Inequitable Air Pollution Exposure in California: How Electric Vehicles Can Help

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Summary

Cars, trucks, and buses contribute to fine particulate matter (PM$_{2.5}$) air pollution in California, and exposure to this pollution is inequitable. On average, African American and Latino Californians are exposed to PM$_{2.5}$ pollution 19 and 17 percent higher, respectively, than the state average while white Californians are exposed to 17 percent lower concentrations. There are also disparities in exposure linked to income: the lowest-income households in the state live where exposure to PM$_{2.5}$ pollution is 26 percent higher than the households with the highest incomes. Therefore, there are clear inequities in vehicle pollution exposure in California.

Electrification of vehicles is a promising strategy for reducing air pollution as total PM$_{2.5}$ pollution exposure from on-road vehicles in California is over 60-fold higher than that the exposure in the state from electricity generating facilities. A simulation analyzing the effect of replacing gasoline-powered light-duty vehicles with electric vehicles shows the potential for reducing both overall exposure and inequities in exposure. A hypothetical replacement of 10 percent of gasoline light duty vehicles with battery electric vehicles (EVs) would show a net benefit for PM$_{2.5}$ pollution exposure for every county in California and reductions would be on average highest for African Americans and Latinos in the state.

Keywords: air pollution, environment, modeling, particulate matter, environmental justice

1 Introduction

Transportation constitutes a significant source of both global warming emissions and air pollution in California. This analysis quantifies the formation of fine particulate matter air pollution from on-road vehicles and identifies the locations and populations most exposed to this pollution. The analysis measures the annual average exposure to fine particulate matter using a 2014 estimate of emissions as input data [1]. Research links exposure to particulate matter smaller than 2.5 micrometers (PM$_{2.5}$) in diameter—20 times smaller than even fine human hair—to increased illness and death, primarily from heart and lung diseases [2]. The use of buses, cars, and trucks in California both directly produces PM$_{2.5}$ and also produces gases that lead to the formation of additional PM$_{2.5}$ via atmospheric reactions. Modeling the exposure to PM$_{2.5}$ from transportation is important to understand the impacts of current vehicles and identify opportunities to reduce exposure by switching from combustion-powered to electric-drive vehicles.

2   Methods

To assess chronic exposure to particulate air pollution in California, a model of pollutant generation and transport (InMAP) was used [3]. InMAP estimates both the transport of primary $PM_{2.5}$ emissions and the formation of secondary $PM_{2.5}$ through atmospheric reactions. Tailpipe and refueling emissions from on-road vehicles were adapted from the US Environmental Protection Agency (EPA) National Emissions Inventory NEI) [1].

The resulting $PM_{2.5}$ concentrations were mapped to census block groups using area-weighted interpolation and combined with data from the 2012–2016 American Community Survey to determine $PM_{2.5}$ exposure by demographic group [4]. We used the population-weighted annual average concentration as the primary metric of exposure to $PM_{2.5}$.

The effect of electrification of 10 percent of light duty gasoline vehicles was simulated by reducing the combustion and refueling emissions in the NEI by 10 percent, while leaving non-combustion $PM_{2.5}$ emissions (brake and tire wear) unchanged. The ratio of combustion to total $PM_{2.5}$ emissions was estimated using the California Air Resources Board's EMFAC2017 database for the on-road fleet emissions factors for light duty gasoline vehicles in calendar year 2014 [5]. Additional electricity generation to fuel electric vehicles was estimated by assuming an average EV efficiency of 0.317 kWh/mi (derived from a sales-weighted average of efficiency data for EVs sold through September 2019) and average annual vehicle miles traveled of 11,400 miles per year to calculate an estimate of the aggregate electricity demand for a 10 percent EV fleet. The emissions increase for the increase in electricity demand was estimated by using the NEI and the Emissions & Generation Resource Integrated Database (eGRID) data for total electricity generation for calendar year 2014 [6]. The increased demand for electricity was assumed to increase all electricity emissions sources equally, increasing emissions by a factor of 2.1 percent. This assumption does not reflect constraints on generation facilities or the addition of new capacity to serve future increased demand from EVs, but allows for an allocation of electricity emissions based on the current location and rates of pollution emissions.

