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The Diminishing Returns of Stringent Vehicle Emission Policies on Urban Air Quality: A Case Study of Los Angeles

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Abstract

Due to high levels of congestion and pollution, California has historically had waivers from the United States Environmental Protection Agency (EPA) to enforce stricter vehicle emissions standards than the rest of the country. The US Congress recently passed legislation that would partially restrict these waivers, with further legislation pending. This could significantly degrade air quality in Los Angeles, which is already facing challenges from ozone pollution. To address this concern, this study investigates the potential effects of revoking the California emissions waivers on Los Angeles County air quality. Results from two simulation programs, CEPAM from the California Air Resources Board and MOVES5 from the EPA, were used to project the increase in concentrations of different ozone-causing pollutants in Los Angeles if the vehicle waivers were to be revoked. The results from the simulations indicate that there would not be a significant change in pollutant levels. Since ozone is largely produced from these pollutants, this suggests that ozone levels would also be relatively unaffected. More complicated simulations would be needed to translate the vehicle emission levels to ozone levels directly, so further research may be needed to take this next step. Additionally, the results indicate that more research around other emission sources besides vehicles would be beneficial to reducing ozone levels in Los Angeles.

Keywords: vehicle emissions standards, air quality modeling, ground-level ozone, California Air Resources Board (CARB), EPA waivers, air pollution

1. Introduction

Ground-level ozone is a gaseous air pollutant that can have serious health impacts. Asthma, inflammation of the airways, and emphysema are some of the health risks associated with ozone pollution (US EPA, 2015). This has prompted many countries to take action to eliminate the pollutant. Both North America and Europe have seen improvements in ozone

pollution within recent decades (Sicard et al., 2023).

In the United States, 182 counties are currently categorized by the US EPA as nonattainment areas for ozone pollution (EPA, 2025a). Los Angeles, a heavily populated county in California, has seen a great reduction in ozone pollution (California Air Resources Board, 2025a). Despite this, Los Angeles is the only metropolitan area in the United States currently designated as an extreme nonattainment zone for ozone (EPA, 2025b). As is often the case, the harmful effects of this pollution disproportionately affect minority and disadvantaged communities (Ofodile et al., 2025).

Los Angeles has struggled with air quality issues for many years, the largest contributing factor being ground-level ozone (EPA, 2025b). Of all the criteria pollutants (ozone, PM2.5, PM10, SO2, Pb), the only one listed by the EPA as being "extreme nonattainment" for the LA area is ozone. The three main factors that contribute to this issue are the topography, population, and weather of Los Angeles (Kim et al., 2022). Ozone is formed in a chemical reaction when pollutants such as volatile organic compounds (VOCs), carbon monoxide (CO), and oxides of nitrogen (NOx) combine with sunlight (US EPA, 2015). To reduce ozone levels, California began regulating these pollutants, which are often emitted by vehicles. In 1967, the California Air Resources Board (CARB) was formed to combat air pollution and create regulations on vehicle emissions for California (US Congress, 2025). These regulations would limit the acceptable amount of certain pollutant emissions. Shortly after, the federal government began enacting national air quality regulations, which would normally replace state laws. But due to California's preexisting regulations and challenging air quality issues, the federal government granted California waivers that allowed the state to set its own stricter standards (California Air Resources Board, 2025b).

Since then, California has been a leader in implementing stricter regulations that have dramatically reduced the pollution from vehicle emissions (California Air Resources Board, 2025a). The EPA has granted numerous waivers to California to implement better emissions standards (US Congress, 2025). However, President Donald Trump recently signed congressional resolutions that would revoke three current EPA waivers, and California filed suit in federal court to block this action (White House, 2025; CA Dept of Justice, 2025). In addition, there are currently three bills in Congress that would either restrict or eliminate the EPA waiver program (Rep. Joyce, 2025; Rep. Nehls, 2025; Sen. Mullin, 2025).

