Mobility, Energy, and Emissions Impacts of SAEVs to Disadvantaged Communities in California

September 2024

A Research Report from the National Center for Sustainable Transportation

Xinwei Li, Cornell University

Alan Jenn, University of California, Davis

National Center for Sustainable Transportation
A USDOT University Transportation Center

UC DAVIS
Institute of Transportation Studies

TECHNICAL REPORT DOCUMENTATION PAGE

1. Report No. NCST-UCD-RR-24-21	**2. Government Accession No.** N/A	**3. Recipient's Catalog No.** N/A
4. Title and Subtitle Mobility, Energy, and Emissions Impacts of SAEVs to Disadvantaged Communities in California		**5. Report Date** September 2024 **6. Performing Organization Code** N/A
7. Author(s) Xinwei Li, Ph.D., http://orcid.org/0000-0002-6262-5343 Alan Jenn, Ph.D., http://orcid.org/0000-0003-4232-0697		**8. Performing Organization Report No.** UCD-ITS-RR-24-08
9. Performing Organization Name and Address University of California, Davis Institute of Transportation Studies 1605 Tilia Street, Suite 100 Davis, CA 95616		**10. Work Unit No.** N/A **11. Contract or Grant No.** USDOT Grant 69A3551747114
12. Sponsoring Agency Name and Address U.S. Department of Transportation Office of the Assistant Secretary for Research and Technology 1200 New Jersey Avenue, SE, Washington, DC 20590		**13. Type of Report and Period Covered** Final Research Report (October 2022 – December 2023 **14. Sponsoring Agency Code** USDOT OST-R
15. Supplementary Notes DOI: https://doi.org/10.7922/G28050XS		

16. Abstract

This study delves into the energy and emissions impacts of Shared Autonomous and Electric Vehicles (SAEVs) on disadvantaged communities in California. It explores the intersection of evolving transportation technologies—electric, autonomous, and shared mobility—and their implications for equity, energy consumption, and emissions. Through high-resolution spatial and temporal analyses, this research evaluates the distribution of benefits and costs of SAEVs across diverse populations, incorporating environmental justice principles. Our quantitative findings reveal that electrification of the vehicle fleet leads to a 63% to 71% decrease in CO2 emissions even with the current grid mix, and up to 84%-87% under a decarbonized grid with regular charging. The introduction of smart charging further enhances these benefits, resulting in a 93.5% - 95% reduction in CO2 emissions. However, the distribution of these air quality benefits is uneven, with disadvantaged communities experiencing approximately 15% less benefits compared to more advantaged areas. The study emphasizes the critical role of vehicle electrification and grid decarbonization in emissions reduction, and highlights the need for policies ensuring equitable distribution of SAEV benefits to promote sustainable and inclusive mobility.

17. Key Words Shared, autonomous, electric vehicles, equity, environmental justice, disadvantaged communities		**18. Distribution Statement** No restrictions.	
19. Security Classif. (of this report) Unclassified	**20. Security Classif. (of this page)** Unclassified	**21. No. of Pages** 35	**22. Price** N/A

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

NCST

About the National Center for Sustainable Transportation

The National Center for Sustainable Transportation is a consortium of leading universities committed to advancing an environmentally sustainable transportation system through cutting-edge research, direct policy engagement, and education of our future leaders. Consortium members include: the University of California, Davis; California State University, Long Beach; Georgia Institute of Technology; Texas Southern University; the University of California, Riverside; the University of Southern California; and the University of Vermont. More information can be found at: ncst.ucdavis.edu.

Disclaimer

Acknowledgments

This study was funded, partially or entirely, by a grant from the National Center for Sustainable Transportation (NCST), supported by the U.S. Department of Transportation (USDOT) through the University Transportation Centers program. The authors would like to thank the NCST and the USDOT for their support of university-based research in transportation, and especially for the funding provided in support of this project.

