Effect of California Vehicle Emissions Standards on Los Angeles Air Quality

Abstract

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 due to high levels of congestion and pollution. US Congress has 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, I investigated the potential effects of revoking the California emissions waivers on Los Angeles County air quality. Although I expected to see a large increase in ozone levels, my investigation showed revoking California waivers would be unlikely to cause a large change. There are two main reasons for this result. First, the California vehicle regulations have already reduced the contributions of vehicles to the point where they are a small part of the total emissions inventory. Second, because of the success of the California standards, the EPA has in recent years adopted the current California standards in its nationwide emissions standards.

Main Body

Introduction

182 counties in the United States are currently categorized by the US EPA as nonattainment areas for ozone pollution (EPA, 2025). Ground-level ozone is a gas and 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 in eliminating the pollutant. Both North America and Europe have seen improvements in ozone pollution

within recent decades (Sicard et al., 2023). Los Angeles, a heavily populated county in California, has also seen a great reduction of ozone pollution (*Pollution Standards Authorized by the California Waiver: A Crucial Tool for Fighting Air Pollution Now and in the Future | California Air Resources Board*, 2025). Despite this, Los Angeles is the only metropolitan area in the United States currently designated as an extreme nonattainment zone for ozone (EPA, 2025). 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, and the largest contributing factor has been ground-level ozone (EPA, 2025). 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). So, 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. They created a set of regulations on vehicle emissions for California (*California and the Clean Air Act (CAA) Waiver*, 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, California was granted waivers that allowed the state to set its own more strict standards (*History | California Air Resources Board*, 2025).

Since then, California has been a leader in implementing stricter regulations which have dramatically reduced the pollution from vehicle emissions (*Pollution Standards Authorized by the California Waiver: A Crucial Tool for Fighting Air Pollution Now and in the Future | California Air Resources Board*, 2025). The EPA has granted numerous waivers to California to implement better emissions standards (*California and the Clean Air Act (CAA) Waiver*, 2025). But recently, President Trump signed congressional resolutions that would revoke three current EPA waivers, and California filed suit in

federal court to block this action (House, 2025; “In the United States District Court for the Northern District of California,” June 2025). In addition, there are currently three bills in Congress which would either restrict or completely eliminate the EPA waiver program (Rep. Joyce, 2025; Rep. Nehls, 2025; Sen. Mullin, 2025).

I investigated the impact the vehicle emissions waivers have on air pollution in Los Angeles and estimated how much the air quality will be affected if California’s EPA waivers are revoked. This matters because over 10 million people live in Los Angeles County that would potentially be affected by the revocation of these waivers (*Los Angeles County, California - Census Bureau Profile*, 2023). Los Angeles, which is already highly impacted by ozone pollution, will likely suffer from the revocation of these waivers because car companies will be able to sell cars in California with less strict regulations. This will contribute to the worsening of air quality and a higher concentration of air pollutants such as CO, NOx and VOCs which will lead to higher concentrations of ozone. I predicted that if the EPA California emissions waivers are revoked, the air quality in Los Angeles would worsen dramatically.

Methods

As mentioned in the introduction, the primary issue regarding the air quality in Los Angeles is ozone. So, I decided to look specifically at ground-level ozone while examining the effects on air pollution. This complicated my approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. I decided to focus on these three pollutants instead of ozone because they are the main precursors to ozone and are directly affected by the vehicle emissions standards.

To test my hypothesis, I needed to find 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. I achieved this using two simulation tools: the California Emission

Projection Analysis Model (CEPAM), and the latest version of the EPA's Motor Vehicle Emission Simulator (MOVES5) (*CEPAM | California Air Resources Board*, 2025; US EPA, 2016).

CEPAM is a tool created by CARB to model pollution processes in California. CARB has stored simulation results for different geographical areas, years, and pollutants to make a user accessible database (*Emissions for User Defined Query | California Air Resources Board*, 2025). I chose to project emissions data for three different pollutants over a +/- 10-year time span in order to show how the pollutant levels change with time. I collected data for the amount of Reactive Organic Gases (ROGs), CO, and NOx produced in LA county in the years 2015-2035 in 5-year intervals. ROG is the terminology used by CARB, while the EPA has changed their terminology from ROG to VOC, but these terms are essentially synonymous (US EPA, 2014). CEPAM breaks down the various emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). Examples from the five CEPAM source categories are shown in Table 1.

Table 1: Components of Source Categories for CEPAM2019 Projections

Source Type	**Sample Components**
Stationary	Fuel combustion, waste disposal, petroleum production, industrial
Areawide	Solvent evaporation, residential fuel, farming, construction, cooking
On Road	Motorcycle, cars, light duty truck, heavy diesel truck, buses, RV
Other Mobile	Planes, boats, trains, off road equipment, farm equipment
Natural	Biogenic, geogenic, wildfire

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. A method to estimate the increase in emissions if the California waivers are revoked is also needed, and this is where the MOVES5 simulator became useful. MOVES5 by default simulates vehicle emissions using the national EPA standards, but can also simulate data using California standards by including a special low-emission vehicle (LEV) database when running (*MOVES5 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA-420-B-24-043, November*

2024). Using MOVES5 I was able to model vehicle emissions data for LA County using both national EPA standards (no LEV) and California (LEV) standards. In contrast to CEPAM, MOVES5 only deals with emissions from vehicle sources, so I had to incorporate the MOVES5 estimates into the CEPAM results to come up with a new total emissions projection.

With the data gathered from CEPAM and MOVES5, I used Excel to calculate the total change in emissions. First, I made separate sheets for all three pollutants. On each sheet, I created a table containing the year being examined and the tons of the pollutants per day being produced by the five source categories. I then created a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent the baseline pollutant levels with California emission standards in place.

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

Finally, to find the impact on the total air pollutant levels, I needed to add the increased vehicle pollutants to those from other sources from CEPAM. The bar graph I created showed that on road vehicles only account for a portion of the total emissions. I calculated a new total without California emissions standards by adding the revised emissions data for on road vehicles to the total amount for all other sources. I then produced a set of (No LEV):(LEV) total emissions ratios 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

Finally, I made a graph illustrating the changes in the total pollutant level for each pollutant and year.

Results and Discussion

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.

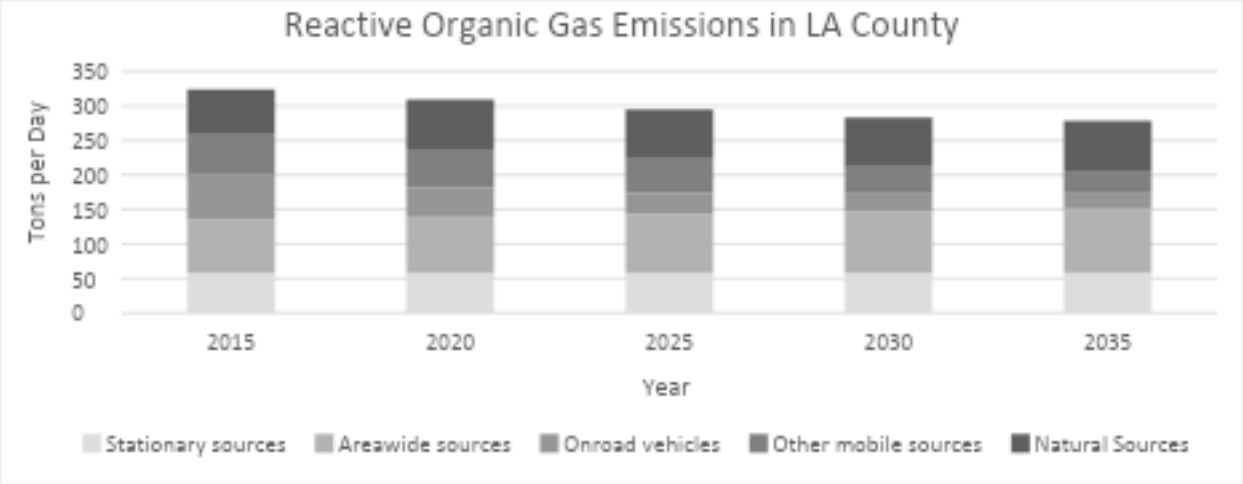

Figure 1: CEPAM estimates of ROG emissions in LA County by source and year

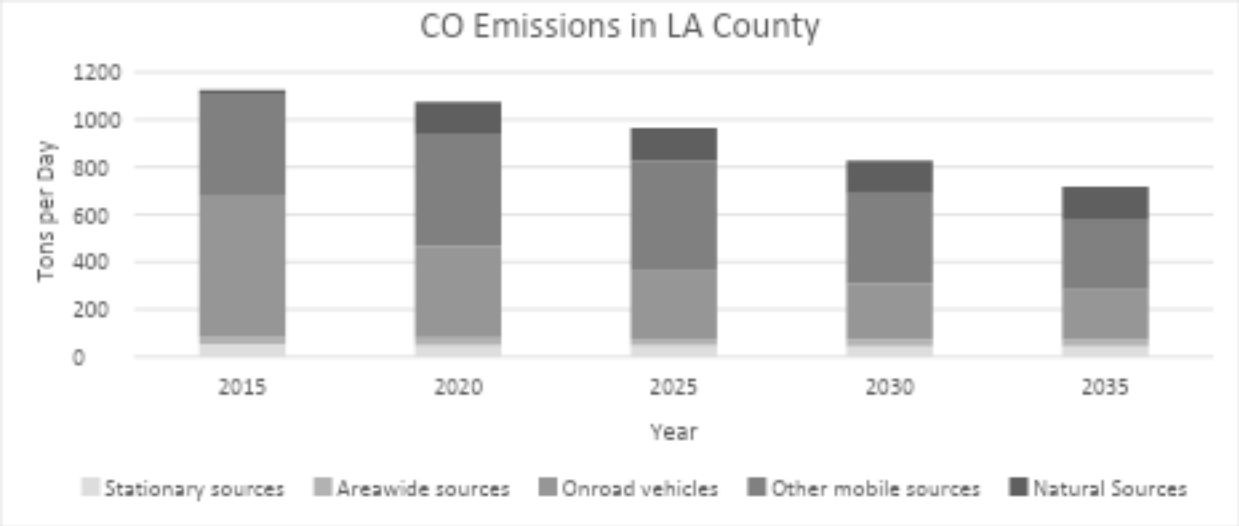

Figure 2: CEPAM estimates of CO emissions in LA County by source and year

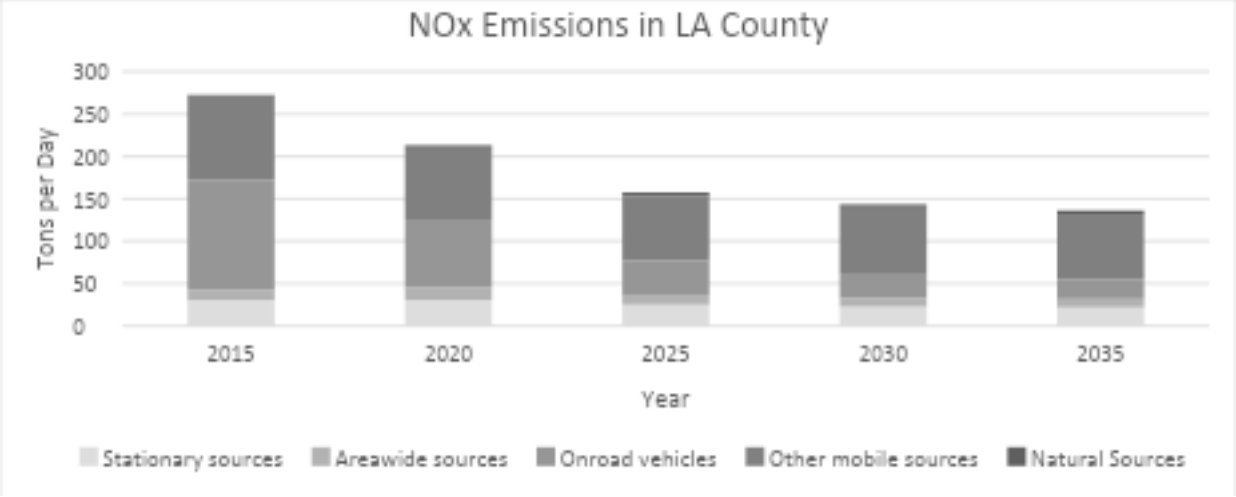

Figure 3: CEPAM estimates of NOx emissions in LA County by source and year

The bar graphs convey two important ideas. First, the emissions are growing smaller over time. Secondly, on road vehicles (green portion) currently account for less than half of the total emissions. This is especially apparent for ROGs. Both of these trends can be viewed as validating the overall success of the California vehicle emission standards, particularly in reducing the contribution from on road vehicles.

Figure 4 shows the LA County vehicle emissions increase factor F calculated by MOVES5 between the “no LEV” and “LEV” case. The simulations show the largest increase for CO, but it is not dramatic,

only about 20%, and the other pollutant increases are even smaller. This was a bit surprising as I expected the California emissions standards to make a bigger difference.