The goal of this study is to investigate the impact that the vehicle emissions waivers have on air pollution in Los Angeles and estimate how air quality would be affected if California's EPA waivers are revoked. This matters because over 10 million people live in Los Angeles County, who would potentially be affected by the revocation of these waivers (US Census Bureau 2023). The revocation of these waivers would allow car companies to sell cars in California with fewer regulations, threatening areas like Los Angeles that are already highly impacted by ozone pollution. This could contribute to the worsening of air quality and a higher concentration of air pollutants such as CO, NOx, and VOCs, leading in turn to higher concentrations of ozone.

As mentioned above, the primary issue regarding the air quality in Los Angeles is ozone. Therefore, this study focused on ground-level ozone while examining effects on air pollution. This complicates the approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. These three pollutants are the focus of the study since they are the main precursors of ozone and are directly affected by vehicle emissions standards.

To determine the effects on LA air quality, estimates were generated of the difference in vehicle emissions with and

without current California emissions standards, as well as the contribution of vehicle emissions to the total air pollution inventory in Los Angeles. These estimates were produced using two simulation tools: the California Emission Projection Analysis Model (CEPAM) and the latest version of the EPA's Motor Vehicle Emission Simulator (MOVES5) (California Air Resources Board, 2025c; US EPA, 2016).

CEPAM is a tool created by CARB to model pollution processes in California. It breaks down the various emission sources in LA County into five main categories (Stationary, Area-wide, On Road, Other Mobile, and Natural). CARB stores simulation results for different geographical areas, years, and pollutants to make a user-accessible database (California Air Resources Board, 2025d). This tool was used to generate data for the amount of Reactive Organic Gases (ROGs), CO, and NOx produced in LA County from 2015–2035 in 5-year intervals. ROG is the terminology used by CARB, while the EPA has changed its terminology from ROG to VOC; these terms are essentially synonymous (US EPA, 2014).

While CEPAM is a useful tool for projecting emissions data, it only calculates pollutant levels under the assumption that the California vehicle emissions standards are in effect. Instead, the MOVES5 simulator becomes a useful method to estimate the increase in emissions if the California waivers are revoked. MOVES5 simulates vehicle emissions using the national EPA standards by default, but it can also simulate data using California standards by accounting for a special low-emission vehicle (LEV) database (MOVES5 Technical Guidance, November 2024). MOVES5 enables a model of vehicle emissions data for LA County using both national EPA standards (no LEV) and California (LEV) standards.

2. Methods

The primary data sources used for this investigation were the two simulation tools mentioned above (CEPAM and MOVES5). Simulation results were projected over a +/- 10-year time span (2015–2035) to show how the pollutant levels would be expected to change over time.

CEPAM results were obtained from the user-accessible database maintained by CARB, to project expected pollutant levels broken down by year, pollutant type, and source type. To determine the changes in vehicle emissions should the California waiver be revoked, MOVES5 simulations were conducted with and without incorporating the LEV database. In contrast to CEPAM, MOVES5 only deals with emissions from vehicle sources, so it is necessary to incorporate the MOVES5 estimates into the CEPAM results to generate a new total emissions projection.

With the data gathered from CEPAM and MOVES5, a Microsoft Excel spreadsheet was created to calculate the total change in emissions. Separate sheets were created for each of the three pollutants. On each sheet, a table was created containing the year being examined and the tons of pollutants per day being produced by the five source categories. The results were then displayed using a stacked bar chart for each pollutant to compare the amount of the sources in the total emissions over time. This data represents the baseline pollutant levels with California emission standards in place.

The next objective was to estimate the increase in vehicle emissions that would be expected without California standards. To do this, the MOVES5 "no LEV" data was divided by the "LEV" data to create a vehicle emissions increase factor, F. This process was replicated for five years and three pollutants, giving fifteen different increase factors. Multiplying the CEPAM on-road source estimates by these factors gave a new set of on-road pollutant levels expected without California standards (no LEV).

To find the impact on the total air pollutant levels, the increased vehicle pollutants were added to those from other CEPAM

sources. The bar charts mentioned earlier showed that on-road vehicles only account for a portion of the total emissions. A new total without California emissions standards was calculated by adding the revised emissions data for on-road vehicles to the total amount for all other sources. This produced a set of (No LEV):(LEV) total emissions ratios, obtained by dividing the total "no LEV" pollutant estimate by the original CEPAM baseline numbers.

