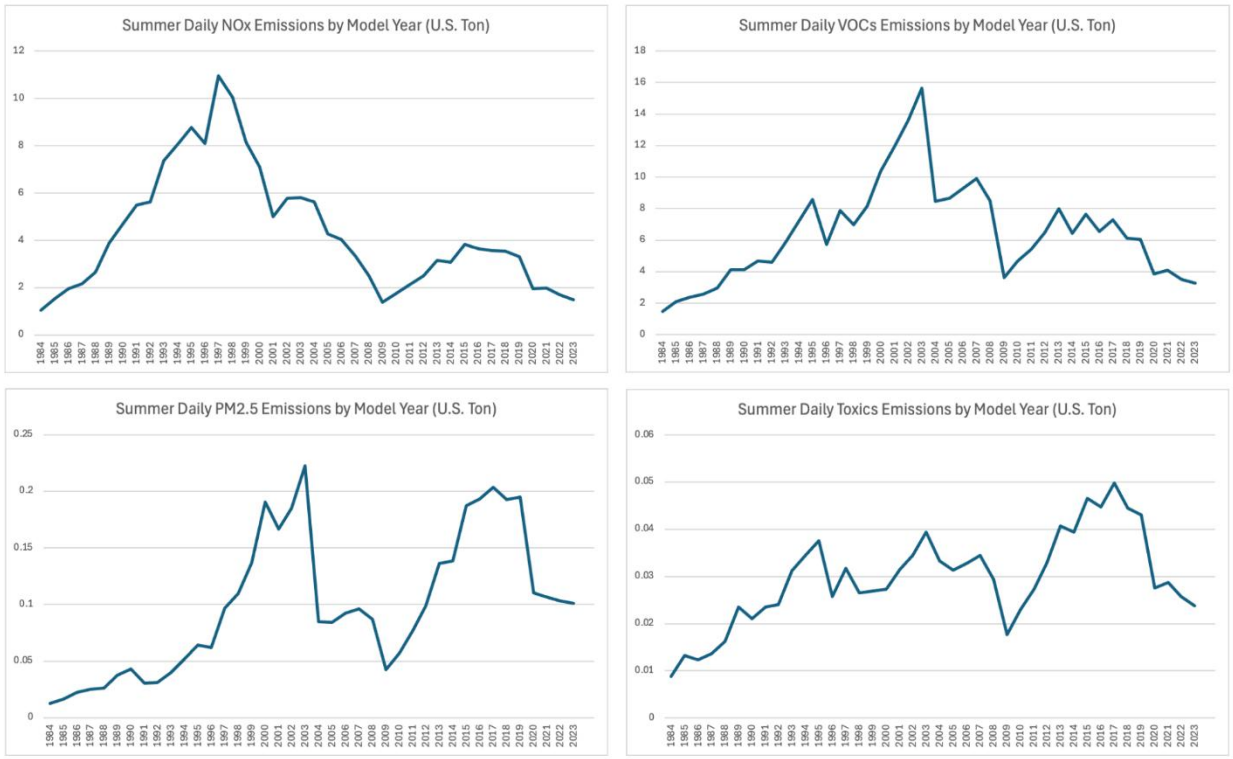


Figure 5: Total daily emissions by model year for (Summer 2023). Source: UCS, MOVES, EMFAC

As of 2023, California had 5.6 million pre-2004 gasoline passenger cars and trucks, which accounted for just 10 percent of miles driven (and 16 percent of registered) compared to all

passenger cars and trucks. However, these vehicles accounted for the majority of pollution, as shown in Table 4 below.

Table 4: Share of emissions from pre and post 2004 gasoline passenger vehicles in California in 2023.		
	Pre-2004 Gasoline	2004-2023 Gasoline
Vehicles Registered	5,623,650	29,225,142
Percent total miles travelled	10%	90%
NOx	69%	31%
VOCs	56%	44%
PM2.5	43%	57%
Toxics	49%	51%

Modeling a gasoline flexibility fee funded vehicle retirement program

Our hypothesis, based on this data, is that accelerating the replacement of older vehicles could offset pollution from changes in gasoline formulation. Table 5 below summarizes the emissions reductions in 2030 associated with a vehicle replacement program that replaces 500,000 pre-2004 vehicles with newer vehicles, 90 percent of which are battery electric vehicles. We also modeled a similar program in LA County retiring 125k vehicles, which is roughly proportional in scale the 500k statewide program.