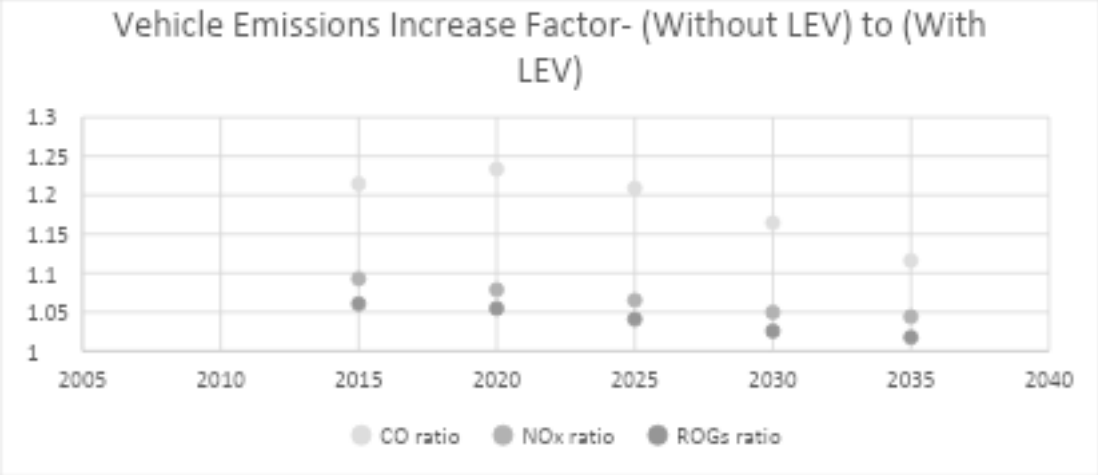

Figure 4: MOVES5 estimated ratio of LA County vehicle emissions - (without LEV standards) divided by (with LEV standards)

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

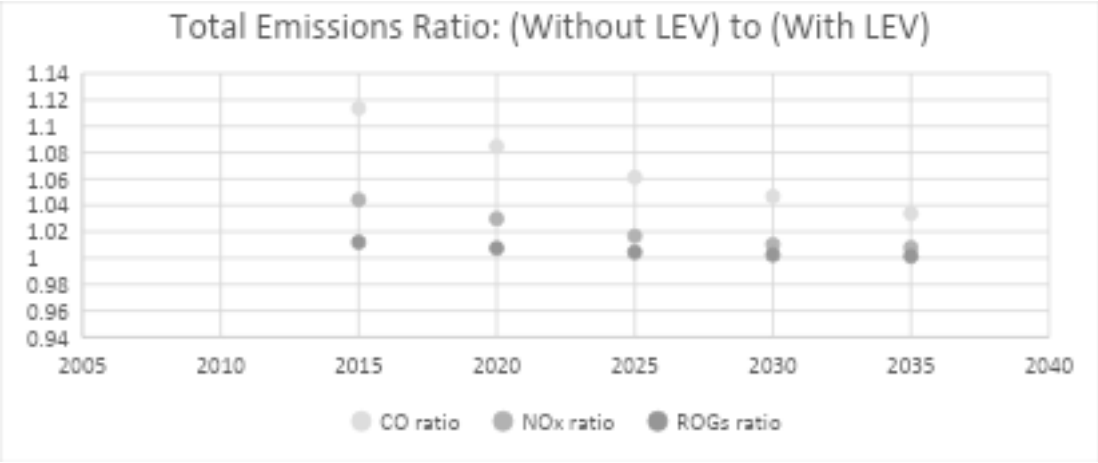

Figure 5: Estimated total emissions increase ratio in LA County from CEPAM and MOVES5 simulations

My 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 around 20% at most. When these slight increase factors are applied to the baseline CEPAM data, the change becomes much 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.

This result is mostly due to two factors, both of which seem a bit surprising. First, as can be seen in Figures 1-3, the majority of emissions in LA County come from other sources besides on 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 cause a dramatic change in the pollutant levels.

Further research into why MOVES5 did not show a larger difference between the "no LEV" and "LEV" cases revealed some interesting facts that may provide at least a partial explanation. According to the EPA, the current national Tier 3 standards are harmonized with (meaning the same as) 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 more closely align with California as time goes on. So in the end, there may not be that much difference between California and national EPA standards, as the MOVES5 results seem to indicate.

One issue I ran into is that the MOVES5 data and CEPAM data do not agree very well. The vehicle emissions levels indicated from MOVES5 for LA County are usually about double the size of the CEPAM on road source numbers. CEPAM uses a different vehicle emission simulation program also developed by CARB called EMmission FACtor (EMFAC) (*On-Road (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 (*(PDF) MOVES vs. EMFAC*, January, 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, I only

used MOVES5 to estimate an increase factor due to the change from California to national EPA standards, and then applied this factor to the baseline CEPAM on road source data. This should help to minimize the effects of any discrepancy between the programs.

Another issue is that because the formation of ozone is based on many factors, examining the precursors does not directly correlate vehicle emissions to ozone production. While some more complex simulation tools such as the Community Multiscale Air Quality Modeling System (CMAQ) can provide a more complete picture, they were too complicated for me to run and are more advanced than the models I used (Environmental Protection Agency).

Conclusion

This paper investigated the air pollution problems in Los Angeles and the effect of the California vehicle emissions waivers on these issues. I found that although emissions would increase if these waivers were revoked, the increase would not be as significant as I expected.

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 the other sources. In particular, other mobile sources (planes, trains, farm equipment etc.) are now the dominant sources of CO and NOx, so further reductions in these levels will almost certainly require tighter regulation of these sources.

Because I confined my research to the changes in ozone precursors, rather than ozone itself, I was unable to make direct projections of ozone concentration. I would encourage other scholars to use chemical transport models such as CMAQ from the EPA to estimate the actual change in ozone levels. I would also suggest further research in other emission sources in LA, such as areawide sources. The components that make up these sources are sometimes less regulated and contribute a significant amount to ROG emissions.

In the end, the results of my research show that the California standards have been effective, and this plays a part in why my hypothesis was incorrect. I originally assumed that because of the regulation's effectiveness, revoking these waivers would have large effects on the air quality of California. But it seems that these regulations have contributed to such a reduction in vehicle emissions that on road vehicles account for a much smaller piece of the total emissions. The California standards have now been adopted by the rest of the country, minimizing the effect of the waivers on air pollution even further. Therefore, the California vehicle emissions waivers have reduced vehicle emissions so much that revoking them would have a much smaller impact on air pollution than I expected.

Acknowledgements

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Submission 100092 – Editorial Feedback

This paper targets a very important topic: Urban pollution and projected changes in pollutant levels. However, there are several points to address in the manuscript and the presentation of analyses before the manuscript can enter into the peer review pipeline.

- The title is too broad and does not inform the reader of the overall result and/or takeaway message of the paper.
- The abstract should contain an explicit description, albeit brief, of the methods
- The interpretation of the results within the abstract suggests you know definitively why the results generated were as such. In reality, and in science, there are likely a confluence of different factors and a researcher's job is to understand the degree to which each may influence a dependent variable i.e. pollutant levels. Your wording and analyses should reflect your efforts toward this rather than a weaker, likely insufficient determination of causality
- Your abstract should end on future directions and what your results mean for our understanding of the topic i.e. what is the thesis and its big implications?
- It is unclear how Table 1 categories fit into the schema for the quantitative bar graphs
- The figures should be imported using higher resolution image formats
- The figures should be presented in a different format. The current stacked format is not conducive to examining the contributions or expected contributions of each source to pollutants levels. The author should reorder the stacks with a most to least, or least to most organization. It may also be important to simply separate the stacks into distinct lines or another format that would help reviewers and readers appreciate how each source contributes to pollutant levels.
- The results section should be distinct from the discussion.
- The hypothesis that the primary determinant of AQ in Los Angeles is ozone is quickly defeated. The author states that the primary pollutants of interest in the paper are NO, VOCs and CO. Thus, it would seem prudent to the focus of your paper that you focus on these and not ozone. Thus, your thesis should also be refocused as necessary.

Revocation of California Vehicle Emissions Standards Has Minimal Impact on Los Angeles Air Quality

Abstract

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 due to high levels of congestion and pollution. US Congress has 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, I investigated the potential effects of revoking the California emissions waivers on Los Angeles County air quality. I used results from two simulation programs (CEPAM from the California Air Resources Board and MOVES5 from the EPA) 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. Much more complicated simulations would be needed to translate the vehicle emission levels I calculated to ozone levels directly, so further research may be needed to take this next step. Additionally, my results indicate that more research around other emissions types of sources besides vehicles would be beneficial to reducing ozone levels in Los Angeles.

Main Body

Introduction

182 counties in the United States are currently categorized by the US EPA as nonattainment areas for ozone pollution (EPA, 2025). Ground-level ozone is a gas and 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 in eliminating the pollutant. Both North America and Europe have seen improvements in ozone pollution within recent decades (Sicard et al., 2023). Los Angeles, a heavily populated county in California, has also seen a great reduction of ozone pollution (*Pollution Standards Authorized by the California Waiver: A Crucial Tool for Fighting Air Pollution Now and in the Future | California Air Resources Board*, 2025). Despite this, Los Angeles is the only metropolitan area in the United States currently designated as an extreme nonattainment zone for ozone (EPA, 2025). 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, and the largest contributing factor has been ground-level ozone (EPA, 2025). 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). So, 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. They created a set of regulations on vehicle emissions for California (*California and the Clean Air Act (CAA) Waiver*, 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, California was granted waivers that allowed the state to set its own more strict standards (*History | California Air Resources Board*, 2025).

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three pollutants because they are the main precursors of ozone and are directly affected by the vehicle emissions standards. This is not a direct projection of ozone levels, however, and in order to take the next step from the precursors to the ozone levels, much more complex simulations are required. These take into consideration many other factors such as weather and topography. Such simulation programs exist, for instance the Community Multiscale Air Quality Modeling System (CMAQ) from the EPA (Environmental Protection Agency). These tools are more complex than I can use, so I had to limit my investigation to the ozone precursors NOx, CO, and VOCs.

To test my hypothesis, I needed to find 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. I achieved this using two simulation tools: the California Emission Projection Analysis Model (CEPAM), and the latest version of the EPA's Motor Vehicle Emission Simulator (MOVES5) (*CEPAM | California Air Resources Board*, 2025; US EPA, 2016).

CEPAM is a tool created by CARB to model pollution processes in California. CARB has stored simulation results for different geographical areas, years, and pollutants to make a user accessible database (*Emissions for User Defined Query | California Air Resources Board*, 2025). I chose to project emissions data for three different pollutants over a +/- 10-year time span in order to show how the pollutant levels change with time. I collected data for the amount of Reactive Organic Gases (ROGs), CO, and NOx produced in LA county in the years 2015-2035 in 5-year intervals. ROG is the terminology used by CARB, while the EPA has changed their terminology from ROG to VOC, but these terms are essentially synonymous (US EPA, 2014).

CEPAM breaks down the various emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). Each of these five main categories is composed of many other subcategories. Some names of the main categories are not very indicative of

what the subcategories are, so Table 1 is provided to give a better understanding of what the five main source type categories actually represent.

Table 1: Components of Source Categories for CEPAM2019 Projections

Source Type	Sample Components
Stationary	Fuel combustion, waste disposal, petroleum production, industrial
Areawide	Solvent evaporation, residential fuel, farming, construction, cooking
On Road	Motorcycle, cars, light duty truck, heavy diesel truck, buses, RV
Other Mobile	Planes, boats, trains, off road equipment, farm equipment
Natural	Biogenic, geogenic, wildfire

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. A method to estimate the increase in emissions if the California waivers are revoked is also needed, and this is where the MOVES5 simulator became useful. MOVES5 by default simulates vehicle emissions using the national EPA standards, but can also simulate data using California standards by including a special low-emission vehicle (LEV) database when running (*MOVES5 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity (EPA-420-B-24-043, November 2024*). Using MOVES5 I was able to model vehicle emissions data for LA County using both national EPA standards (no LEV) and California (LEV) standards. In contrast to CEPAM, MOVES5 only deals with emissions from vehicle sources, so I had to incorporate the MOVES5 estimates into the CEPAM results to come up with a new total emissions projection.

With the data gathered from CEPAM and MOVES5, I used Excel to calculate the total change in emissions. First, I made separate sheets for all three pollutants. On each sheet, I created a table containing the year being examined and the tons of the pollutants per day being produced by the five source categories. I then created a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent the baseline pollutant levels with California emission standards in place.

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

Finally, to find the impact on the total air pollutant levels, I needed to add the increased vehicle pollutants to those from other sources from CEPAM. The bar graph I created showed that on road vehicles only account for a portion of the total emissions. I calculated a new total without California emissions standards by adding the revised emissions data for on road vehicles to the total amount for all other sources. I then produced a set of (No LEV):(LEV) total emissions ratios 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

Finally, I made a graph illustrating the changes in the total pollutant level for each pollutant and year.

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.