Letting V represent the baseline CEPAM estimate of vehicle emissions, T represent the baseline CEPAM estimate of total emissions, and F be the emissions increase factor from MOVES5, then the ratio R of "no LEV" to "LEV" total emissions is expressed by the quantity

$$R = \frac{T-V+FV}{T} = 1 + \frac{V}{T}(F - 1))$$

R = Ratio of total emissions without California standards to total with California standards
T = Total emissions from CEPAM (with California standards)
V = Vehicle emissions from CEPAM (with California standards)
F = Increase factor of vehicle emissions from MOVES5

The numerator of the equation above represents a new total emissions level based on replacing the original vehicle emissions "V" with an increased level "FV," then dividing this new total emissions level by the original level "T" to determine a ratio "R". Finally, a graph was produced to illustrate the ratios of the total pollutant level for each pollutant and year.

3. Results

Figures 1-3 show stacked bar graphs depicting CEPAM simulated pollutant levels for LA County over the time period 2015–2035. Note that these predictions were made with the California emission regulations in effect. Each bar shows how much different sources contributed to the total pollutant inventory.

The bar graphs convey two important ideas. First, the emissions are decreasing over time. Secondly, on-road vehicles (in purple) currently account for less than half of the total emissions. This is especially apparent for ROGs. Both of these trends could validate the overall success of the California vehicle emission standards, particularly in reducing the contribution from on-road vehicles.