Table 5: Emissions changes associated with a vehicle replacement program implemented in 2030 replacing 500k pre-2004 vehicles with 90% EVs Statewide, or 125k in LA County.				
	Summer		Winter	
	Statewide 500k	LA County 125k	Statewide 500k	LA County 125k
NOx	-11.72%	-12.40%	-11.53%	-12.27%
VOCs	-10.35%	-10.72%	-10.13%	-10.67%
PM2.5	-6.08%	-6.09%	-6.68%	-6.53%
Toxics	-9.30%	-9.55%	-8.52%	-8.73%

The choice of 500,000 vehicle replacements was based on a proposed mitigation fee of 25 cents per gallon of non-CA-RFG gasoline. In recent years California has consumed roughly 12 billion gallons of gasoline per year. If all this gasoline was replaced under the program we envision, subject to a 25 cent per gallon fee, it would generate roughly $3 billion per year. Assuming a program cost of $10,000 per car[3] plus 10 percent overhead, this should be sufficient to support the retirement of at least 500,000 pre-2004 cars within two years. This suggests the per gallon fee is adequate to fund the required mitigation, but we anticipate the flexibility program would be used infrequently so that the pollution to be mitigated and the number of vehicles replaced would be proportionally smaller.

[3] *For reference, the cost per car of the Clean Cars for All program have been less than $9K per year*

The 25 cent per gallon fee also protects the stability of the California gasoline marketplace. California refineries are designed to produce California gasoline, and if the regulations changed suddenly such that lower spec gasoline could be sold in California with no fee or a very low fee, it might place these refineries at a disadvantage to imported gasoline produced to lower specifications. Setting the fee to use gasoline that does not meet the spec at a level larger than the cost difference between the fuels will ensure that using California spec gasoline will be the least cost strategy to supply California fuel, and limit the use of other fuels to circumstances when sufficient California spec fuel is not available.

Price differences on the wholesale spot market between Los Angeles gasoline and New York and Gulf Coast gasoline are shown in Figure 6 below. Between 2021 and 2025, the median weekly spot market price difference was 18 cents per gallon and 64 percent of the time the difference was below 25 cents a gallon.