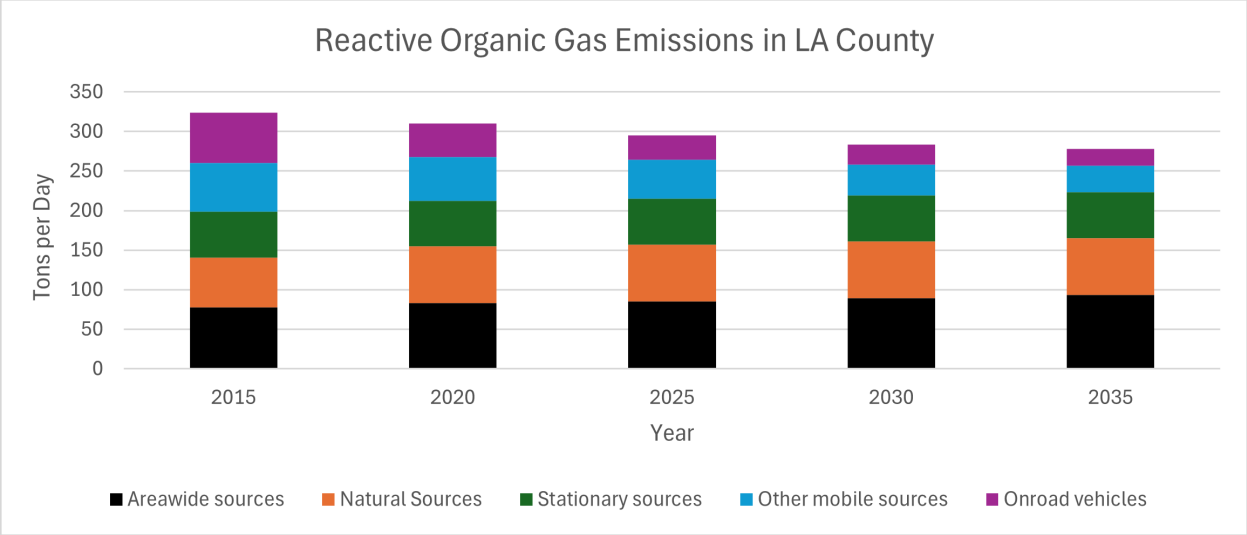

Figure 1: CEPAM estimates of ROG emissions in LA County by source and year

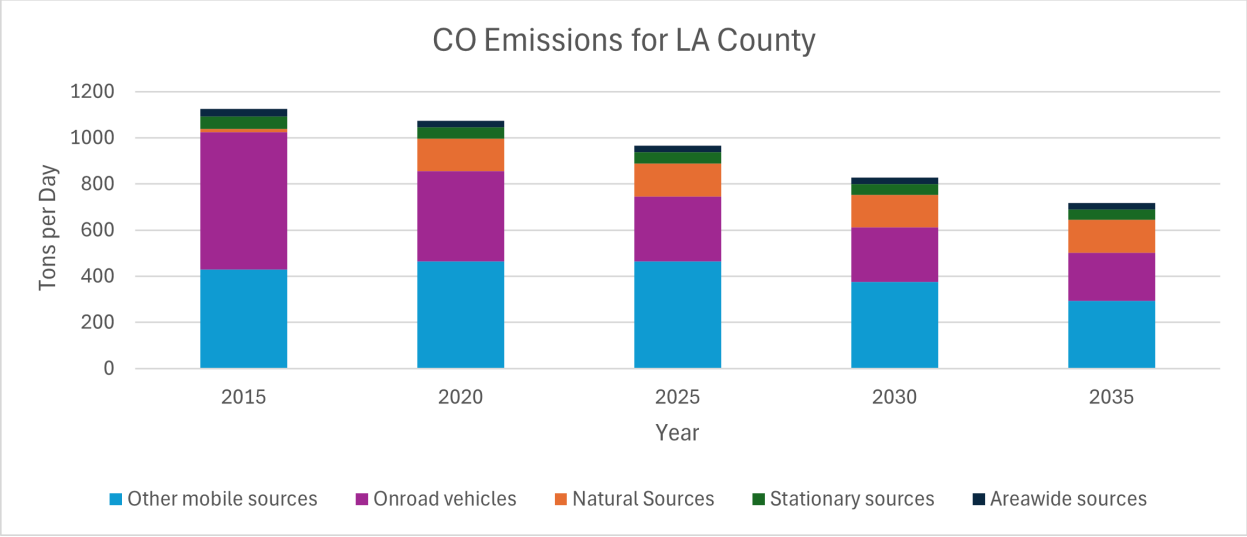

Figure 2: CEPAM estimates of CO emissions in LA County by source and year

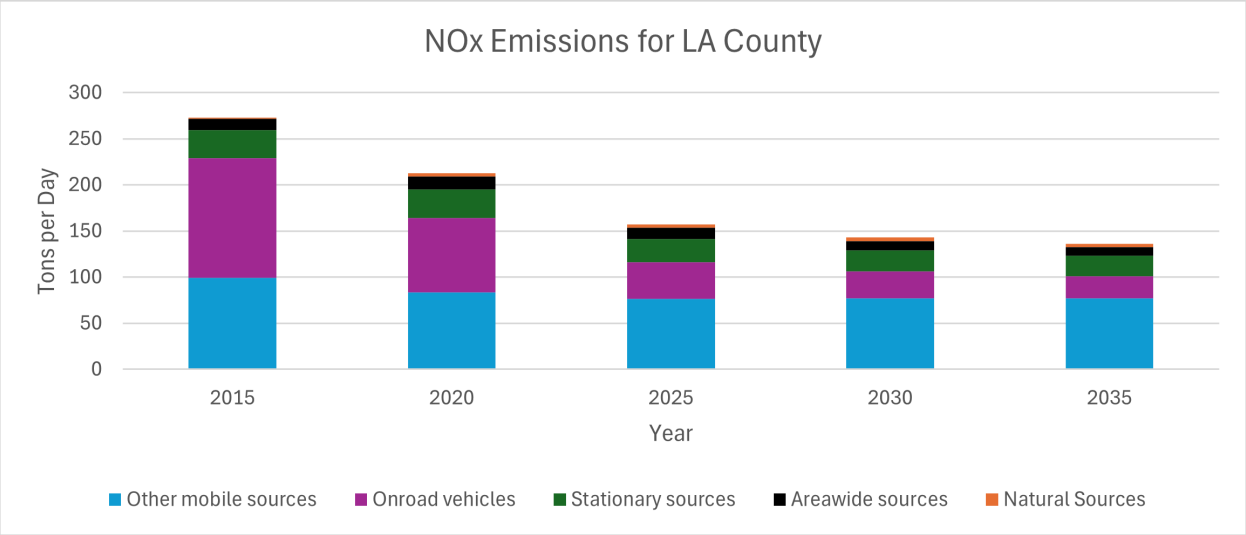

Figure 3: CEPAM estimates of NOx emissions in LA County by source and year

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

Figure 4 shows the LA County vehicle emissions increase factor F calculated by MOVES5 between the “no LEV” and “LEV” case. The simulations show the largest increase for CO, but it is not dramatic, only about 20%, and the other pollutant increases are even smaller. This was a bit surprising as I expected the California emissions standards to make a bigger difference.

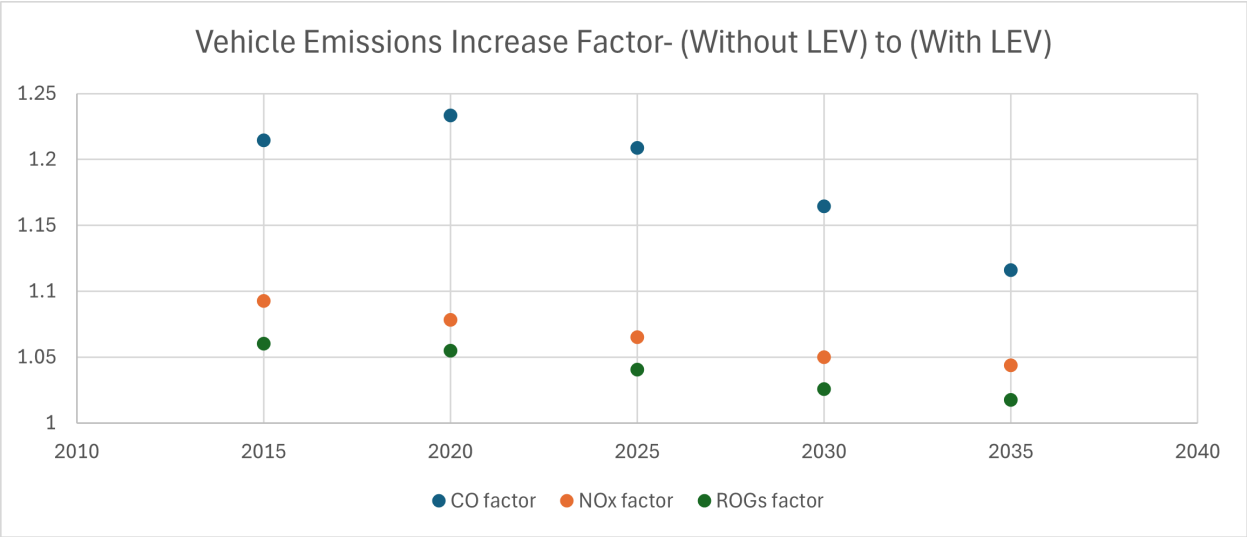

Figure 4: MOVES5 estimated ratio of LA County vehicle emissions - (without LEV standards) divided by (with LEV standards)

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

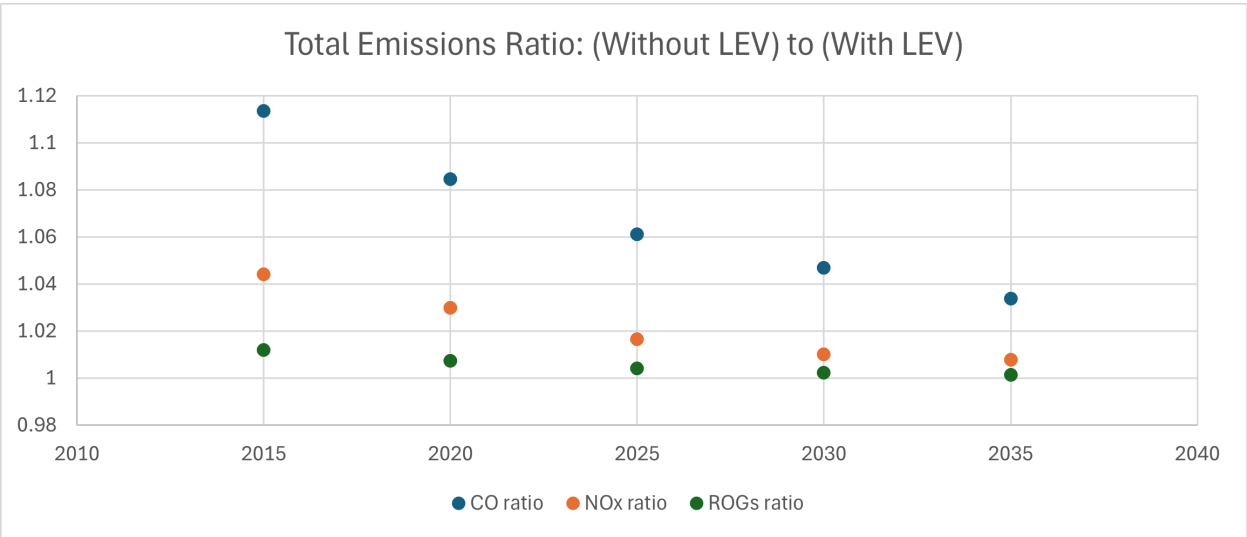

Figure 5: Estimated total emissions increase ratio in LA County from CEPAM and MOVES5 simulations

Discussion

My 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 around 20% at most. When these slight increase factors are applied to the baseline CEPAM data, the change becomes much 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 seems 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 a bit surprising. First, as can be seen in Figures 1-3, the majority of emissions in LA County come from other sources besides on 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 cause a dramatic change in the pollutant levels.

Further research into why MOVES5 did not show a larger difference between the “no LEV” and “LEV” cases revealed some interesting facts that may provide at least a partial explanation. According to the EPA, the current national Tier 3 standards are harmonized with (meaning the same as) 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 more closely align with California as time goes on. So in the end, there may not be that much difference between California and national EPA standards, as the MOVES5 results seem to indicate.

One issue I ran into is that the MOVES5 data and CEPAM data do not agree very well. The vehicle emissions levels indicated from MOVES5 for LA County are usually about double the size of the CEPAM on road source numbers. CEPAM uses a different vehicle emission simulation program also developed by CARB called EMmission FACtor (EMFAC) (*On-Road (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 (*(PDF) MOVES vs. EMFAC*, January, 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, I only used MOVES5 to estimate an increase factor due to the change from California to national EPA standards, and then applied this factor to the baseline CEPAM on road source data. This should help to minimize the effects of any discrepancy between the programs.

Conclusion

This paper investigated the air pollution problems in Los Angeles and the effect of the California vehicle emissions waivers on these issues. I found that although emissions would increase if these waivers were revoked, the increase would not be as significant as I expected.

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 the other sources. In particular, other mobile sources (planes, trains, farm equipment etc.) are now the dominant sources of CO and NOx, so further reductions in these levels will almost certainly require tighter regulation of these sources.

Because I confined my research to the changes in ozone precursors, rather than ozone itself, I was unable to make direct projections of ozone concentration. I would encourage other scholars to use chemical transport models such as CMAQ from the EPA to estimate the actual change in ozone levels. I would also suggest further research in other emission sources in LA, such as areawide sources. The components that make up these sources are sometimes less regulated and contribute a significant amount to ROG emissions.

In the end, the results of my research show that the California standards have been effective, and this plays a part in why my hypothesis was incorrect. I originally assumed that because of the regulation's effectiveness, revoking these waivers would have large effects on the air quality of

California. But it seems that these regulations have contributed to such a reduction in vehicle emissions that on road vehicles account for a much smaller piece of the total emissions. The California standards have now been adopted by the rest of the country, minimizing the effect of the waivers on air pollution even further. Therefore, the California vehicle emissions waivers have reduced vehicle emissions so much that revoking them would have a much smaller impact on air pollution than I expected.

Acknowledgements

I would like to thank [redacted by Managing Editor] for topic brainstorming, writing strategies, and helpful feedback.

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Review Report

Title: Revocation of California Vehicle Emissions Standards Has Minimal Impact on Los Angeles Air Quality

Final recommendation- Revise and resubmit (Major revisions)

Note:

- Author's original lines are highlighted in **red.**
- Reviewer comments are provided in **black**.

General: The findings of this study underscore the complex interplay between primary pollutants and secondary ozone formation, revealing notable temporal shifts in emission contributions across source categories. By integrating simulation outputs with empirical data, the analysis highlights the effectiveness of California's emission standards in curbing baseline pollutant levels. Authors are recommended to seriously follow the given suggestions which will constructively improve the overall readability of your paper.

Titles suggestions:

An academic/journal title needs to be concise, informative, and professional. It should act as a miniature summary of your work, giving the reader a clear idea of your topic.

- Assessing the Marginal Impact of Vehicle Emission Standards on Ozone Levels in the Los Angeles
- The Diminishing Returns of Stringent Vehicle Emission Policies on Urban Air Quality: A Case Study of Los Angeles.

Introduction:

1- Move the second paragraph of the introduction to the first position; the current first paragraph will become the second.

2- When providing references, please avoid including full work titles within the main text. Instead, list complete titles in the reference section at the end. If you're using APA format, kindly follow the appropriate in-text citation guidelines.

e.g. in paragraph 3: (*Pollution Standards Authorized by the California Waiver: A Crucial Tool for Fighting Air Pollution Now and in the Future | California Air Resources Board*, 2025).

(House, 2025; "In the United States District Court for the Northern District of California," June 2025).

Frequent in-text citations can interrupt the natural flow of reading.

3-In the last paragraph, you have mentioned "I investigated the...", you should be writing "The study investigated the..."

This shifts the focus from the researcher to the research itself, which is often preferred in academic and formal writing.

4- Strongly suggested to mention the clear objectives of the study as, the current study has following objectives…….

Methods:

1- The first thing to be considered, please don't write as

So, I decided to look specifically at ground-level ozone while;

As suggested for introduction, please use the correct way of grammatical subject of the sentence.

- **"I investigated the..."** — the subject is **"I"**, which is a **first-person pronoun**.
- **"The study investigated the..."** — the subject becomes **"The study"**, which is a **third-person noun phrase**.

Therefore, strongly suggested to replacing "I" or we with "The study," you should be using the **first-person subject**.

This shift is common in academic and formal writing to maintain objectivity and focus on the research rather than the researcher.

Please follow this throughout the paper even if I don't mention this now onwards.

2- It is recommended to remove this from the methodology section and instead include a brief paragraph in the introduction. This paragraph should clarify that your study focuses on ozone as a secondary pollutant and explain how you will address the role of primary air pollutants in relation to ozone formation.

This complicated my approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. I decided to focus on these three pollutants because they are the main precursors of ozone and are directly affected by the vehicle emissions standards. This is not a direct projection of ozone levels, however, and in order to take the next step from the precursors to the ozone levels, much more complex simulations are required. These take into consideration many other factors such as weather and topography.

Certainly, these are not methods. Once you explain the science, you can just begin with what methods you are using in this section.

3-Please don't write such things. If this is a limitation, mention this in a separate limitations section.
These tools are more complex than I can use, so I had to limit my investigation to the ozone precursors NOx, CO, and VOCs.