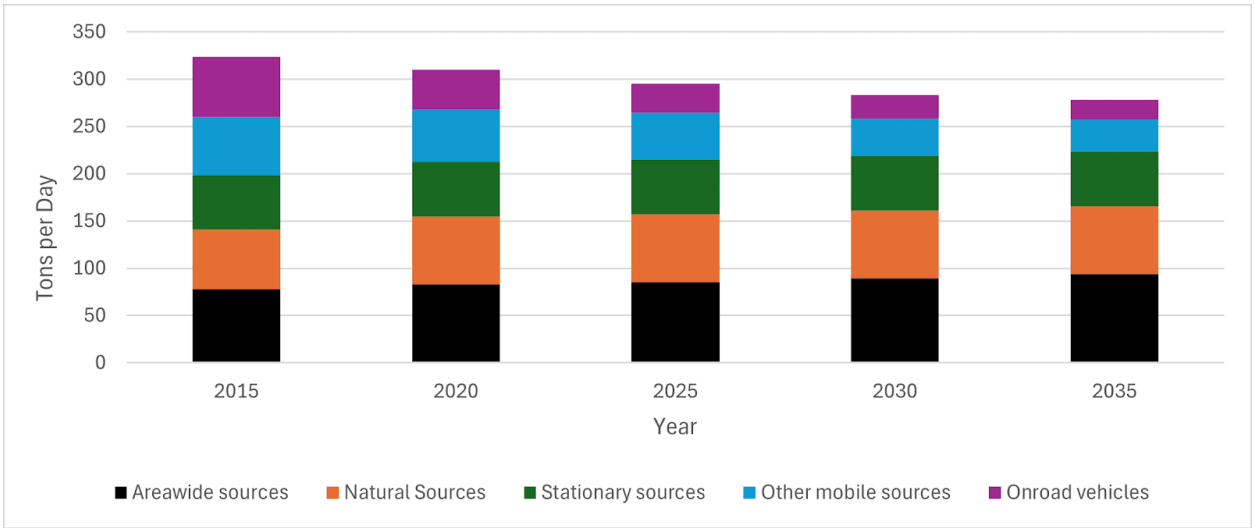

Figure 1: CEPAM estimates of ROG emissions in LA County by source and year

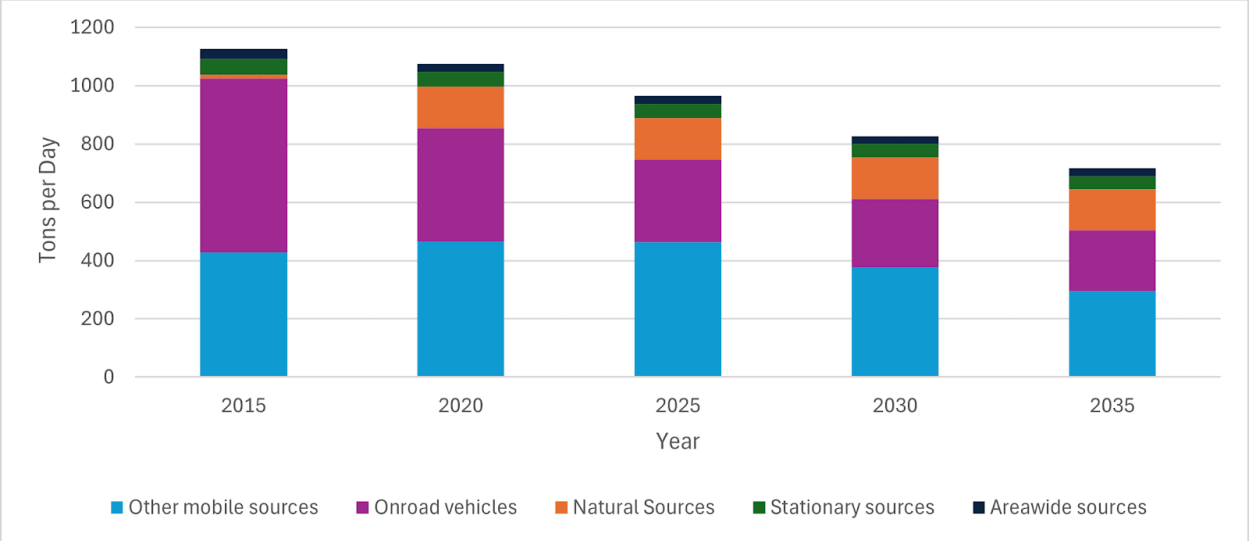

Figure 2: CEPAM estimates of CO emissions in LA County by source and year

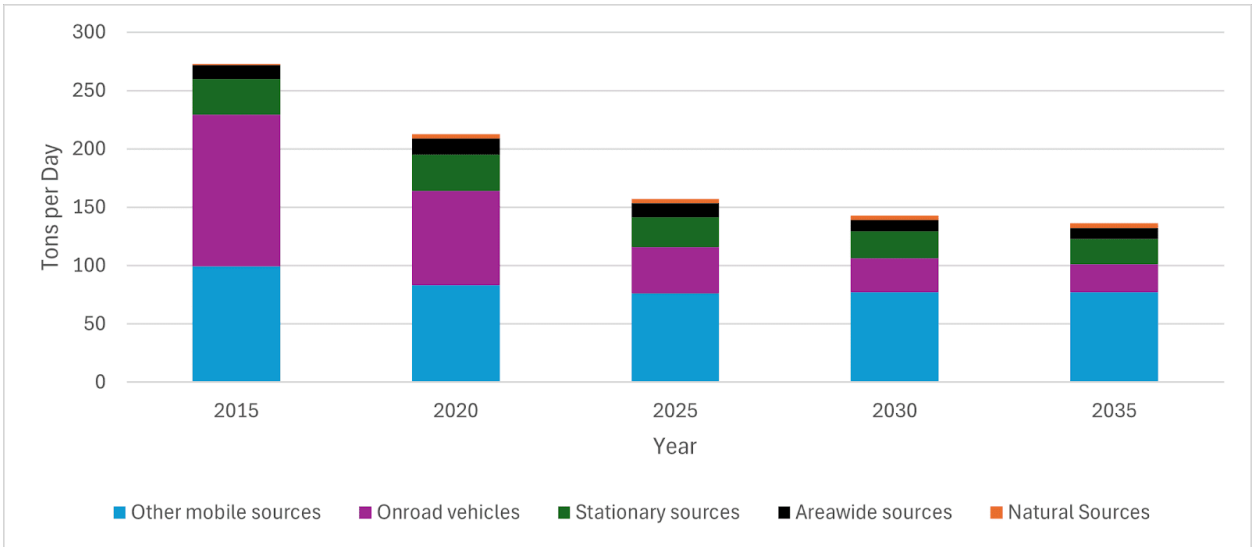

Figure 3: CEPAM estimates of NOx emissions in LA County by source and year

Figure 4 shows the LA County vehicle emissions increase factor F, calculated by MOVES5 between the "no LEV" and "LEV" cases. The simulations show the largest increase for CO, but only by about 20%; he other