Mobility, Energy, and Emissions Impacts of SAEVs to Disadvantaged Communities in California

A National Center for Sustainable Transportation Research Report

September 2024

Xinwei Li, Department of Civil and Environmental Engineering, Cornell University

Alan Jenn, Department of Civil and Environmental Engineering, University of California, Davis

NCST

[page intentionally left blank]

TABLE OF CONTENTS

List of Tables

List of Figures

Mobility, Energy, and Emissions Impacts of SAEVs to Disadvantaged Communities in California

EXECUTIVE SUMMARY

Our study undertakes a comprehensive examination of the intersectional impacts of Shared Autonomous and Electric Vehicles (SAEVs) on disadvantaged communities. This exploration is pivotal in the context of California's evolving transportation landscape and is motivated by the transformative shift in transportation technologies, with a specific focus on Electric Vehicles (EVs) and Autonomous Vehicles (AVs), alongside the burgeoning domain of ride-hailing and car-sharing services. These developments not only respond to consumer preferences but are strategically aligned with broader societal objectives, including energy consumption and emissions reduction, lower transportation costs, and promoting sustainable travel practices. However, central to this transition is the critical concern for equity and environmental justice. The study aims to determine whether the benefits and burdens of these technological advancements are equitably distributed, particularly in disadvantaged communities.

We employ high-resolution analyses to evaluate the distribution of SAEV benefits and costs across different populations, with a particular emphasis on disadvantaged communities. The research methodology encompasses various future scenarios of SAEV adoption, charging behavior, and power sector evolution, examining their air quality implications with high spatial fidelity. This enables the differentiation of impacts across demographics, particularly those associated with disadvantaged communities.

Our quantitative analyses demonstrate significant potential benefits in emissions reductions with the electrification of the vehicle fleet. A 63% to 71% decrease in CO_2 emissions is observed with the current grid mix, rising to 84%-87% under a decarbonized grid with regular charging. Smart charging further enhances these benefits, leading to a 93.5% - 95% reduction in CO_2 emissions. However, the research highlights a disparity in the distribution of these benefits. Disadvantaged communities experience approximately 15% less improvement in air quality compared to more advantaged areas. This finding underscores the necessity for policies that ensure equitable distribution of SAEV benefits and the integration of these vehicles with renewable energy.

Based on these findings, the study recommends the development of policies ensuring equitable access to SAEVs, particularly in disadvantaged communities. This includes infrastructure development like equitable distribution of charging stations and affordability schemes, incentivization of SAEV adoption focusing on emissions reduction and energy efficiency, and integration of SAEVs with renewable energy sources. Additionally, the study emphasizes the importance of data-driven policymaking, community engagement in policy formulation, and regular environmental and health impact assessments to understand the air quality and public health implications in disadvantaged areas.

In conclusion, we provide vital insights into the socio-economic and environmental impacts of transportation technologies. It guides strategic policy formulation for an equitable transition towards sustainable mobility, ensuring that the transportation sector's evolution contributes to a more equitable and sustainable future for all.

Introduction

The transportation sector is undergoing a transformative evolution, characterized by an amalgamation of technological advancements and innovative travel modes. Electric Vehicles (EVs) and Autonomous Vehicles (AVs) represent the forefront of technological innovation, reshaping our understanding of personal mobility. Concurrently, the emergence of ride-hailing platforms such as Uber and Lyft, along with car-sharing services like Turo and ZipCar, are redefining traditional vehicular access and vehicle ownership paradigms (1,2). This confluence of technology and service innovation is not merely a response to evolving consumer preferences but is also strategically aligned with broader societal objectives. Specifically, it addresses the critical need for coupling the transportation sector with the electricity sector, a move that has significant implications for energy consumption, emissions reduction, and the mitigation of climate change (3,4). Furthermore, these advancements contribute to alleviating urban congestion, lowering transportation costs (5), and promoting sustainable travel practices (6).