4-Provide the information about CEPAM and other tools in introduction, include a paragraph in the introduction that outlines the available tools and specifies the features of the tool used in the current study. Please remove it from the methodology section (whole paragraph-4).

CEPAM breaks down the various emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). Each of these five main categories is composed of many other subcategories. Some names of the main categories are not very indicative of what the subcategories are, so Table 1 is provided to give a better understanding of what the five main source type categories actually represent.

5- Please remove Table 1 from the main text. You may simply cite the original source. If deemed necessary, include the table as an annex.

6- I am giving you an example, how to write for a journal. Please follow for whole section:

With the data gathered from CEPAM and MOVES5, I used Excel to calculate the total change in emissions. First, I made separate sheets for all three pollutants. On each sheet, I created a table containing the year being examined and the tons of the pollutants per day being produced by the five source categories. I then created a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent the baseline pollutant levels with California emission standards in place.

Using data obtained from CEPAM and MOVES5, the study quantified the total change in emissions through spreadsheet-based analysis in Microsoft Excel. Separate worksheets were developed for each of the three pollutants under investigation. Each sheet included tabulated data detailing the year of assessment and the daily emission levels (in tons) attributed to five distinct source categories. To visualize temporal and categorical variations, stacked bar charts were generated for each pollutant, illustrating the relative contributions of each source category to overall emissions across the study period. These visualizations reflect baseline pollutant levels under the implementation of California emission standards.

7- It is recommended that the author revise the methodology section to clearly reflect how the study was conducted. While subheadings such as **study area, data collection, 'Pollutant Analysis,' 'Simulation,' and 'Data Interpretation'** are suggested for clarity, these are optional.

An important suggestion is to talk about the dataset. Which time period is represented and why? etc…

The focus should remain on outlining the methods used to carry out the research, the section needs more clarity.

Results

1- Please start the section by providing what Figures 1-3 indicate, move this paragraph before figures, and add some more insight into the figures/results.

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

2- Please remove titles from within the figures, as the figure title is also provided below. This is simply duplication.

Discussion and conclusion

1- This section looks appropriate; going in flow; the only thing is following my first suggestion under the methods section.
2- A good thing can be referring to some other studies/research which have similar or different findings.
3- This is again a limitation of study, which you should mention under limitation section

One issue I ran into is that the MOVES5 data and CEPAM data do not agree very well

4- Based on the science, it would be great if you conclude your study like this (just as an example):

Ozone (O_3) is a secondary pollutant formed through complex photochemical reactions involving primary pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs) in the presence of sunlight. In this study, NO_x and CO are analysed 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.

Lastly, please revise the entire study to remove first-person references such as 'I'. Reframe the content using third-person or passive constructions to maintain academic objectivity.

Reviewer Recommendation: Accept with minor revisions

Overall Impression:
This is a sophisticated and well-executed study for a high school scholar. The author tackles a highly relevant and complex policy question using advanced, professional-grade simulation tools (CEPAM and MOVES5). The methodological approach is logical, and well-explained, demonstrating a strong grasp of both the scientific and regulatory landscape. The most commendable aspect is the author's intellectual honesty; they present a hypothesis, test it rigorously, and then thoughtfully explain why the results did not support their initial prediction. This is a hallmark of excellent scientific practice. The paper is clearly structured, and the writing is professional. With minor revisions to enhance clarity and contextualize the findings, this manuscript will be a strong contribution to the journal.

Strengths:
Originality & Significance:
The research question is timely and politically significant. The approach of combining two different simulation models to isolate the effect of a specific policy change is innovative and demonstrates a high level of critical thinking.

Clarity & Structure:
The paper follows a standard scientific format effectively. The introduction sets a clear context, the methods are described in sufficient detail, and the results are presented logically. The discussion does an excellent job of interpreting the surprising findings.

Use of Evidence & Research Methods:
The methodology is the paper's greatest strength. The use of CEPAM and MOVES5 is appropriate, and the author correctly identifies and skillfully addresses the discrepancy between the two models by using MOVES5 to calculate a relative "increase factor" rather than an absolute value.

Engagement with Literature: The author effectively cites relevant EPA and CARB resources, scientific literature, and current legislative actions to frame the problem and support their analysis.

Areas for Improvement and Suggestions for Minor Revisions:

1. Refine the Abstract and Title for Accuracy:
The current title, "Revocation... Has Minimal Impact," states the conclusion as a definitive fact. However, the paper correctly notes that it only analyzes precursor pollutants, not ozone itself. To be perfectly accurate and align with the paper's own limitations, consider softening the title. For example: "Revocation of California Vehicle Emissions Standards: A Modeled Analysis of Precursor Pollutants in Los Angeles."

Similarly, the abstract could more explicitly state that the study models precursor pollutants (NOx, ROGs, CO) and infers, rather than directly models, the impact on ozone. This small change will strengthen the scientific precision of the claims.

2. Enhance Clarity in the Methods Section:
The mathematical formula for calculating the ratio `R` is correct but appears duplicated in the text. This should be cleaned up for a final version. While the method is sound, the explanation of why the formula `R = 1 + (V/T)(F - 1)` works could be slightly expanded for readers less comfortable with algebra. A brief sentence explaining that it calculates the new total by replacing the original vehicle emissions (`V`) with the increased emissions (`FV`) would be helpful.

3. Deepen the Discussion on Policy Implications:
The discussion brilliantly identifies the harmonization of state and federal standards as a key reason for the small effect. This is a critical insight. You could briefly expand on what this means for the ongoing political debate. Does it suggest that the fight over the waivers is now more symbolic than substantive, at least for current-model vehicles? This would connect the scientific finding more directly to the policy context introduced at the beginning.

4. Proofreading for Minor Language and Formatting:
There are a few very minor typographical errors (e.g., "MOVESS" is sometimes written as "MOVES5" in the references; the acronym VOC is introduced but then ROG is used consistently, which is fine, but the relationship could be clarified once more).

Conclusion:
This is a great paper that demonstrates remarkable research and analytical skills. The author has not only conducted a rigorous analysis but has also engaged in genuine scientific discovery by adapting their understanding in light of the evidence. The suggested revisions are minor and focus primarily on refining language, enhancing clarity, and sharpening the discussion. The core research is sound, significant, and well-presented.

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

Abstract

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 due to high levels of congestion and pollution. US Congress has 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 emissions sources besides vehicles would be beneficial to reducing ozone levels in Los Angeles.

Main Body

Introduction

Ground-level ozone is a gas and 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 in eliminating 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 of 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, and the largest contributing factor has been 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). So, 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. They created a set of 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, California was granted waivers that allowed the state to set its own more strict standards (California Air Resources Board, 2025b).

Since then, California has been a leader in implementing stricter regulations which 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). But recently, President Trump 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 which would either restrict or completely eliminate the EPA waiver program (Rep. Joyce, 2025; Rep. Nehls, 2025; Sen. Mullin, 2025).

The goal of the current study is to investigate the impact the vehicle emissions waivers have on air pollution in Los Angeles and estimate how the air quality would be affected if California's EPA waivers are revoked. This matters because over 10 million people live in Los Angeles County that would potentially be affected by the revocation of these waivers (US Census Bureau 2023). Los Angeles, which is already highly impacted by ozone pollution, will possibly suffer from the revocation of these waivers because car companies will be able to sell cars in California with less strict regulations. 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. So this study was focused on ground-level ozone while examining the 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 the 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 emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). CARB has stored 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 in the years 2015-2035 in 5-year intervals. ROG is the terminology used by CARB, while the EPA has changed their terminology from ROG to VOC, but 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. A method to estimate the increase in emissions if the California waivers are revoked is also needed, and this is where the MOVES5 simulator becomes useful. MOVES5 by default simulates vehicle emissions using the national EPA standards, but can also simulate data using California standards by including a special low-emission vehicle (LEV) database when running (*MOVES5 Technical Guidance, November 2024*). MOVES5 enables a model of vehicle of emissions data for LA County using both national EPA standards (no LEV) and California (LEV) standards.

Methods

The primary data sources used for this investigation are 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 with 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 performed with and without incorporation of 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 come up with 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 each of the three pollutants. On each sheet, a table was created containing the year being examined and the tons of the pollutants per day being produced by the five source categories. The results were then displayed using a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent 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 were 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 sources from CEPAM. 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 this new total emissions level is divided 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.

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 growing smaller over time. Secondly, on road vehicles (purple portion) currently account for less than half of the total emissions. This is especially apparent for ROGs. Both of these trends can be viewed as validating the overall success of the California vehicle emission standards, particularly in reducing the contribution from on road vehicles.

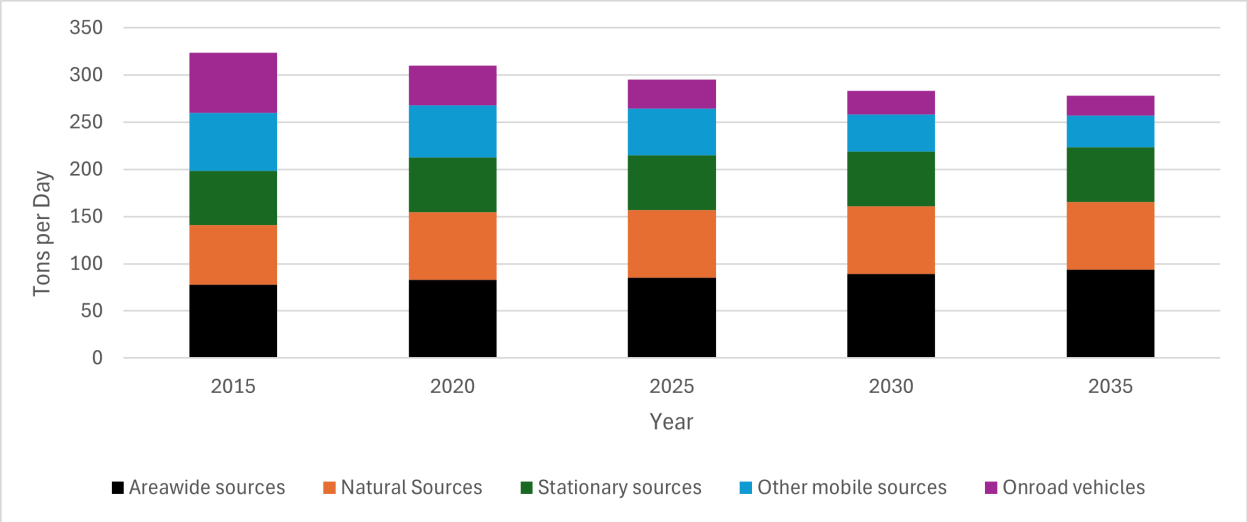

Figure 1: CEPAM estimates of ROG emissions in LA County by source and year

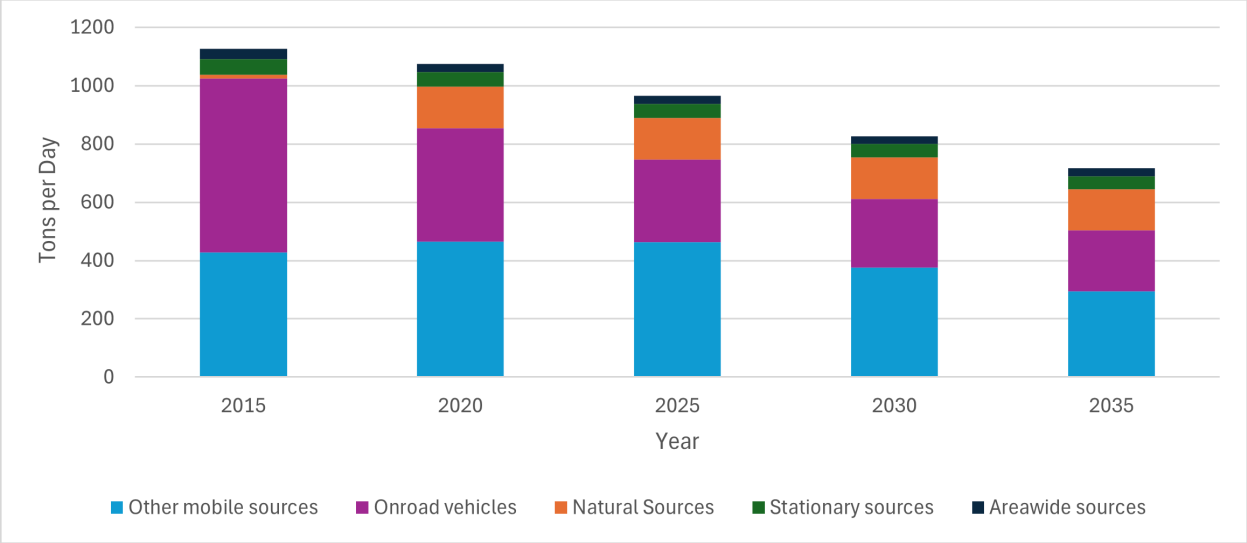

Figure 2: CEPAM estimates of CO emissions in LA County by source and year

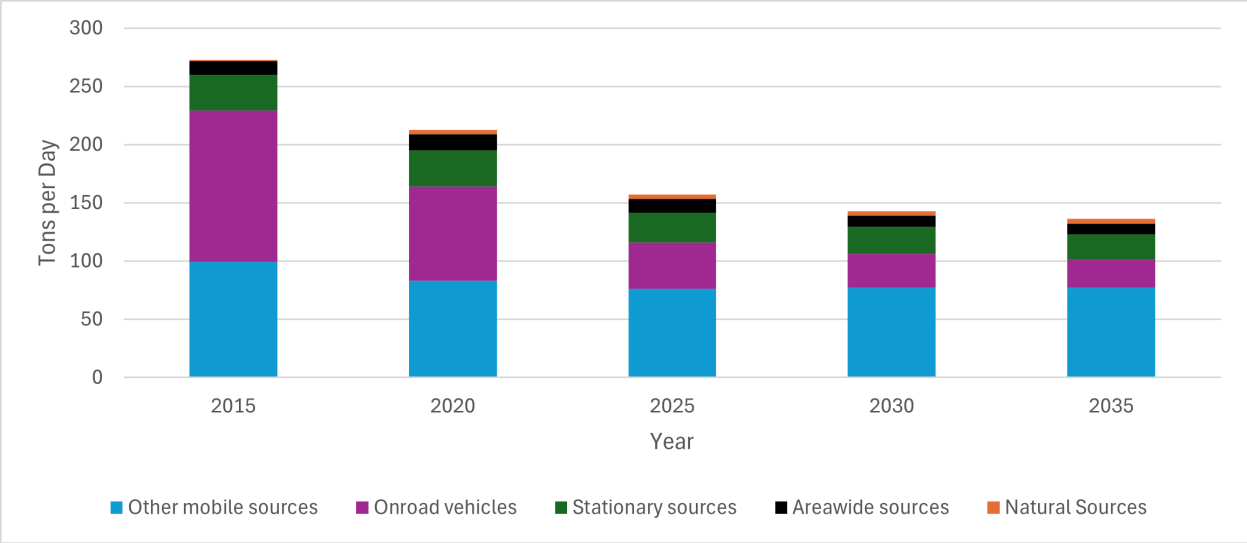

Figure 3: CEPAM estimates of NOx emissions in LA County by source and year

Figure 4 shows the LA County vehicle emissions increase factor F calculated by MOVES5 between the "no LEV" and "LEV" case. The simulations show the largest increase for CO, but it is not dramatic, only about 20%, and the other pollutant increases are even smaller. This seems somewhat surprising as the California emissions standards might reasonably be expected to make a bigger difference.