pollutant increases are even smaller. This seems somewhat surprising as the California emissions standards might reasonably be expected to make a bigger difference.

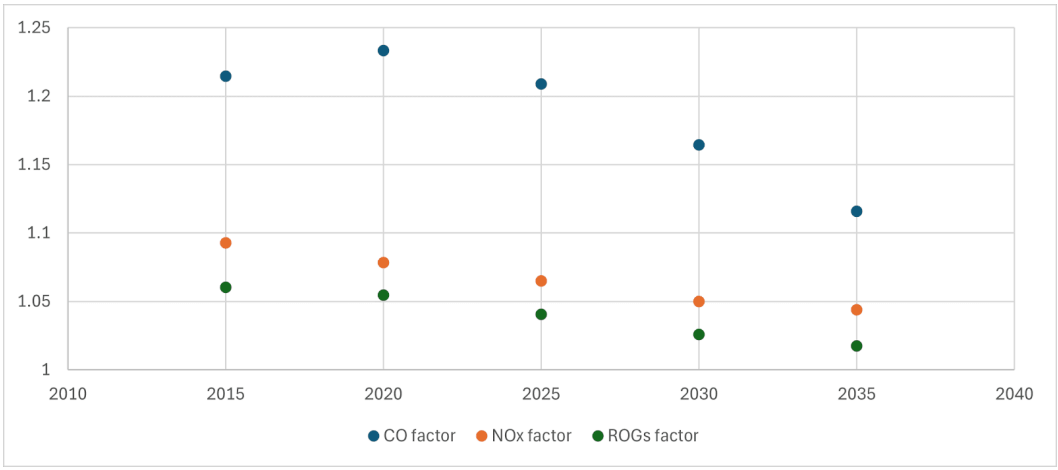

Figure 4: MOVES5 estimated ratio of LA County vehicle emissions - (without LEV standards) divided by (with LEV standards)

Finally, Figure 5 shows the effect on the total pollutant inventory in LA if the California emissions standards were to be revoked. The effects are small, especially for ROGs and NOx, which only show increases of a few percent at most.