The transition to electric vehicles (EVs) represents a pivotal shift in automotive technology. EVs have witnessed explosive growth in recent years, with sales numbers and market penetration escalating rapidly. This surge is driven by advancements in battery technology, resulting in lower costs and longer driving ranges, coupled with a growing public awareness of environmental issues. The market is further bolstered by governmental policies and incentives aimed at promoting clean energy technologies. Looking ahead, key areas of focus for EVs encompass further enhancements in battery technology, addressing challenges related to charging infrastructure, and the integration of EVs into the broader energy system, including smart grid technologies and renewable energy sources. These developments are critical in maximizing the environmental and societal benefits of EVs, and in ensuring their successful and sustainable integration into the transportation ecosystem.

Simultaneously, autonomous vehicles (AVs), defined as vehicles capable of sensing their environment and operating without human input, represent a significant technological advancement in the transportation sector. They promise enhanced road safety by reducing human error, which is a leading cause of accidents. Additionally, AVs could improve traffic flow and reduce congestion through more efficient driving patterns (7–9). They also hold the potential to provide mobility solutions for those unable to drive, such as the elderly or disabled (10,11). Moreover, when integrated with electric powertrains, AVs contribute to reducing emissions and promoting sustainability (3,4). However, the advancement of AV technology also presents potential challenges. There are concerns regarding cybersecurity, data privacy, and the ethical implications of decision-making algorithms (12). Additionally, there is the risk of increased vehicle miles traveled (VMT) if AVs make driving more convenient, potentially offsetting some environmental benefits (13).

Lastly, the advent of ride-hailing services such as Uber and Lyft has revolutionized the transportation landscape, altering conventional perceptions of mobility and vehicle ownership. These platforms have democratized access to on-demand transportation, offering flexibility, convenience, and a personalized travel experience (5). They have also facilitated the growth of the gig economy, providing flexible employment opportunities.

The benefits of these services extend to increased transportation accessibility in areas poorly served by traditional public transit and providing a viable alternative to personal vehicle ownership, potentially reducing the number of vehicles on the road (14). However, the impact of these services is not unilaterally positive. Criticisms include the high cost and variable pricing, which can limit accessibility for lower-income individuals. Moreover, the phenomenon of induced demand, where the ease of ride-hailing services leads to more people opting to travel by car, has been implicated in contributing to urban congestion (15). Another issue is 'deadheading', the time spent by drivers traveling without passengers, which can increase total vehicle miles traveled (16). These services also potentially detract from public transit systems, as some users may opt for private ride-hailing over public transportation options.

The integration of Shared, Autonomous, and Electric Vehicles (SAEVs) presents a synergistic opportunity that can significantly redefine the future of transportation. This convergence, in Sperling's "Three Revolutions" offers a visionary perspective on how these individual innovations can collectively lead to a more sustainable, efficient, and equitable transportation system (17). Shared mobility maximizes the utility of vehicles, reducing the need for private car ownership and associated environmental impacts. Autonomous technology promises enhanced safety and efficiency in transportation, while electric vehicles contribute to reducing emissions and reliance on fossil fuels.

In the context of the transition towards shared, autonomous, and electric vehicles (SAEVs), the concepts of equity and justice emerge are critically important. Equity in this realm refers to the fair and just distribution of both the benefits and burdens resulting from the adoption of these new transportation technologies. One concern in this transition is the risk of exacerbating existing inequalities or creating new forms of disparity. For instance, there is the potential for SAEVs to be less accessible to low-income communities or those in rural areas, who might not have the same level of access to charging infrastructure or autonomous vehicle technology. Additionally, there is the risk that the benefits of reduced emissions and improved air quality may not be equitably distributed, with disadvantaged communities continuing to bear a disproportionate burden of environmental pollutants. Another issue is the impact on employment, particularly for those in driving professions, as autonomous vehicles become more prevalent. Furthermore, the transition to electric vehicles raises concerns about the affordability of these technologies for all segments of society.