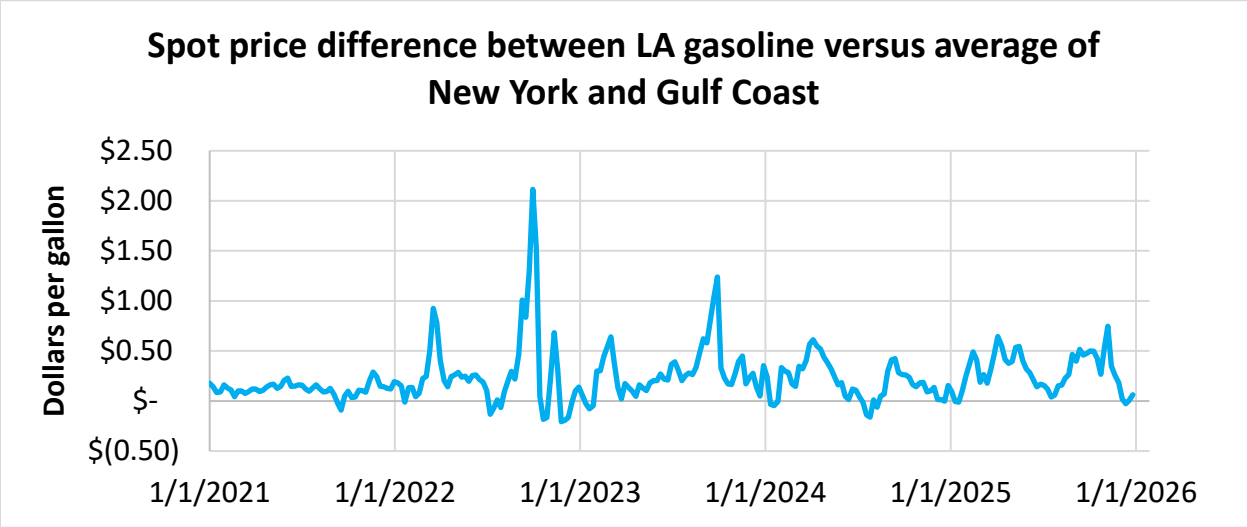


Figure 6: Difference in gasoline spot market prices between Los Angeles and the average of New York and Gulf Coast. Source EIA n.d.

Considering the cost to transport gasoline to California, we believe a fee of 25 cents per gallon is sufficient to ensure that when refineries are operating normally, it will be most cost effective to produce or import on-spec CA-RFG3 gasoline or the gasoline blending components required to produce it at California gasoline terminals. Only when there is a temporary shortage of California-spec gasoline would this flexibility program be attractive. Based on this logic, we expect the utilization of this flexibility program would not exceed 10 percent of the state's gasoline supply, and likely less. For that reason, we have summarized the combined impact a mitigation program assuming that 10 percent of California gasoline is replaced with US Average gasoline and that 50k pre-2004 cars are replaced, 90% of them with EVs.

To assess the potential impact of a flexibility program, we estimate how much money would have been saved between 2021 and 2025 if the flexibility program effectively capped spot market prices at 25 cents per gallon above the average in New York and the Gulf Coast. Assuming that in an average week 250 million gallons of gasoline are consumed in California, this would have saved $5.4 billion in this timeframe. Note that this calculation assumes that all gasoline is sold at the spot market price and that savings are passed along to consumers, both of which oversimplify a complex situation. This estimate is only a rough indication of the

potential impact of more effectively linking California's gasoline markets to the rest of the US. The related question is how much support such a flexibility program might have generated for a vehicle retirement program. Between 2021 and 2025 there were 94 weeks in which the spot market price difference was more than 25 cents. It is beyond the scope of this study to calculate how much non-California gasoline would have been imported. However, to get a rough estimate, we assume that in the weeks with a price difference greater than 25 cents, 10 percent of the gasoline would have been replaced with non-California gasoline. In this case the 25 cent per gallon fee would have generated $587 million or enough to retire more than 50,000 pre-2004 cars. Again, this is a very rough estimate.

Table 6 and Figure 7 summarize our findings. Replacing CA-RFG without a mitigation program significantly increases pollution. A mitigation program of 500k vehicles reduces pollution. And combining the fuel change with the mitigation program would reduce NOx and VOCs but increase Primary PM2.5 and Toxics. The proposed fuel flexibility program would result in a partial replacement of CA-RFG with US-Avg gasoline and generate mitigation funds that would support the replacement program. The final column represents a program that replaces 10 percent of CA-RFG with US-Avg gasoline and funds a replacement program of 50k vehicles. The net result is a small reduction in NOx, VOCs, and Toxics, and a very small increase of primary PM2.5.

Table 6: California statewide emissions in 2030 from gasoline powered passenger cars and trucks in grams per mile driven with different fuel and pre-204 vehicle replacements

Fuel	CA-RFG	US-Avg	CA-RFG	US-Avg	90%CA-RFG - 10% US Avg
Vehicle Replacements	0	0	500k	500k	50k
Oxides of Nitrogen (NOx)	0.130	0.137	0.115	0.124	0.129
Volatile Organic Compounds	0.315	0.318	0.283	0.299	0.312
Primary Exhaust PM2.5 - Total	0.00406	0.00439	0.00382	0.00425	0.00407
Toxics	0.00117	0.00126	0.00106	0.00120	0.00117