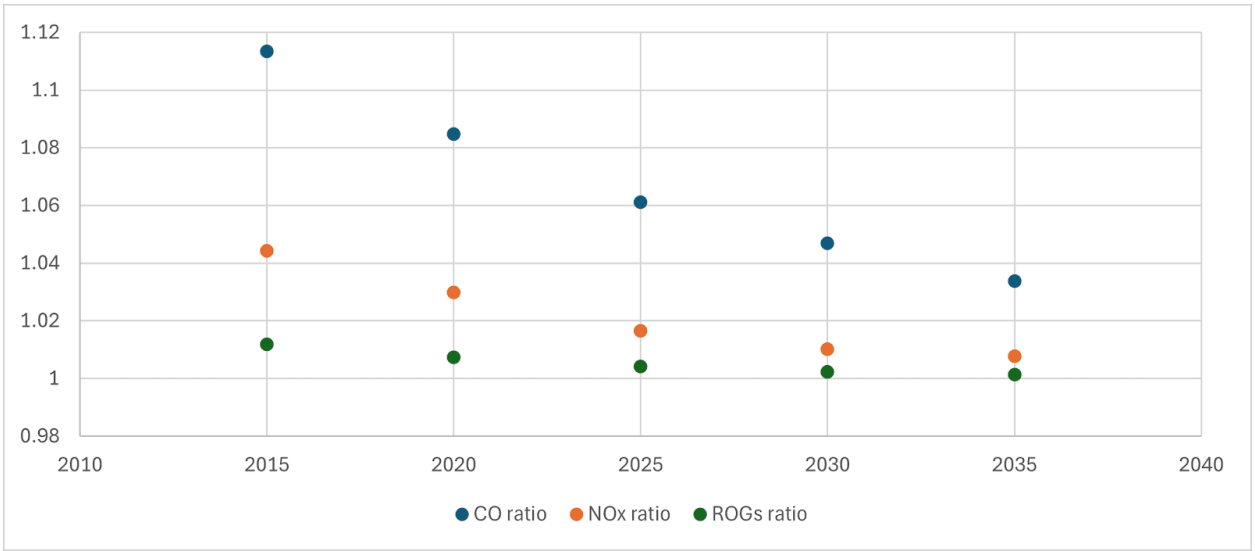

Figure 5: Estimated total emissions increase ratio in LA County from CEPAM and MOVES5 simulations

4. Discussion

The study results suggest that there would be a small change in the total emissions in LA if the California emissions waivers were revoked. The results from MOVES5 show that without the California standards, vehicle emissions of NOx, CO, and ROGs would increase by approximately 20% at most. When these slight increase factors are applied to the baseline CEPAM data, the change becomes even smaller. Because on-road vehicles contribute only a fraction of the total emissions, a 20% increase in this contribution results in less than a 10% increase in the total inventory. Again, these results do not correlate directly to ozone levels; however, if the precursors increase by less than 10%, it is reasonable to expect that there will not be a dramatic change in ozone levels.

The small change in the precursors is mostly due to two factors, both of which seem unexpected. First, as can be seen in Figures 1-3, the majority of emissions in LA County come from sources other than road vehicles. This is particularly true for ROGs and NOx. Second, changing from California emissions standards to the national EPA standards in MOVES5 did not dramatically change pollutant levels.

Further research into why MOVES5 did not show a larger difference between the “no LEV” and “LEV” cases revealed only a partial explanation. According to the EPA, the current national Tier 3 standards are harmonized with current California vehicle (LEV III) standards (Lattanzio & McCarthy, 2014). This means the EPA has essentially replicated the California standards in setting the current Tier 3 standards, which began taking effect in 2017. Therefore, the national fleet would be expected to align closer to California over time. The MOVES5 results seem to indicate that, in the end, there may not be a

notable difference between California and national EPA standards.

The most controversial of the three emissions waivers being revoked is probably the so-called zero-emissions vehicle (ZEV) mandate. This would require increasing percentages of new light-duty vehicles to be zero-emissions until 2035, at which point 100% of new sales would need to be ZEVs. Interestingly, CARB justifies this restriction based on LA air quality, stating in part that "Projections indicate that with all existing programs in effect (including the waiver for Advanced Clean Cars), the Los Angeles area will not meet federal ozone standards in 2031. Only increased electrification of the vehicle fleet will achieve the necessary reductions." (EPA, 2025). Yet CARB's own simulations show that on-road vehicles currently account for a minority of the ozone precursor inventory in LA, particularly for VOCs and NOx. Given this, it would seem that the benefits of further electrification would be marginal. Therefore, while the ZEV mandate may yield important long-term benefits for greenhouse gas emissions and technological advancement, its efficacy as the primary tool for achieving near-term federal ozone standards in Los Angeles may be limited without complementary regulations on non-road mobile sources. It should also be noted that ozone formation is a complex chemical process that depends not only on the total inventory of precursors but also on their relative abundance. As such, the ZEV mandate may have further-reaching consequences than might be expected simply from a modest reduction of total precursor inventory. A complete assessment of these effects would require more complicated models, as discussed further below.