To address these issues, it is crucial to adopt a proactive approach that prioritizes equity and justice. This involves ensuring that policy decisions and technological advancements are guided by the principle of not leaving any population behind or disproportionately impacted. It necessitates the inclusion of diverse stakeholders in the decision-making process and the implementation of measures that specifically target the alleviation of potential inequalities. This could include investing in infrastructure in underserved areas, subsidizing costs for low-income households, and providing training for workers transitioning from traditional automotive industries. Ultimately, the goal is to ensure that the transition to SAEVs is inclusive and contributes to the broader objective of creating a more equitable and just society.

Despite the near-unanimous consensus on the benefits of Shared, Autonomous, and Electric Vehicles (SAEVs), a notable gap exists in the current body of literature: the lack of studies examining how a transition towards SAEVs could disproportionately affect different populations. This oversight highlights a critical aspect of environmental justice, which emphasizes the fair treatment and meaningful involvement of all people, irrespective of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies (18). Environmental justice is particularly pertinent in the context of a shift in our transportation sector towards SAEVs, as this transition could inadvertently create disparities in who bears the costs and who reaps the benefits.

This project aims to fill this gap by conducting the first investigation of the energy and emissions benefits from SAEVs at a high spatial resolution, enabling the differentiation of benefits and costs to various populations in California. By incorporating the principles of environmental justice, this research will provide a more nuanced understanding of the impacts of SAEVs, ensuring that the transition to this new transportation paradigm is equitable and inclusive. The goal is not only to quantify the energy and emissions benefits but also to identify and address potential disparities, ensuring that all segments of society benefit from the transition to SAEVs. This approach represents a critical step forward in ensuring that the transportation sector's evolution contributes to a more equitable and sustainable future for all. The remainder of the report is organized as follows: Data and Methods describing the approach taken in this project to conduct our analysis, Results displaying the findings of our research, and a Conclusion and Discussion discussing the broader implications of our work.

Literature Review

The advent of and commercialization of shared vehicle services (Uber and Lyft), autonomous vehicles (Waymo and Cruise), and electric vehicles has led to rapid growth in the academic community to study the potential impacts of each of these shifts in the transportation system. While a plethora of studies exist across each of these topics individually, the combination and examination of their synergies remains in its infancy. Nevertheless, these studies have begun to indicate there are large potential benefits from an energy and emissions standpoint from SAEVs. There are already several simulation-based case studies showing tremendous emissions decreases within certain regions including a fivefold reduction in emissions in California (19), 66.5 tons of GHG emissions per vehicle per year in addition to a $2,200 in annual cost savings in Ann Arbor, Michigan (20), a higher cost but large potential environmental benefit in Austin, Texas (5,21), a 50% reduction in GHGs relative to EVs charging at home in Toronto, Canada (22), a decrease in the size of the private car fleet down to 10%-14% in Tokyo, Japan (23), and a 41% decrease in carbon footprint by 2050 in Sweden (24). While the assumptions and conditions amongst the regions represented across these studies vary quite dramatically, the results from this body of work are consistently pointing to large decreases in emissions and energy impacts (though a few studies disagree on the directionality of costs)—despite issues related to the increased power consumption from AV hardware and deadheading (mileage accrued from autonomous vehicles that have no passengers).

More systemic large-scale simulations of SAEVs have also been examined recently. These include a demonstration of not only the GHG benefits but large improvements in air quality benefits through 2050 thanks to SAEVs (25,26). Additionally, some studies are beginning to investigate the coupling of SAEVs with non-transportation sectors such as an in-depth examination of land-use policies associated with large-scale shifts in the transportation system, ultimately resulting in over 50% reductions in energy consumption and PM emissions (increasing to above 75% with full electrification) (27). Several studies have coupled SAEV dominant systems alongside detailed power sector models, with outcomes consistent with many of the case studies: massive GHG savings, lower system costs, and reduced fleet sizes (3,4,25,28), with the exception of a single study indicating negative environmental outcomes on a per-vehicle basis (29).