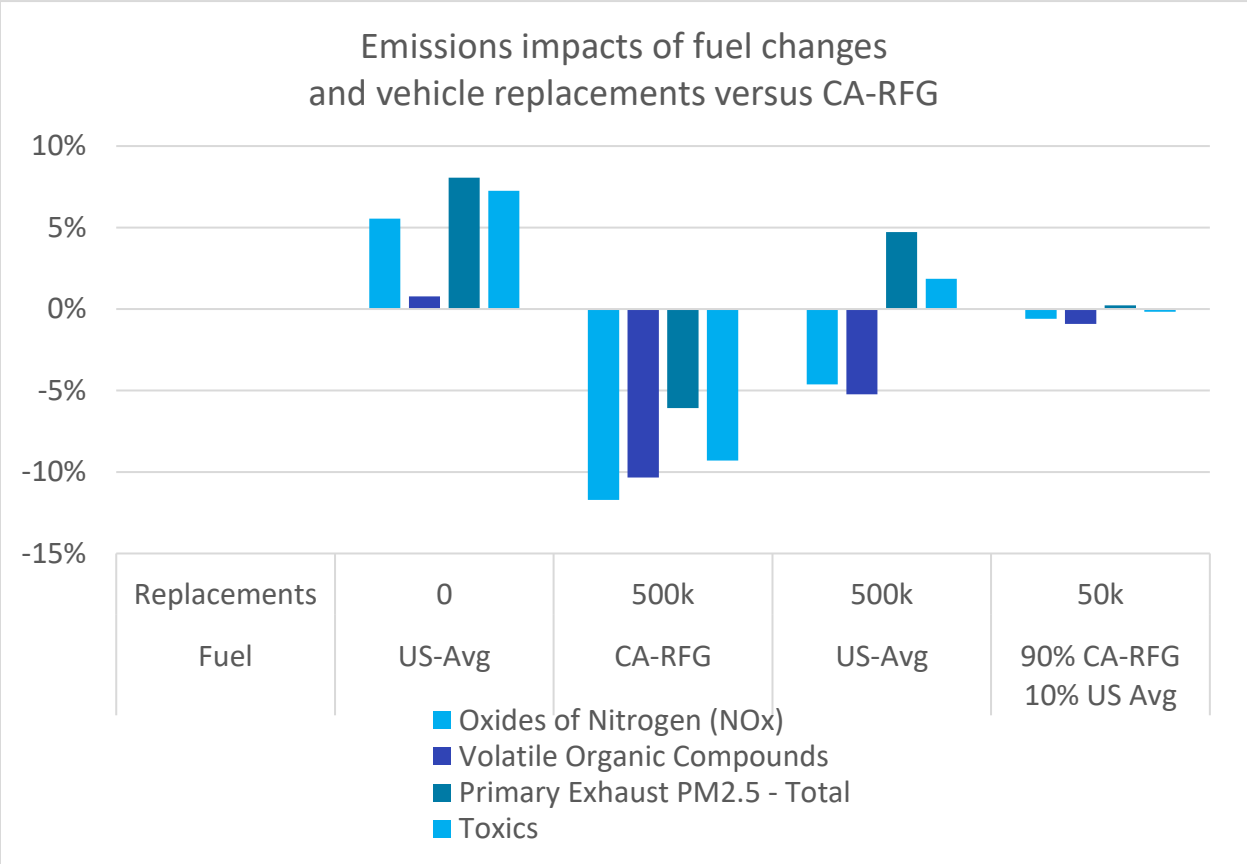


Figure 7: Summary emissions changes versus CA-RFG and the baseline fleet versus changing California gasoline to US-AVG gasoline, an accelerated vehicle retirement program that leaves California gasoline unchanged and retires 500,000 pre 2004 vehicles and replaces 90 percent of them with EVs, changing California gasoline to US average gasoline and implementing the previously mentioned accelerated vehicle retirement program for 500,000 vehicles, and a combined result assuming that 10% of California fuel is replaced with US average fuel and 50,000 pre 2004 vehicles are retired and 90 percent of them are replaced with EVs.