One cause for concern in this study is that the MOVES5 data and CEPAM data do not completely align. The vehicle emissions levels indicated from MOVES5 for LA County are typically about twice the size of the CEPAM on-road source numbers. CEPAM uses a different vehicle emission simulation program, also developed by CARB, called EMission FACtor (EMFAC) (California Air Resources Board, 2025). MOVES5 and EMFAC are complex programs that sometimes use different approaches, and other researchers have also observed similar discrepancies between these tools (*MOVES vs. EMFAC*, 2008). CEPAM would generally be preferred for modeling processes in California since it is designed specifically for California as opposed to the entire nation (US EPA, 2022). For this reason, MOVES5 was only used to estimate an increase factor due to the change from California to national EPA standards, which was then applied to the baseline CEPAM on road source data. This should help to minimize the effects of any discrepancy between the programs.

Another obvious limitation of the study is that it only examines ozone precursors, not ozone itself. Translating the precursor levels to actual ozone levels is a much more complicated process that requires consideration of additional factors such as meteorological conditions and topography. These types of simulations are generally referred to as Chemical Transport Models, and several are available, such as the Community Multiscale Air Quality Modeling System (CMAQ) from the EPA (EPA, 2025c). However, these models generally require significant computing resources and are thus beyond the scope of this current investigation.

5. Conclusion

Ozone is a secondary pollutant formed through complex photochemical reactions involving primary pollutants such as NOx, CO, and VOCs in the presence of sunlight. In this study, these three primary pollutants were analyzed as key precursors influencing ozone formation. By examining their temporal and spatial variations, the research infers ozone concentration trends and highlights the interplay between emission sources and atmospheric chemistry under regulated conditions.

This paper focuses on the air pollution problems in Los Angeles and the effect of the California vehicle emissions waivers on

these issues. The results show that although emissions would increase if these waivers were revoked, the increase would probably not be very significant. Because of all the regulations on vehicle emissions in California, they are now a small enough fraction of the total inventory that it is difficult to make reductions in the total inventory without addressing other sources.

Since this research is confined to the changes in ozone precursors, rather than ozone itself, it is unable to make direct projections of ozone concentration. A potential extension of these results would use chemical transport models such as CMAQ from the EPA to estimate the actual change in ozone levels. The results of this study also suggest that further research on other emission sources in LA, such as areawide sources, might be useful. The components that make up these sources are sometimes less regulated and contribute a significant amount to ROG emissions.

6. References

California Air Resources Board. (2025a). *Pollution standards authorized by the California waiver: A crucial tool for fighting air pollution now and in the future*. https://ww2.arb.ca.gov/resources/fact-sheets/pollution-standards-authorized-california-waiver-crucial-tool-fighting-air

California Air Resources Board. (2025b). *History*. https://ww2.arb.ca.gov/about/history

California Air Resources Board. (2025c). *CEPAM*. https://ww2.arb.ca.gov/cepam

California Air Resources Board. (2025d). *Emissions for user defined query*. https://ww2.arb.ca.gov/applications/emissions-user-defined-query

California Air Resources Board. (2025e). *On-road (EMFAC)*. https://ww2.arb.ca.gov/our-work/programs/msei/on-road-emfac

California Department of Justice. (2025). *Case 3:25-cv-04966*. https://oag.ca.gov/system/files/attachments/press-docs/Filed%20Waiver%20Resolution%20Complaint.pdf

Kim, S.-W., McDonald, B. C., Seo, S., Kim, K.-M., & Trainer, M. (2022). Understanding the paths of surface ozone abatement in the Los Angeles Basin. *Journal of Geophysical Research: Atmospheres*, *127*(4), Article e2021JD035606. https://doi.org/10.1029/2021JD035606

Lattanzio, R. K., & McCarthy, J. E. (2014). Tier 3 motor vehicle emission and fuel standards. In L. Murphy (Ed.), *U.S. and EU motor vehicle standards: Elements, considerations and trade issues* (pp. 37–54). Nova Science Publishers.