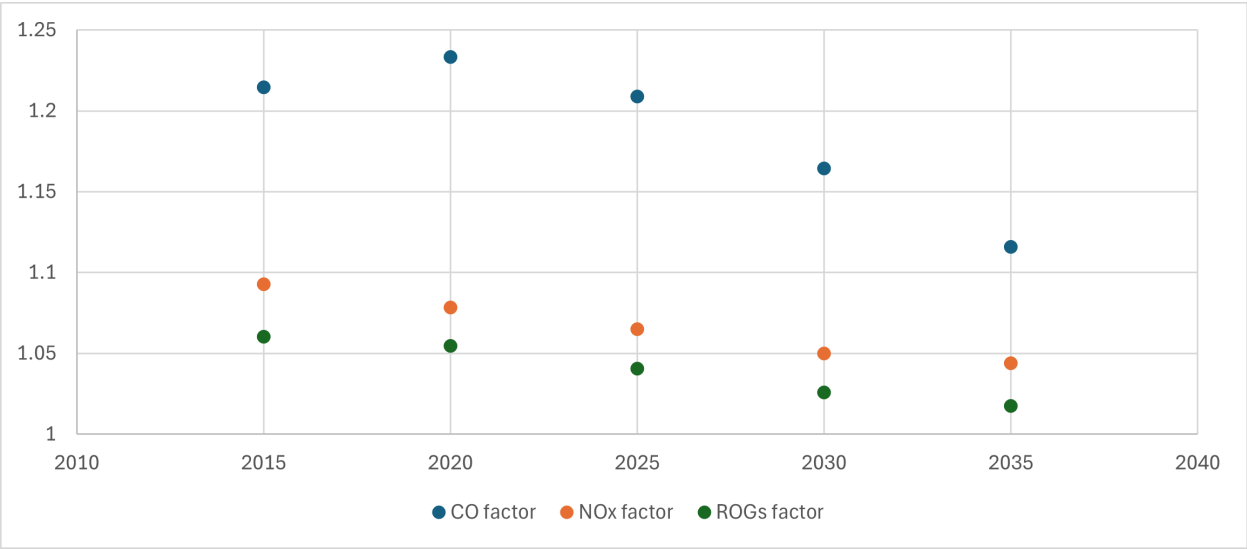

Figure 4: MOVES5 estimated ratio of LA County vehicle emissions - (without LEV standards) divided by (with LEV standards)

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

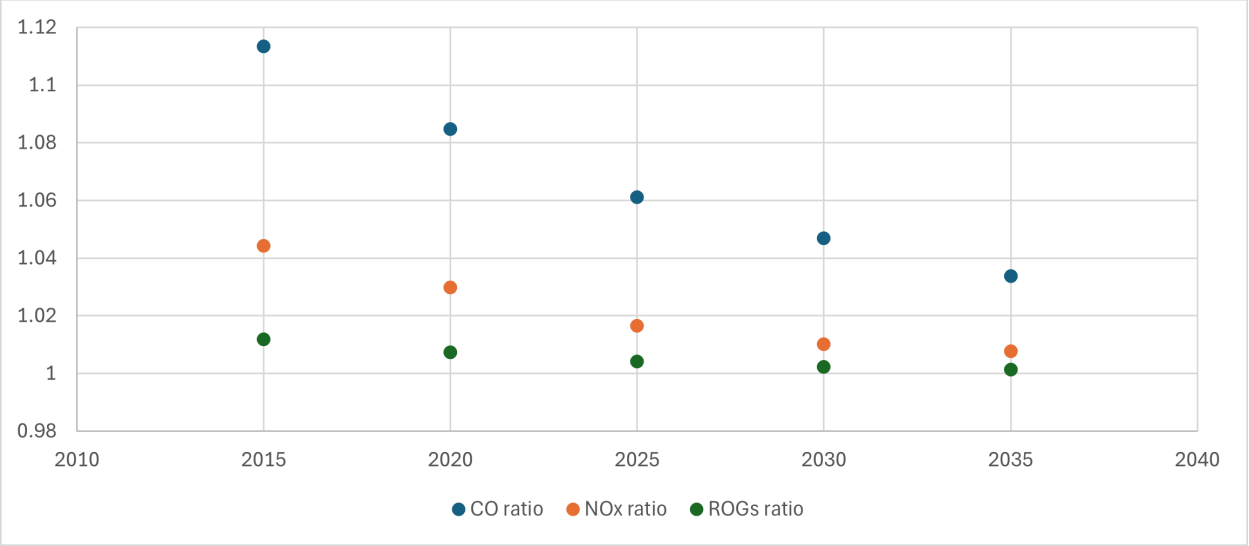

Figure 5: Estimated total emissions increase ratio in LA County from CEPAM and MOVES5 simulations

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 around 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 seems 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 a bit surprising. First, as can be seen in Figures 1-3, the majority of emissions in LA County come from other sources besides on 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 cause a dramatic change in the pollutant levels.

Further research into why MOVES5 did not show a larger difference between the “no LEV” and “LEV” cases revealed some interesting facts that may provide at least a partial explanation. According to the EPA, the current national Tier 3 standards are harmonized with (meaning the same as) 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 more closely align with California as time goes on. So in the end, there may not be that much difference between California and national EPA standards, as the MOVES5 results seem to indicate.

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. It is interesting that 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, 2025a). Yet CARB’s own simulations show that on road vehicles currently account for a minority of the ozone precursor inventory in LA, particularly for VOC’s and NOx. Given this, it would seem that the benefits of further electrification would be marginal. Figures 1-3 suggest that a more effective target for regulation might be the “other mobile sources” category, although it might be more difficult to control these sources.

One issue that might be a cause for concern in this study is that the MOVES5 data and CEPAM data do not agree very well. The vehicle emissions levels indicated from MOVES5 for LA County are usually about double the size of the CEPAM on road source numbers. CEPAM uses a different vehicle

emission simulation program also developed by CARB called EMmission 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 (*(PDF) MOVES vs. EMFAC*, January, 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 only the precursors to ozone are examined, 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 the current investigation.

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 are 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 focused 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 the other sources. In particular, other mobile sources (planes, trains, farm equipment etc.) are now the dominant sources of CO and NOx, so further reductions in these levels will almost certainly require tighter regulation of these sources.

Since this research was confined to the changes in ozone precursors, rather than ozone itself, it was 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.

In the end, the results of this study show that the California standards have been effective, and this plays a part in why projected effects of revoking the waivers would be small. One might reasonably anticipate the opposite- that because of the regulation's effectiveness, revoking these waivers would have large effects on the air quality of California. But it seems that these regulations have contributed to such a reduction in vehicle emissions that on road vehicles account for a much smaller piece of the total emissions. The California standards have now been adopted by the rest of the country, minimizing the effect of the waivers on air pollution even further. Therefore, the California vehicle emissions waivers have reduced vehicle emissions so much that revoking them would have a much smaller impact on air pollution than might be expected.

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The Diminishing Returns of Stringent Vehicle Emission Policies on Urban Air Quality: A Case Study of Los Angeles~~: Revocation of California Vehicle Emissions Standards Has Minimal Impact on Los Angeles Air Qualit The Diminishing Returns of Stringent Vehicle Emission Policies on Urban Air¶ Quality: A Case Study of Los Angeles. y~~

Abstract

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 due to high levels of congestion and pollution. US Congress has 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, ~~I investigated the~~this study investigates the potential effects of revoking the California emissions waivers on Los Angeles County air quality. ~~I used results~~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. M~~Much m~~ore complicated simulations would be needed to translate the vehicle emission levels ~~I calculated~~ to ozone levels directly, so further research may be needed to take this next step. Additionally, the~~my~~ results indicate that more research around other emissions ~~types of~~ sources besides vehicles would be beneficial to reducing ozone levels in Los Angeles.

Main Body

Introduction

~~182 counties in the United States are currently categorized by the US EPA as nonattainment areas for ozone pollution (EPA, 2025a).~~ Ground-level ozone is a gas and 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 in eliminating the pollutant. Both North America and Europe have seen improvements in ozone pollution within recent decades (Sicard et al., 2023).

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Los Angeles has struggled with air quality issues for many years, and the largest contributing factor has been 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). So, 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. They

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which will lead to higher concentrations of ozone. I predicted that if the EPA California emissions waivers are revoked, the air quality in Los Angeles would worsen dramatically.

As mentioned abovein the introduction, the primary issue regarding the air quality in Los Angeles is ozone. So, I decided to look specifically this study was focused onat ground-level ozone while examining the effects on air pollution. This complicatesd my the approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. I decided to focus on theseThese three pollutants are the focus of the study sincebecause they are the main precursors of ozone and are directly affected by the vehicle emissions standards. This is not a direct projection of ozone levels, however, and in order to take the next step from the precursors to the ozone levels, much more complex simulations are required. These take into consideration many other factors such as weather and topography. Such simulation programs exist, for instance the Community Multiscale Air Quality Modeling System (CMAQ) from the EPA (Environmental Protection Agency). These tools are more complex than I can use, so I had to limit my investigation to the ozone precursors NOx, CO, and VOCs.

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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. A method to estimate the increase in emissions if the California waivers are revoked is also needed, and this is where the MOVES5 simulator becomes useful. MOVES5 by default simulates vehicle emissions using the national EPA standards, but can also simulate data using California standards by including a special low-emission vehicle (LEV) database when running (*MOVES5 Technical Guidance, November 2024*). MOVES5 enables a model of vehicle of emissions data for LA County using both national EPA standards (no LEV) and California (LEV) standards.

CEPAM breaks down the various emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). Each of these five main categories is composed of many other subcategories. Some names of the main categories are not very indicative of what the subcategories are, so Table 1 is provided to give a better understanding of what the five main source type categories actually represent.¶

Table 1: Components of Source Categories for CEPAM2019 Projections

Source Type¶	**Sample Components**¶
Stationary¶	Fuel combustion, waste disposal, petroleum production, industrial¶
Areawide¶	Solvent evaporation, residential fuel, farming, construction, cooking¶
On Road¶	Motorcycle, cars, light duty truck, heavy diesel truck, buses, RV¶
Other Mobile¶	Planes, boats, trains, off road equipment, farm equipment¶
Natural¶	Biogenic, geogenic, wildfire¶

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¶

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Methods

The primary data sources used for this investigation are the two simulation tools mentioned above (CEPAM and MOVES5). Simulation results were projected over a +/- 10-year time span (2015-2035)~~015-2035)~~ to show how the pollutant levels would be expected to change with 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. ~~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. A method to estimate the increase in emissions if the California waivers are revoked is also needed, and this is where the MOVES5 simulator becomes useful. MOVES5 by default simulates vehicle emissions using the national EPA standards, but can also simulate data using California standards by including a special low-emission vehicle (LEV) database when running (*MOVES5 Technical Guidance, November 2024*). MOVES5 enables a model vehicle of emissions data for~~

~~LA County using both national EPA standards (no LEV) and California (LEV) standards.~~ To determine the changes in vehicle emissions should the California waiver be revoked, MOVES5 simulations were performed with and without incorporation of the LEV database.~~the LEV database incorporatedfor both LEV and NO LEV casesj.~~ 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 come up with a new total emissions projection.

~~5 data used for this investigation are~~ As mentioned in the introduction, the primary issue regarding the air quality in Los Angeles is ozone. So, I decided to look specifically at ground-level ozone while examining the effects on air pollution. This complicated my approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. I decided to focus on these three pollutants because they are the main precursors of ozone and are directly affected by the vehicle emissions standards. This is not a direct projection of ozone levels, however, and in order to take the next step from the precursors to the ozone levels, much more complex simulations are required. These take into consideration many other factors such as weather and topography. Such simulation programs exist, for instance the Community Multiscale Air Quality Modeling System (CMAQ) from the EPA (Environmental Protection Agency). These tools are more complex than I can use, so I had to limit my investigation to the ozone precursors NOx, CO, and VOCs.¶

To test my hypothesis, I needed to find 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. I achieved this using two simulation tools: the California Emission Projection Analysis Model (CEPAM), and the latest version of the EPA's Motor Vehicle Emission Simulator (MOVES5) (*CEPAM* / California Air Resources Board, 2025c; US EPA, 2016).¶

CEPAM is a tool created by CARB to model pollution processes in California. CARB has stored simulation results for different geographical areas, years, and pollutants to make a user accessible

database ((*Emissions for User Defined Query | California Air Resources Board*, 2025d). I chose to project emissions data for three different pollutants over a +/- 10-year time span in order to show how the pollutant levels change with time. I collected data for the amount of Reactive Organic Gases (ROGs), CO, and NOx produced in LA county in the years 2015-2035 in 5-year intervals. ROG is the terminology used by CARB, while the EPA has changed their terminology from ROG to VOC, but these terms are essentially synonymous (US EPA, 2014).¶

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standards (no LEV) and California (LEV) standards. In contrast to CEPAM, MOVES5 only deals with emissions from vehicle sources, so I had to incorporate the MOVES5 estimates into the CEPAM results to come up with a new total emissions projection.¶

With the data gathered from CEPAM and MOVES5, I used Excel toa Microsoftn Excel spreadsheet was created to calculatecalculate the total change in emissions. Separateeoparate First, I made separate sheets were created for alleach of the three pollutants. On each sheet, I created a tablea table was created containing the year being examined and the tons of the pollutants per day being produced by the five source categories. I then createdThe resultsse data were then representeddisplayed using a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent the baseline pollutant levels with California emission standards in place.