Conclusion

A well-designed program to allow the voluntary use of US Average gasoline in exchange for contribution of 25 cents per gallon to a mitigation program that supports a vehicle retirement program focused on pre-2004 passenger cars and trucks would result in an overall decrease in pollution. In addition to the net pollution benefits, adding flexibility to the gasoline market in periods when the supply of CA-RFG is inadequate to meet demand should reduce gasoline price spikes. This could potentially save billions of dollars, but the precise extent of these savings depends on many market factors beyond the scope of the study. Because the program is voluntary and the fee discourages the use of non-California gasoline when supplies are adequate, it will not result in gasoline price increases or undercut in-state producers of CA-RFG. Support for a well-designed vehicle retirement program has environmental justice benefits by reducing tailpipe pollution that us concentrated in neighborhoods with a higher concentration of pre-2004 vehicles, and by reducing the exposure of low income-beneficiaries of the retirement program to gasoline prices.

Methodology[4]

EPA's MOtor Vehicle Emission Simulator (MOVES) model was used to develop estimates of emission reductions for a non CARBOB fee allowance program. The most recently published version, MOVES5, was used and modeling methodology follows guidance provided in the MOVES5 Technical Guidance document.[5]

EPA recommends running MOVES at the county scale. Because California has a large number of counties, MOVES was run at the county scale for one selected county (Los Angeles) and with a county developed to represent the entire state. While the preferred methodology is to complete runs for all 58 California counties, this representative county methodology was selected for this preliminary analysis.

The gasoline formulation data was sourced from the MOVES5 default database which (for 2021+) was produced from an analysis of ~16,500 retail survey samples collected between January 2021-December 2023. The samples were aggregated by season (winter, summer, shoulder) and fuel region. The MOVES "California RFG" fuel region includes the entire state of California and Phoenix, AZ area counties using fuel produced by California refineries. The winter season includes January, February, March, November, and December. The summer season includes May, June, July, August, and September. The shoulder season is April and October.[6] To analyze results by fuel season, runs were completed for just the months of January, April, and May, with inputs edited to be representative of the entire fuel season.

CARB's Emissions Mobile Source Inventory (EMFAC) model was used for vehicle fleet characteristics. The EMFAC fleet database is updated with data from California's 2023 vehicle registration database, and the EMFAC emissions inventory provides projections for vehicle population and activity beyond 2023.[7]

Data was inputted to MOVES using the County Data Manager. Below are details on the data preparation for each input.

- Source type population:
    - Developed from EMFAC inventory.
    - MOVES and EMFAC categorize vehicles differently. EMFAC categories T1, T2, T3, and T4 (GVWR ≤10,000 lbs) were combined into a light duty truck category, and then split into passenger trucks and light commercial trucks by the MOVES default split. EMFAC categories T5, T6, and T7 (GVWR >10,000 lbs) were combined into a heavy duty truck category, and then split into refuse truck, single unit short haul truck, single unit long haul truck, combination short haul truck, and combination long haul truck based on the MOVES default split.

[4] *Detailed inputs and databases required to replicate our analysis will be made available online by the end of March 2026.*