3   Results

3.1 Exposure to $PM_{2.5}$ from current on-road transportation sources is unequal and inequitable

This analysis finds that many persons of color are exposed to higher than average levels of particulate matter air pollution from buses, cars, and trucks in California. On average, African American and Latino Californians are exposed to $PM_{2.5}$ pollution 19 and 17 percent higher, respectively, than the state average while white Californians are exposed to 17 percent lower concentrations. (Figure 1).
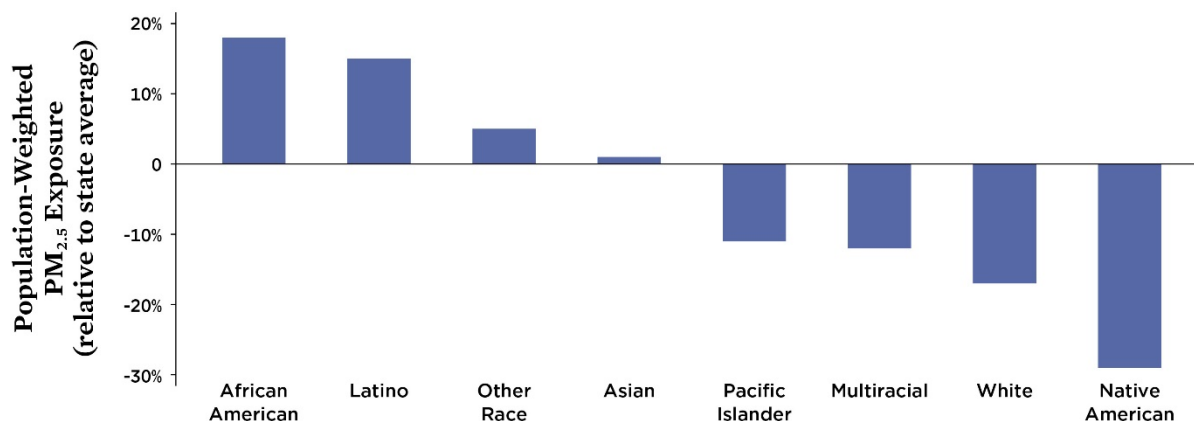
Figure 1: African American and Latino Californians have 19 and 15 percent higher exposure to PM$_{2.5}$ from on road transportation, respectively, than the state average, while white Californians are exposed to 17 percent lower concentrations.

Exposure to PM$_{2.5}$ from cars, trucks, and buses is not equally or equitably distributed across the state. People living in Los Angeles County are exposed to 50 percent more vehicle pollution than the state average and 250 percent more than the San Francisco Bay Area. There are also disparities in exposure linked to income: the lowest-income households in the state live where exposure to PM$_{2.5}$ pollution is 26 percent higher than the households with the highest incomes.

3.2 Electrification of vehicles could reduce pollution exposure and inequities in exposure

The estimated exposure to PM$_{2.5}$ from electricity generating units currently in California is approximately 60-fold lower than the exposure from on-road vehicles. Therefore, electrification of vehicles in California is a promising solution for reducing air pollution exposure, even if combustion-based electricity generation provides electricity for vehicle recharging.

To illustrate the potential benefits of vehicle electrification, the change in PM$_{2.5}$ pollution exposure resulting from replacing 10 percent of light duty gasoline vehicles with battery EVs was estimated. The reduction in emissions for gasoline combustion and refueling emissions from displaced gasoline vehicles was estimated and compared to the potential increase in emissions from electricity generation. For all counties in the state, replacing combustion vehicles with battery EVs would result in a net reduction in PM$_{2.5}$ exposure, with Los Angeles, Orange, and San Diego counties showing the largest benefit (Figure 2). The benefits could also help to address the inequity in PM$_{2.5}$ pollution exposure. On average, African Americans would experience reductions in exposure 16 percent higher than the state average and Latinos would be see reductions 14 percent greater than the average Californian.

This analysis investigates a hypothetical 10 percent reduction in gasoline vehicle combustion emissions, applied uniformly to current emission locations across the state. However, actual deployment of EVs may not provide uniform reductions in emissions as sales and use of EVs may be concentrated in certain demographic groups or geographic areas, and therefore benefits could differ from the scenario presented here. Future analysis should consider scenarios of EV deployment that reflect current trends in sales and also policies that encourage sales and use of EVs in areas that are currently burdened with high levels of air