My nextThe next objective was to estimate the increase in vehicle emissions that would be expected without California standards. To do this, I dividedthe MOVES5 "no LEV" data were divided byby the "LEV" data to create a vehicle emissions increase factor, F. I did thisThis was replicated 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 me a new set of on road pollutant levels expected without California standards (no LEV).

TFinally, to find the impact on the total air pollutant levels, I needed to addthe increased vehicle pollutants were added to those from other sources from CEPAM. The bar graph I createdcharts mentioned earlier showed that on road vehicles only account for a portion of the total emissions. I calculated aA 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. I thenThis 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)

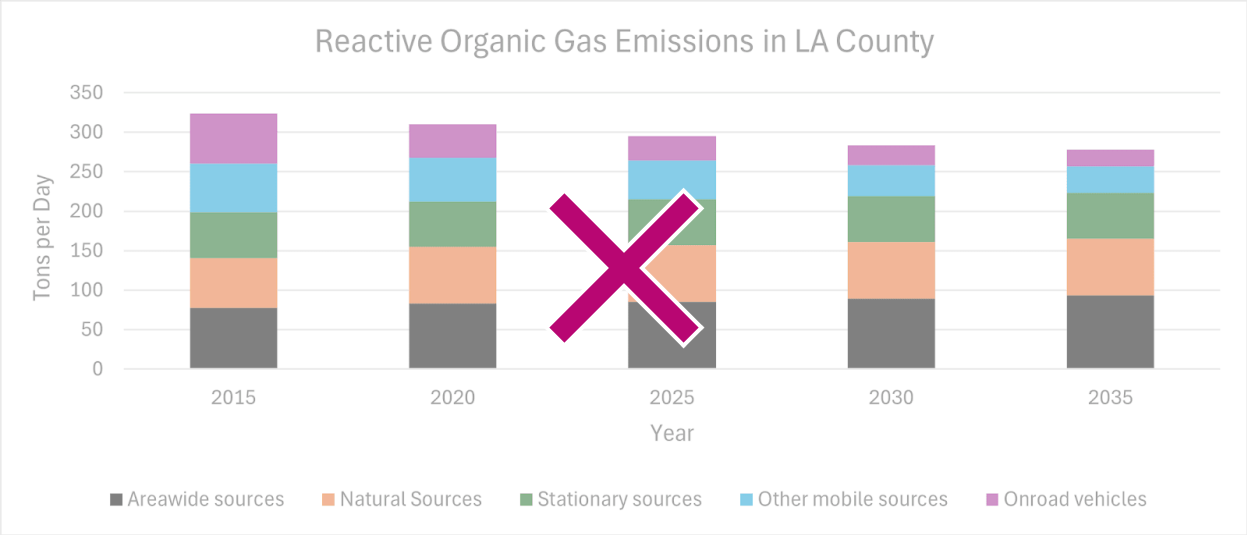
F = Increase factor of vehicle emissions from MOVES5

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 this new total emissions level is divided by the original level "T" to determine a ratio "R". Finally, ~~I made a graph~~a graph was produced to illustrate~~ing~~ the ~~changes~~ ratios of~~in~~ the total pollutant level ~~r~~for each pollutant and year.

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 growing smaller over time. Secondly, on road vehicles (purple portion) currently account for less than half of the total emissions. This is especially apparent for ROGs. Both of these trends can be viewed as validating the overall success of the California vehicle emission standards, particularly in reducing the contribution from on road vehicles.



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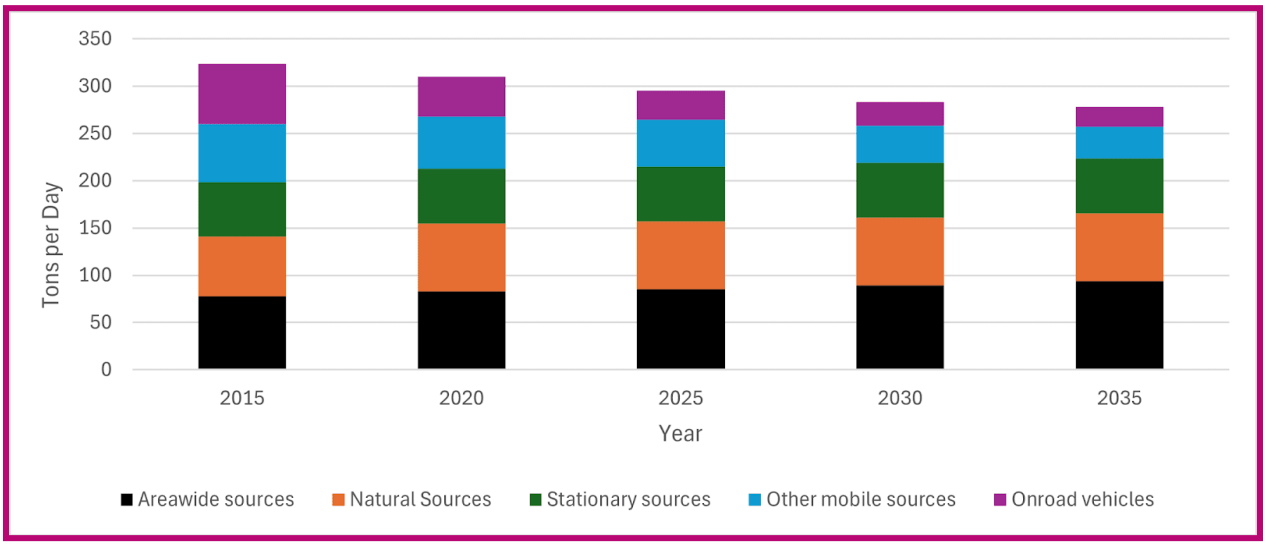

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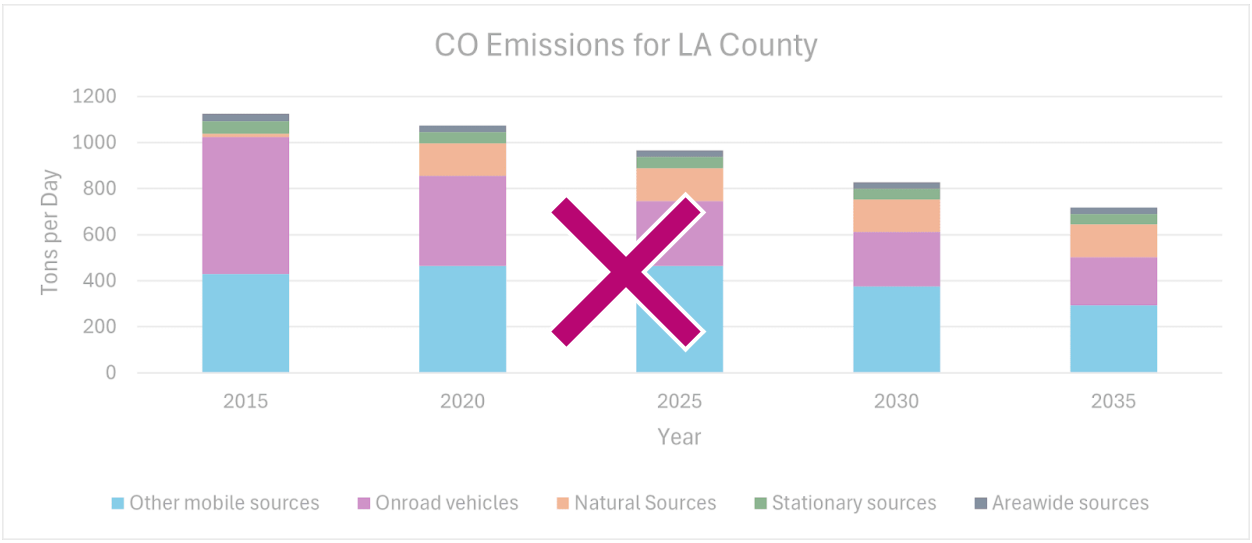
236 *Figure 1: CEPAM estimates of ROG emissions in LA County by source and year*



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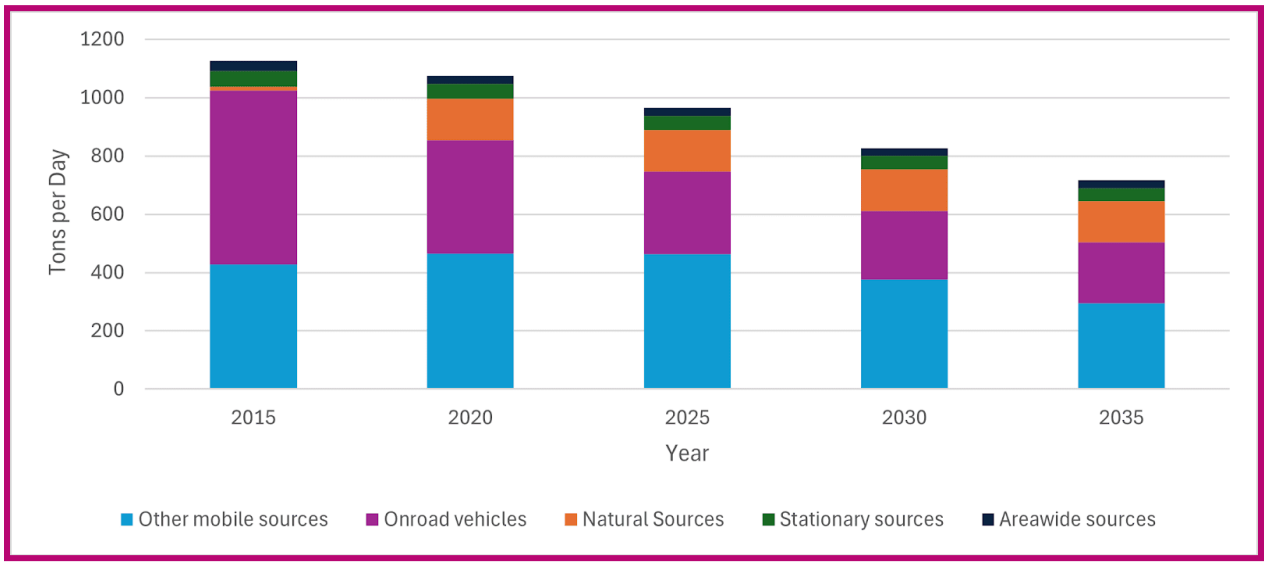

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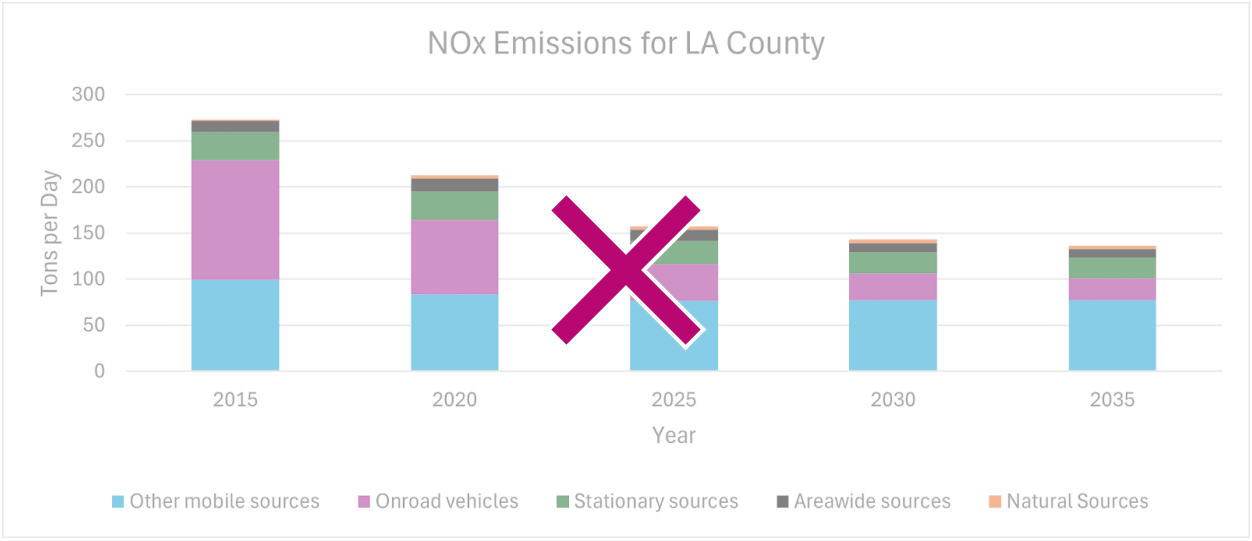
239 *Figure 2: CEPAM estimates of CO emissions in LA County by source and year*