[5] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101CTM3.pdf

[6] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101CUJZ.pdf

[7] https://arb.ca.gov/emfac/

- Age distribution:
    - Following EPA guidance, MOVES5 national defaults were used for long-haul trucks (single unit and combination) and age distributions for all other vehicle types were developed from the EMFAC inventory.
    - From the EMFAC inventory vehicles with an "unknown" model year were ignored and vehicles with a future model year (e.g. model year 2031 in calendar year 2030) were assigned age 0. Vehicles older than age 40 were assigned age 40.
    - EMFAC categories T1, T2, T3, and T4 were combined into a light duty truck category, and used for both passenger trucks and light commercial trucks. EMFAC categories T5, T6, and T7 were combined into a heavy duty truck category, and used for refuse trucks, single unit short haul trucks, and combination short haul trucks.
- Fuel usage fraction: MOVES5 default used.
- Fuel supply and fuel formulation:
    - MOVES5 defaults were used when modeling with the California RFG gasoline formulation.
    - To model national average E10 the fuel properties for each fuel formulation with a fuel subtype of 12 (corresponds to E10) and year 2023 (2021+ have the same properties) were averaged and used to update the fuel formulation table. These results align with the MOVES5 default e10fuelproperties table, which is used for national scale runs.
- Alternate Vehicle Fuel and Technology (AVFT):
    - The AVFT table defines the fraction of vehicles that are able to run on different fuel types. EPA recommends that hybrid gasoline/electric and plug-in hybrid electric vehicles are modeled as gasoline vehicles. Fuel-cell electric vehicles were categorized with battery electric vehicles.
    - EMFAC categories T1, T2, T3, and T4 were combined into a light duty truck category, and used for both passenger trucks and light commercial trucks. CNG vehicles were removed as MOVES5 does not model the CNG fuel type for these vehicle types.
    - EMFAC categories T5, T6, and T7 were combined into a heavy duty truck category, and used for refuse trucks, single unit short haul trucks, and combination short haul trucks.
    - The MOVES5 default was used for single unit and combination long haul trucks. MOVES5 models only gasoline motorcycles.
    - Results were run through the AVFT tool to fill in any missing values with zeros.

- Meteorology:
    - The MOVES5 default meteorology data was averaged across the summer, shoulder, and winter months.
    - The MOVES5 default meteorology data is split by county. For the state-wide inputs the meteorology data for all California counties was averaged by the 2023 VMT from each county in the EMFAC inventory.
- Average Speed Distribution:
    - Average speed distribution data for each county is available through the 2020 National Emissions Inventory (NEI) supporting documents.[8] EPA purchased 2020 Streetlight data to develop MOVES inputs for the 2020 NEI.[9]
    - For the state-wide inputs the 2020 NEI data for all California counties was averaged by the 2023 VMT from each county in the EMFAC inventory.
- Vehicle Type VMT:
    - Developed from EMFAC inventory.
    - Split into HPMS vehicle type categories (rather than the MOVES vehicle type categories). EMFAC categories T1, T2, T3, and T4 (GVWR ≤10,000 lbs) were combined into the HPMS light duty vehicle category.
    - EMFAC categories T5, T6, and T7 (GVWR >10,000 lbs) were combined and split into the "single unit trucks" and "combination trucks" HPMS categories based on the MOVES default split.
- Hour, day and month VMT distributions: MOVES5 default used.
- Road type distribution: MOVES5 default used.
- Inspection and maintenance programs:
    - MOVES5 default used for Los Angeles county run.
    - No program for statewide run.

The Low Emission Vehicle (LEV) tool, which creates a special input database to model California LEV standards, was used. The tool updates HC, CO, NOx, and PM start and running emission rates based on EPA and CARB analysis of the LEV programs.

Vehicle replacement methodology:

- For statewide runs, 500,000 pre-2004 passenger cars and trucks were replaced with 90% electric and 10% gasoline 2004+ model year vehicles. For Los Angeles county runs, 150,000 pre-2004 passenger cars and trucks were replaced.

[8] https://gaftp.epa.gov/Air/nei/2020/doc/supporting_data/onroad/CDBs_for_all_counties/

[9] https://www.epa.gov/system/files/documents/2023-01/NEI2020_TSD_Section5_Onroad_0.pdf

- In the age distribution table, percentages were updated to reflect the replacement of pre-2004 vehicles with 2004+ vehicles. The population of pre-2004 vehicles were evenly decreased across all pre-2004 model years, and the population of 2004 or younger vehicles were evenly increased across all model years.

In the alternate vehicle fuel and technology (AVFT) table, the fuel engine fractions for gasoline, electric, and diesel passenger cars and trucks were updated. The fuel engine fractions were updated for all 2004+ model years for passenger cars and trucks to capture 10% of the population for gasoline, 90% for electric, and 0% for diesel vehicles.

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