MOVES5 technical guidance. (2024, November). U.S. Environmental Protection Agency. https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101CTM3.pdf

Ofodile, J., Pfannerstill, E. Y., Arata, C., Pusede, S. E., Ivey, C. E., & Goldstein, A. H. (2025). Inequality in hazardous air pollutant emissions and concentrations measured over Los Angeles. *Environmental Science & Technology*, 59(15), 7588–7599. https://doi.org/10.1021/acs.est.5c00808

Rep. Joyce, J. [R-PA-13]. (2025, January 13). *H.R.346 - 119th Congress (2025-2026): Preserving Choice in Vehicle Purchases Act* [Legislation]. https://www.congress.gov/bill/119th-congress/house-bill/346

Rep. Nehls, T. E. [R-TX-22]. (2025, March 18). *H.R.2218 - 119th Congress (2025-2026): Stop CARB Act of 2025* [Legislation]. https://www.congress.gov/bill/119th-congress/house-bill/2218/text

ResearchGate. (2008, January). *MOVES vs. EMFAC: A comparative assessment based on a Los Angeles County case study*. https://www.researchgate.net/publication/237741337_MOVES_vs_EMFAC_A_COMPARATIVE_ASSESSMENT_BASED_ON_A_LOS_ANGELES_COUNTY_CASE_STUDY

Sen. Mullin, M. [R-OK]. (2025, March 12). *S.996 - 119th Congress (2025-2026): Preserving Choice in Vehicle Purchases Act of 2025* [Legislation]. https://www.congress.gov/bill/119th-congress/senate-bill/996

Sicard, P., Agathokleous, E., Anenberg, S. C., De Marco, A., Paoletti, E., & Calatayud, V. (2023). Trends in urban air pollution over the last two decades: A global perspective. *Science of the Total Environment*, 858, Article 160064. https://doi.org/10.1016/j.scitotenv.2022.160064

U.S. Census Bureau. (2023). *Los Angeles County, California*. https://data.census.gov/profile/Los_Angeles_County,_California?g=050XX00US06037

U.S. Congress. (2025, May). [Legislation]. https://www.congress.gov/crs-product/R48168

U.S. Environmental Protection Agency. (2014, August 18). *Technical overview of volatile organic compounds* [Overviews and Factsheets]. https://www.epa.gov/indoor-air-quality-iaq/technical-overview-volatile-organic-compounds

U.S. Environmental Protection Agency. (2015, May 29). *Ground-level ozone basics* [Overviews and Factsheets]. https://www.epa.gov/ground-level-ozone-pollution/ground-level-ozone-basics

U.S. Environmental Protection Agency. (2016, February 12). *MOVES and mobile source emissions research* [Collections and Lists]. https://www.epa.gov/moves

U.S. Environmental Protection Agency. (2022, April 15). *Is MOVES the best tool for my work?* [Overviews and Factsheets]. https://www.epa.gov/moves/moves-best-tool-my-work

U.S. Environmental Protection Agency. (2025a). *Green Book*. https://www3.epa.gov/airquality/greenbook/jbtc.html

U.S. Environmental Protection Agency. (2025b). *Green Book*. https://www3.epa.gov/airquality/greenbook/ancl3.html

U.S. Environmental Protection Agency. (2025c). *CMAQ: The Community Multiscale Air Quality Modeling System*. https://www3.epa.gov/cmaq

White House. (2025, June 12). *Statement by the president*.

https://www.whitehouse.gov/briefings-statements/2025/06/statement-by-the-president/

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Mentor Contribution Statement

Maria Gómez Saldarriaga is a Ph.D. Candidate in the Integrated Coastal Sciences Program at East Carolina University. As Allison's mentor during her participation in the IRIS program, Maria provided guidance from the initial stages of developing Allison's research project through the completion and polishing of her manuscript. Maria's role during the program was centered on ensuring that Allison's project advanced in alignment with program milestones and scholarly standards.

During the entire program, Allison worked with remarkable independence and initiative. Allison is fully responsible for defining her research questions, conducting the analysis, interpreting results, and drafting all sections of the manuscript. Maria's primary contributions involved providing periodic feedback to strengthen clarity, organization, and citation formatting, as well as offering suggestions to improve transitions across sections.

Maria also reviewed Allison's progress weekly during the program to confirm that she was meeting deadlines. The intellectual content, analysis, and written products are entirely Allison's own. Because Maria recognized the quality of her work, Maria was responsible for selecting her paper for submission to Convergence.

For any questions, readers may contact Maria directly.