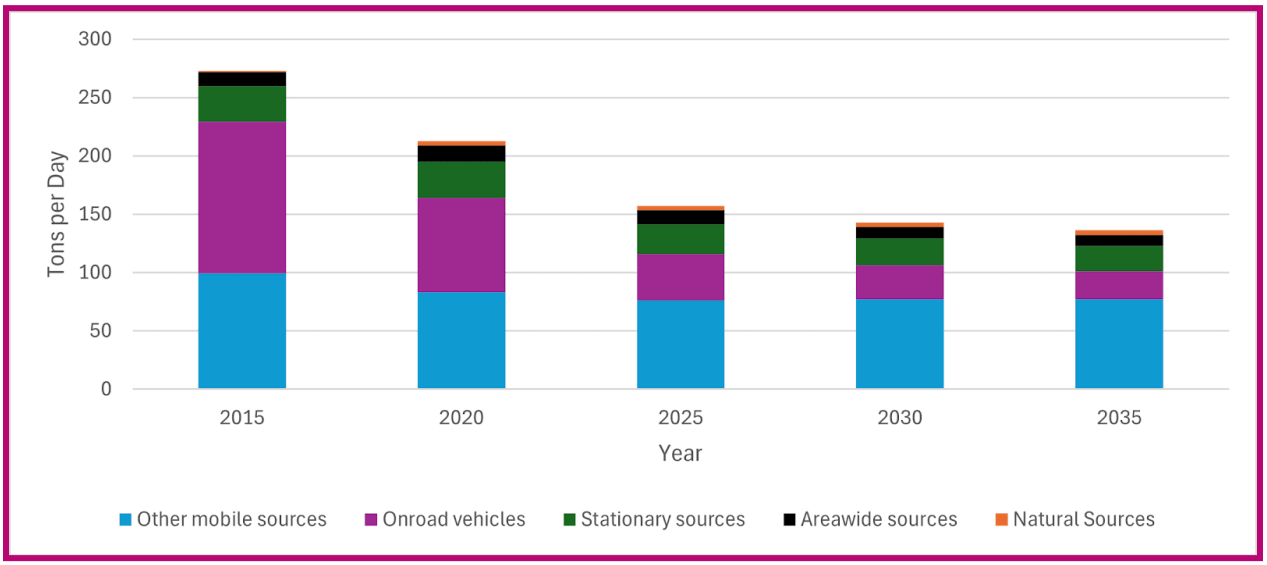
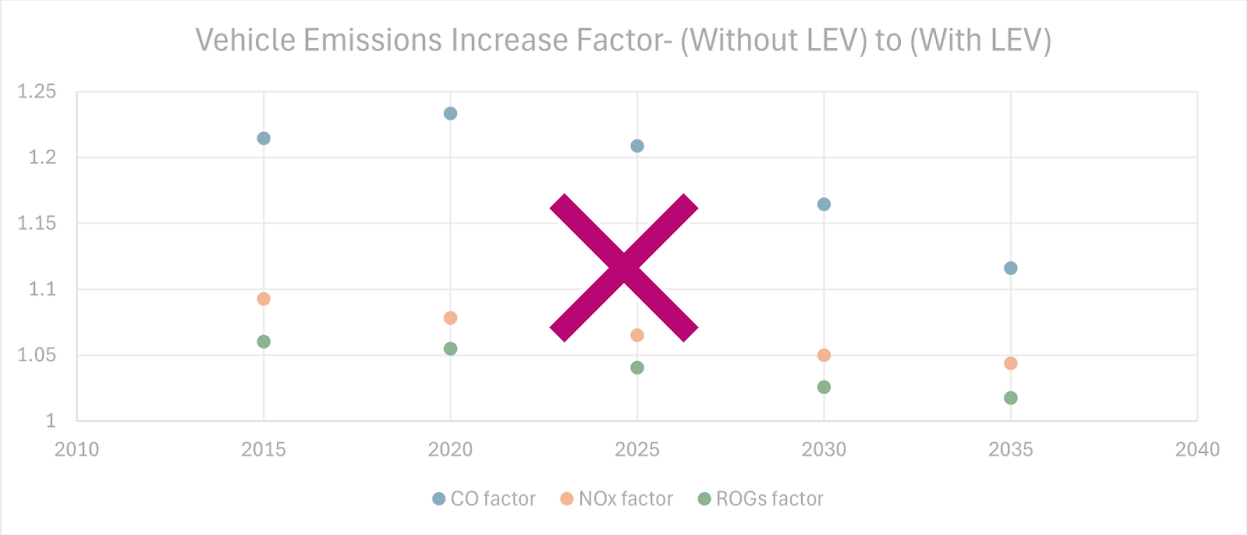


Figure 3: CEPAM estimates of NOx emissions in LA County by source and year

~~The bar graphs convey two important ideas. First, the emissions are growing smaller over time. Secondly, on-road vehicles (purple portion) currently account for less than half of the total emissions. This is especially apparent for ROGs. Both of these trends can be viewed as validating the overall success of the California vehicle emission standards, particularly in reducing the contribution from on-road vehicles.¶~~

Figure 4 shows the LA County vehicle emissions increase factor F calculated by MOVES5 between the "no LEV" and "LEV" case. The simulations show the largest increase for CO, but it is not dramatic,

only about 20%, and the other pollutant increases are even smaller. This ~~is~~was ~~a bit~~ seems somewhat surprising as ~~I expected~~ the California emissions standards might reasonably be expected to make a bigger difference.



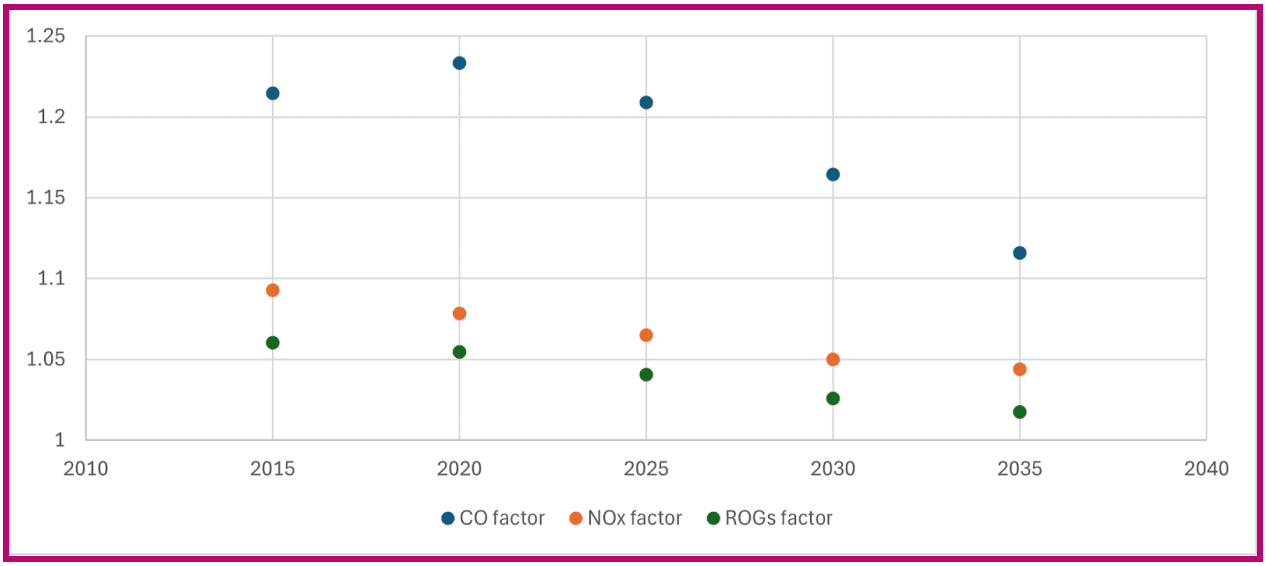
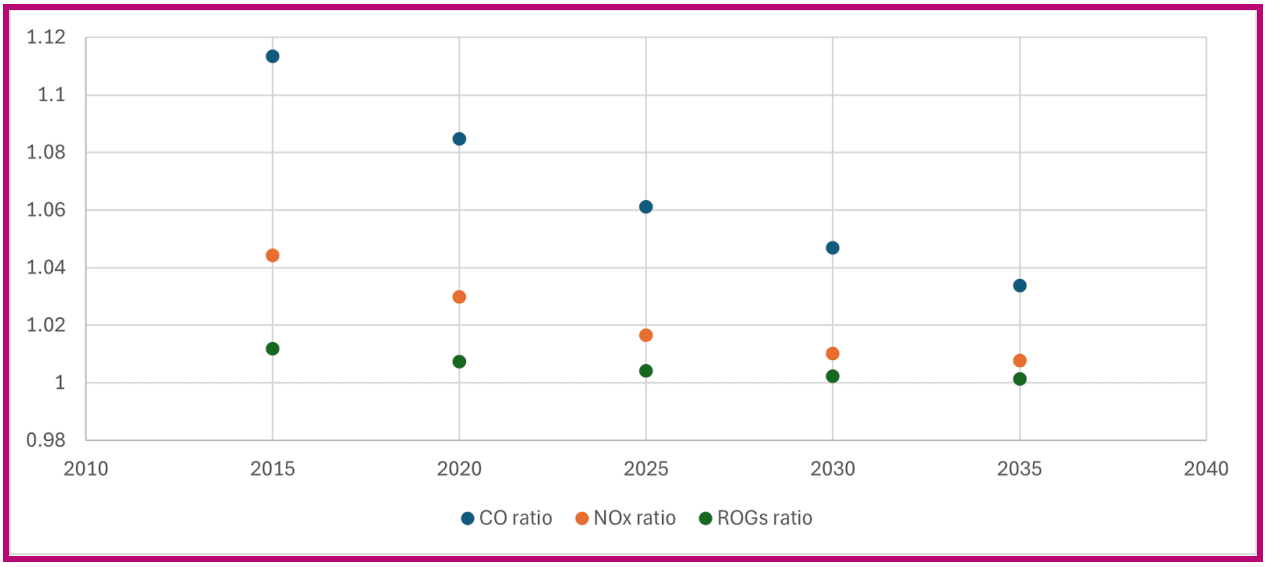


Figure 4: MOVES5 estimated ratio of LA County vehicle emissions - (without LEV standards) divided by (with LEV standards)

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



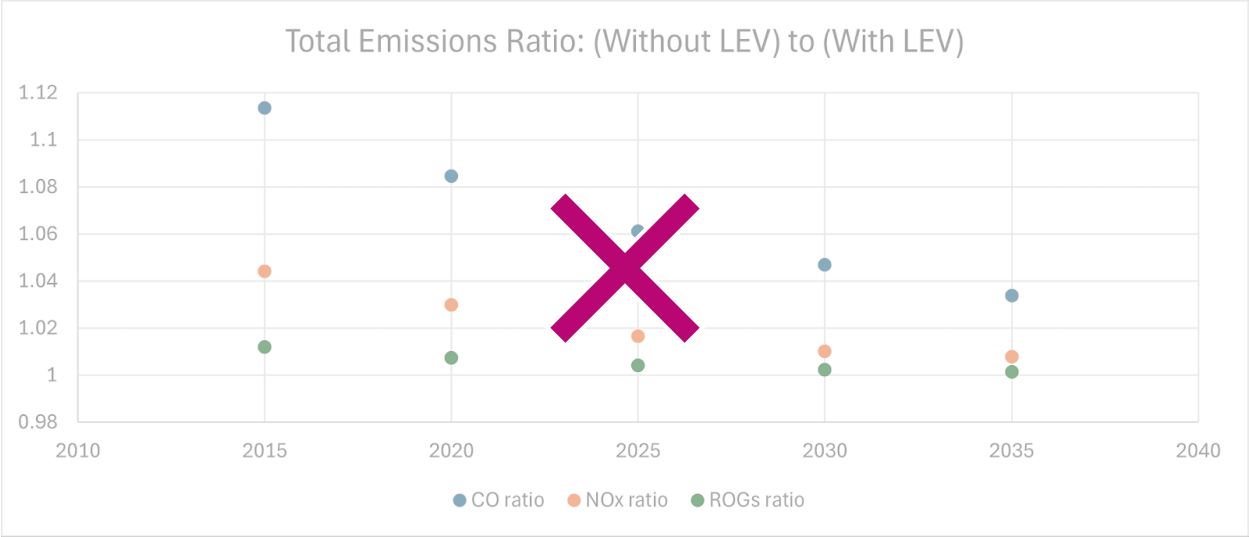


Figure 5: Estimated total emissions increase ratio in LA County from CEPAM and MOVES5 simulations

Discussion

~~My results~~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 around 20% at most. When these slight increase factors are applied to the baseline CEPAM data, the change becomes even~~much~~ 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 seems 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 a bit surprising. First, as can be seen in Figures 1-3, the majority of emissions in LA County come from other sources besides on 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 cause a dramatic change in the pollutant levels.

Further research into why MOVES5 did not show a larger difference between the "no LEV" and "LEV" cases revealed some interesting facts that may provide at least a partial explanation. According to the EPA, the current national Tier 3 standards are harmonized with (meaning the same as) 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 more closely align with California as time goes on. So in the end, there may not be that much difference between California and national EPA standards, as the MOVES5 results seem to indicate.

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 c~~This would require increasing percentages of new light duty vehicles to be zero-emissions until 2035,~~:~~ at which point ~~all~~ 100% of new sales would need to be ZEVs. It is interesting that CARB ~~supports the argument for~~justifies ~~the necessity of~~ this restriction based on LA air quality, stating in part that ~~aying~~ "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, 2025a). Yet CARB's own simulations show that on road vehicles currently account for a ~~small part~~minority of the ozone precursor ~~total~~ inventory in LA,

particularly for VOC's and NOx. Given this, ~~fact i~~it would seem that the benefits of further electrification would be marginal. Figures 1-3 suggest that a~~A~~ more effective ~~much better~~ target for regulation might be the "other mobile sources" category, although it ~~would most likely~~might be more difficult to control these sources.~~y e~~

One ~~issue I ran into is~~issue that might be a cause for concern in this study is~~is~~ that the MOVES5 data and CEPAM data do not agree very well. The vehicle emissions levels indicated from MOVES5 for LA County are usually about double the size of the CEPAM on road source numbers. CEPAM uses a different vehicle emission simulation program also developed by CARB called EMmission FACtor (EMFAC) (~~*On-Road (EMFAC) /*~~ California Air Resources Board, 2025~~d~~). MOVES5 and EMFAC are complex programs that sometimes use different approaches, and other researchers have also observed similar discrepancies between these tools (*(PDF) MOVES vs. EMFAC*, January, 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, ~~I only used~~ MOVES5 was only used to estimate an increase factor due to the change from California to national EPA standards, which was~~and~~ then applied ~~this factor~~ 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 only the precursors to ozone are examined, not ozone itself. Translating the precursor levels to actual ozone levels is a much more complicated process that requires~~while the~~ consideration of additional~~other~~ factors such as meteorological conditions and topography. These types of simulations are generally referred to as Chemical Transport Models~~s~~ 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 the current investigation.

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 are 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.¶

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~~spatial variationsand spatial variations, the research infers ozone concentration trends and highlights the interplay¶~~
~~betweeninterplay between emission sources and atmospheric chemistry under regulated conditions.¶~~
¶

This paper ~~investigated~~ focused on the air pollution problems in Los Angeles and the effect of the California vehicle emissions waivers on these issues. ~~I found~~The results show that although emissions

would increase if these waivers were revoked, the increase would probably not be veryas significant. as I expected. ¶

¶

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 the other sources. In particular, other mobile sources (planes, trains, farm equipment etc.) are now the dominant sources of CO and NOx, so further reductions in these levels will almost certainly require tighter regulation of these sources.

Because Since I confined mythis research was confined to the changes in ozone precursors, rather than ozone itself, I wasit was unable to make direct projections of ozone concentration. I would encourage other scholars toA potential extension of these results would use chemical transport models such as CMAQ from the EPA to estimate the actual change in ozone levels. I would alsoThe results of thise study also suggest that further research onin 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.

In the end, the results of this study my research show that the California standards have been effective, and this plays a part in why projected effects of revoking the waivers would be small. my hypothesis was incorrect. I originally assumedOne might reasonably expectanticipate the opposite- that because of the regulation's's effectiveness, revoking these waivers would have large effects on the air quality of California. But it seems that these regulations have contributed to such a reduction in vehicle emissions that on road vehicles account for a much smaller piece of the total emissions. The California standards have now been adopted by the rest of the country, minimizing the effect of the waivers on air pollution even further. Therefore, the California vehicle emissions waivers have reduced vehicle

emissions so much that revoking them would have a much smaller impact on air pollution than might be expected.