pollution exposure. In addition, electricity grid responses to EV demand will likely not uniformly impact existing electricity generating sources [7]. And looking forward, increased EV deployment could help support continued growth in renewable energy deployment, further reducing grid emissions associated with EV charging. Exploring more detailed electricity generation scenarios would be helpful to evaluate future health benefits of widespread EV deployment.
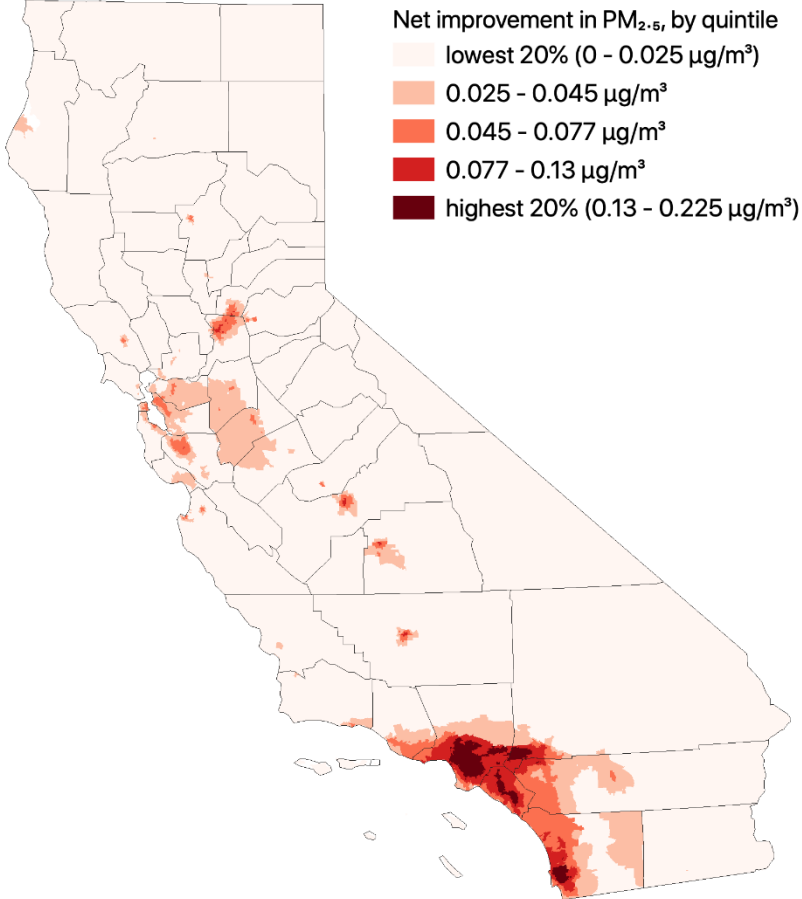

Figure 2: Net benefits for simulated 10 percent replacement of gasoline passenger vehicles. Benefits are highest in Los Angeles, Orange, and San Diego Counties. Net benefit of EV deployment is measured by estimated change in $PM_{2.5}$ concentration. Map colors show census tracts, binned by quintiles of net benefits with the darkest color showing the 20 percent of census tracts with the highest reduction in $PM_{2.5}$ concentration.

4   Conclusion

Cleaner technologies are now available to replace gasoline, diesel, and other combustion-powered vehicles, making a large fraction of tailpipe transportation emissions avoidable. By supporting strategies such as cleaner fuels, the reduction of miles driven, and the electrification of vehicles—and by targeting clean technology deployment to benefit the most affected communities—both air pollution and carbon emissions that cause climate change can be reduced, while addressing the inequity of $PM_{2.5}$ exposure.

Quantifying the net benefits for switching from petroleum-fueled internal combustion engines (ICE) to electric motors in our transportation system is important to the design of policy and regulation. In this research the decrease in tailpipe and refueling emissions attributable to replacing ICE vehicles with electric vehicles was compared to the potential increase in $PM_{2.5}$ pollution exposure due to increased electricity generation. For California, there was a net benefit (reduction in $PM_{2.5}$ exposure) for every county, with urban Southern California counties showing the highest benefit. Higher projected benefits for African American and Latino Californians shows the potential for EV deployment to address existing inequities in pollution exposure. Future work will explore policies to both maximize the air quality benefits of EVs and provide equitable solutions for people living in California.

References

[1]   US Environmental Protection Agency (EPA). *2014 National emissions inventory. Version 1.* 2014. Online at www.epa.gov/air-emissions-inventories/2014-national-emissions-inventory-nei-data, accessed on 2019-01-13.

[2]   D. E. Schraufnagel et al., *Air Pollution and Noncommunicable Diseases: A Review by the Forum of International Respiratory Societies' Environmental Committee, Part 1: The Damaging Effects of Air Pollution.* Chest Journal (2019). Online at https://doi.org/10.1016/j.chest.2018.10.042.

[3]   Tessum, C.W., J.D. Hill, and J.D. Marshall. *InMAP: A model for air pollution interventions.* PLoS ONE (2017) Online at https://doi.org/10.1371/journal.pone.0176131.

[4]   US Census Bureau. *Summary file: 2012–2016 American community survey.* 2018. Online at www.census.gov/programs-surveys/acs/data/summary-file.2016.html. Accessed on 2019-01-13.

[5]   California Air Resources Board. *EMFAC 2017 Web Database.* Online at https://www.arb.ca.gov/emfac/2017/, accessed on 2020-03-17.

[6]   US Environmental Protection Agency (EPA). *Emissions & Generation Resource Integrated Database (eGRID2014).* 2017. Online at https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid. Accessed on 2020-3-17.

[7]   Electric Power Research Institute (EPRI). *Environmental Assessment of a Full Electric Transportation Portfolio: Volume 1: Background, Methodology, and Best Practices.* 2014. Online at https://www.epri.com/#/pages/product/3002006875/. Accessed on 2020-03-26.

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