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Review Report

Title: Revocation of California Vehicle Emissions Standards Has Minimal Impact on Los Angeles Air Quality

Final recommendation- Revise and resubmit (Major revisions)

Note:

- Author's original lines are highlighted in **red.**
- Reviewer comments are provided in **black**.

Author responses below in blue

General: The findings of this study underscore the complex interplay between primary pollutants and secondary ozone formation, revealing notable temporal shifts in emission contributions across source categories. By integrating simulation outputs with empirical data, the analysis highlights the effectiveness of California's emission standards in curbing baseline pollutant levels. Authors are recommended to seriously follow the given suggestions which will constructively improve the overall readability of your paper.

Titles suggestions:

An academic/journal title needs to be concise, informative, and professional. It should act as a miniature summary of your work, giving the reader a clear idea of your topic.

- Assessing the Marginal Impact of Vehicle Emission Standards on Ozone Levels in the Los Angeles
- The Diminishing Returns of Stringent Vehicle Emission Policies on Urban Air Quality: A Case Study of Los Angeles.

The title has been changed to the second suggested option

Introduction:

1- Move the second paragraph of the introduction to the first position; the current first paragraph will become the second.

The first and second paragraphs have been reworded. The intent here was to make a progression from general to specific. This was perhaps not very well achieved in the original wording mainly due to the leading sentence referencing the US situation and then jumping back to a more global perspective. A complete swap of the first 2 paragraphs did not seem to accomplish that goal either though. I have moved the leading sentence to the second paragraph which hopefully makes the narrative follow a general-specific progression better.

2- When providing references, please avoid including full work titles within the main text. Instead, list complete titles in the reference section at the end. If you're using APA format, kindly follow the appropriate in-text citation guidelines.

e.g. in paragraph 3: (*Pollution Standards Authorized by the California Waiver: A Crucial Tool for Fighting Air Pollution Now and in the Future | California Air Resources Board*, 2025).

(House, 2025; "In the United States District Court for the Northern District of California," June 2025).

Frequent in-text citations can interrupt the natural flow of reading.

Agreed. I used Zotero for the references and I do not understand why it made some of the in-text citations so long. I don't know if it is a problem with Zotero or if I was somehow using it incorrectly. I have redone the references manually, hopefully they conform to the APA style better.

3-In the last paragraph, you have mentioned "I investigated the...", you should be writing "The study investigated the..."

This shifts the focus from the researcher to the research itself, which is often preferred in academic and formal writing.

Understood- all first-person references have been removed; this also applies to the other comments regarding this topic below

4- Strongly suggested to mention the clear objectives of the study as, the current study has following objectives…….

Methods:

1- The first thing to be considered, please don’t write as

So, I decided to look specifically at ground-level ozone while;

As suggested for introduction, please use the correct way of grammatical subject of the sentence.

- **"I investigated the..."** — the subject is **"I"**, which is a **first-person pronoun**.
- **"The study investigated the..."** — the subject becomes **"The study"**, which is a **third-person noun phrase**.

Therefore, strongly suggested to replacing "I" or we with "The study," you should be using the **first-person subject**.

This shift is common in academic and formal writing to maintain objectivity and focus on the research rather than the researcher.

Please follow this throughout the paper even if I don’t mention this now onwards.

2- It is recommended to remove this from the methodology section and instead include a brief paragraph in the introduction. This paragraph should clarify that your study focuses on ozone as a secondary pollutant and explain how you will address the role of primary air pollutants in relation to ozone formation.

This complicated my approach to measuring data because vehicles do not directly produce ozone. Instead, they emit other air pollutants such as NOx, VOCs, and CO. I decided to focus on these three pollutants because they are the main precursors of ozone and are directly affected by the vehicle emissions standards. This is not a direct projection of ozone levels, however, and in order to take the next step from the precursors to the ozone levels, much more complex simulations are required. These take into consideration many other factors such as weather and topography.

Certainly, these are not methods. Once you explain the science, you can just begin with what methods you are using in this section.

3-Please don't write such things. If this is a limitation, mention this in a separate limitations section.

These tools are more complex than I can use, so I had to limit my investigation to the ozone precursors NOx, CO, and VOCs.

The distinction between the primary pollutants and ozone, and associated limitations of the study, has been moved to the Discussion section

4-Provide the information about CEPAM and other tools in introduction, include a paragraph in the introduction that outlines the available tools and specifies the features of the tool used in the current study. Please remove it from the methodology section (whole paragraph-4).

CEPAM breaks down the various emissions sources in LA County into five main categories (Stationary, Areawide, On Road, Other Mobile, and Natural). Each of these five main categories is composed of many other subcategories. Some names of the main categories are not very indicative of what the subcategories are, so Table 1 is provided to give a better understanding of what the five main source type categories actually represent.

Most of the background discussion regarding the simulation tools has been moved from the Methods section to the Introduction

5- Please remove Table 1 from the main text. You may simply cite the original source. If deemed necessary, include the table as an annex.

Table 1 and associated discussion have been removed

6- I am giving you an example, how to write for a journal. Please follow for whole section:

With the data gathered from CEPAM and MOVES5, I used Excel to calculate the total change in emissions. First, I made separate sheets for all three pollutants. On each sheet, I created a table containing the year being examined and the tons of the pollutants per day being produced by the five source categories. I then created a stacked bar chart for each pollutant to illustrate how the amount of the sources in the total emissions compared to each other over time. These data represent the baseline pollutant levels with California emission standards in place.

Using data obtained from CEPAM and MOVES5, the study quantified the total change in emissions through spreadsheet-based analysis in Microsoft Excel. Separate worksheets were developed for each of the three pollutants under investigation. Each sheet included tabulated data detailing the year of assessment and the daily emission levels (in tons) attributed to five distinct source categories. To visualize temporal and categorical variations, stacked bar charts were generated for each pollutant, illustrating the relative contributions of each source category to overall emissions across the study period. These visualizations reflect baseline pollutant levels under the implementation of California emission standards.

7- It is recommended that the author revise the methodology section to clearly reflect how the study was conducted. While subheadings such as **study area, data collection, 'Pollutant Analysis,' 'Simulation,' and 'Data Interpretation'** are suggested for clarity, these are optional.

An important suggestion is to talk about the dataset. Which time period is represented and why? etc…

The focus should remain on outlining the methods used to carry out the research, the section needs more clarity.

Results

1- Please start the section by providing what Figures 1-3 indicate, move this paragraph before figures, and add some more insight into the figures/results.

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

This discussion has been moved to the beginning of the Results section

2- Please remove titles from within the figures, as the figure title is also provided below. This is simply duplication.

Figure titles have been removed

Discussion and conclusion

1- This section looks appropriate; going in flow; the only thing is following my first suggestion under the methods section.
2- A good thing can be referring to some other studies/research which have similar or different findings.
3- This is again a limitation of study, which you should mention under limitation section

One issue I ran into is that the MOVES5 data and CEPAM data do not agree very well

4- Based on the science, it would be great if you conclude your study like this (just as an example):

Ozone (O_3) is a secondary pollutant formed through complex photochemical reactions involving primary pollutants such as nitrogen oxides (NO_x), carbon monoxide (CO), and volatile organic compounds (VOCs) in the presence of sunlight. In this study, NO_x and CO are analysed 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 paragraph has mostly been adopted as the opening paragraph of the Conclusion

Lastly, please revise the entire study to remove first-person references such as 'I'. Reframe the content using third-person or passive constructions to maintain academic objectivity.

All first-person references have been removed

Reviewer Recommendation: Accept with minor revisions

Author responses in blue

Overall Impression:

This is a sophisticated and well-executed study for a high school scholar. The author tackles a

highly relevant and complex policy question using advanced, professional-grade simulation tools

(CEPAM and MOVES5). The methodological approach is logical, and well-explained,

demonstrating a strong grasp of both the scientific and regulatory landscape. The most

commendable aspect is the author's intellectual honesty; they present a hypothesis, test it

rigorously, and then thoughtfully explain why the results did not support their initial prediction.

This is a hallmark of excellent scientific practice. The paper is clearly structured, and the writing

is professional. With minor revisions to enhance clarity and contextualize the findings, this

manuscript will be a strong contribution to the journal.

Strengths:

Originality & Significance:

The research question is timely and politically significant. The approach of combining two

different simulation models to isolate the effect of a specific policy change is innovative and

demonstrates a high level of critical thinking.

Clarity & Structure:

The paper follows a standard scientific format effectively. The introduction sets a clear context,

the methods are described in sufficient detail, and the results are presented logically. The

discussion does an excellent job of interpreting the surprising findings.

Use of Evidence & Research Methods:

The methodology is the paper's greatest strength. The use of CEPAM and MOVES5 is

appropriate, and the author correctly identifies and skillfully addresses the discrepancy

between the two models by using MOVES5 to calculate a relative "increase factor" rather than

an absolute value.

Engagement with Literature: The author effectively cites relevant EPA and CARB resources,

scientific literature, and current legislative actions to frame the problem and support their

analysis.

Areas for Improvement and Suggestions for Minor Revisions:

1. Refine the Abstract and Title for Accuracy:

The current title, "Revocation... Has Minimal Impact," states the conclusion as a definitive fact.

However, the paper correctly notes that it only analyzes precursor pollutants, not ozone itself.

To be perfectly accurate and align with the paper's own limitations, consider softening the title.

For example: "Revocation of California Vehicle Emissions Standards: A Modeled Analysis of

Precursor Pollutants in Los Angeles."

Similarly, the abstract could more explicitly state that the study models precursor pollutants

(NOx, ROGs, CO) and infers, rather than directly models, the impact on ozone. This small change

will strengthen the scientific precision of the claims.

The title has been changed to one of Reviewer 1's suggestions which has a less definitive tone and the need for further study to directly model ozone levels is stated in the Abstract

2. Enhance Clarity in the Methods Section:

The mathematical formula for calculating the ratio `R` is correct but appears duplicated in the

text. This should be cleaned up for a final version. While the method is sound, the explanation

of why the formula `R = 1 + (V/T)(F - 1)` works could be slightly expanded for readers less

comfortable with algebra. A brief sentence explaining that it calculates the new total by

replacing the original vehicle emissions (`V`) with the increased emissions (`FV`) would be

helpful.

A sentence describing the reasoning for the equation for R has been added.

3. Deepen the Discussion on Policy Implications:

The discussion brilliantly identifies the harmonization of state and federal standards as a key

reason for the small effect. This is a critical insight. You could briefly expand on what this means

for the ongoing political debate. Does it suggest that the fight over the waivers is now more

symbolic than substantive, at least for current-model vehicles? This would connect the scientific

finding more directly to the policy context introduced at the beginning.

I added a paragraph describing the most controversial of the 3 waivers which are being revoked (ZEV mandate), as well as discussion of how the results of this study make CARB ‘s justification seem somewhat debatable

4. Proofreading for Minor Language and Formatting:

There are a few very minor typographical errors (e.g., "MOVESS" is sometimes written as

"MOVES5" in the references; the acronym VOC is introduced but then ROG is used consistently,

which is fine, but the relationship could be clarified once more).

MOVES5 is the correct name, referring the most recent released version of the MOVES program series

Conclusion:

This is a great paper that demonstrates remarkable research and analytical skills. The author has

not only conducted a rigorous analysis but has also engaged in genuine scientific discovery by

adapting their understanding in light of the evidence. The suggested revisions are minor and

focus primarily on refining language, enhancing clarity, and sharpening the discussion. The core

research is sound, significant, and well-presented.

Recommendation: Accepted for Publication (only one suggestion)

The author has diligently addressed all suggested revisions, resulting in a significantly improved manuscript.

The abstract now reads with excellent clarity and flow, effectively summarizing the study's objectives, methodology, and key findings. It sets a strong tone for the rest of the paper.

The introduction transitions smoothly from general context to specific research focus. The author's efforts in restructuring this section are commendable, as the revised version presents a more rigorous and academically sound foundation. The inclusion of relevant tools and software provides a robust framework for introducing the broader topic, enhancing the paper's accessibility and relevance.

The methodology section is well-articulated and logically sequenced now. It offers a comprehensive account of the procedures followed, making it easy for other researchers to replicate the study. The clarity and detail in this section reflect a strong command of the research process.

The results section now demonstrates a high level of analytical skill. After following the suggestions, the data presentation has improved, and the interpretation is both insightful and well-supported. This strengthens the overall impact of the research.

The discussion has undergone substantial improvement. With the new changes, it now offers a thoughtful and critical engagement with the findings, situating them effectively within the broader literature. The author's ability to draw meaningful conclusions and suggest future directions adds considerable value to the paper.

Finally, the references have been revised to align with academic standards, especially in text citations, enhancing the credibility and professionalism of the work.

Conclusion: the only modification, I would suggest to author to reconsider the conclusion, ideally a conclusion of the study covers your key findings and highlight their significance, while also suggesting potential implications or directions for future research. In current form, please reduce the wordcount of the section, and try to focus on key findings and future research.

Overall, the manuscript reflects a high standard of scholarship and is well-suited for publication in its current form. I appreciate the author's responsiveness to feedback and the quality of revisions made.

Overall

This revised manuscript is a truly impressive piece of scholarly work. You have addressed the reviewer's comments and strengthened an already strong paper.

Areas for improvement:

1. Consider adding a single sentence to the Results or Discussion section briefly specifying what this category entails. This grounds your conclusion.
2. You could add one final, forward-looking sentence to the paragraph of ZEV mandate to tie it all together. For instance, you might speculate: "*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.*" This subtly connects your findings to the broader climate context and reinforces your main argument about the shifting sources of pollution.
3. Your new paragraph critiquing CARB's justification for the ZEV mandate is effective. However, some might argue that you are comparing apples and oranges: your study looks at mass emissions (tons/day), while ozone formation is a non-linear chemical process dependent on the ratio of VOCs to NOx. The benefit of ZEVs is that they eliminate ALL tailpipe emissions, potentially disrupting the ozone-forming chemical regime in a way that simply reducing mass from other sources might not. Consider adding a single sentence to your ZEV mandate paragraph to acknowledge this complexity and propose a new direction of research to potentially mitigate this limitation of your method.
4. The reference for "California Air Resources Board. (2025e)" currently lacks a title; adding a brief descriptive title (e.g., "EMFAC On-Road Mobile Source Emissions") would complete the citation and enhance its professionalism (unless the CAR document requires you to cite this way)

The revisions you have already made have strengthened the manuscript. The suggestions above are minor points for consideration as you put the final touches on a paper. It has been a pleasure to see the evolution of this work.