Data and Methods

Overview

Our general approach considers several future scenarios of SAEV adoption, charging behavior, and power sector evolution. We examine the air quality implications associated with each of these scenario with relatively high spatial fidelity, which allows us to differentiate impacts across different categories of demographics—specifically those associated with disadvantaged communities. As seen in Figure 1, we begin with a characterization of SAEV travel based on results from Sun et al. (2023) which combines several models including the California Statewide Travel Demand Model (CSTDM, Version 3.0) as well as the Emission FACtors (EMFAC) and Vision models for baseline emissions factors. The energy demands on the electricity system associated with these scenarios are fed into the Grid Optimized Operation Dispatch (GOOD) model, which characterizes the operation of power plants throughout California and the rest of the Western Interconnect (WECC), thus allowing us to determine the upstream emissions impacts from charging SAEVs throughout California. The local pollutant emissions are translated to monetized health damages via the EASIUR modeling platform. We then conduct a spatial impacts analysis employing CalEnviroScreen's characterization of community burden scores, which combines environmental, health, and socioeconomic information in order to determine how the impacts of upstream pollutants associated with the charging of SAEVs are distributed throughout the state.

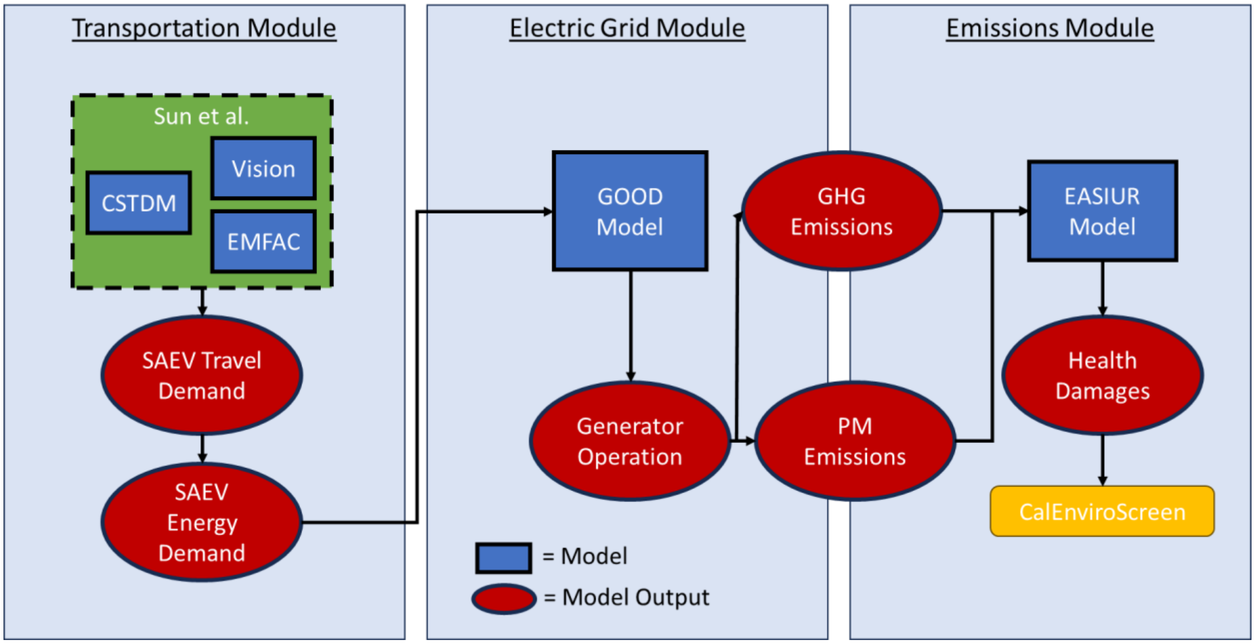

Figure 1. System diagram for SAEV modeling approach. Data on SAEV demands are based on Sun et al. (2023), which determines outputs for the travel demand (total miles) and energy demand (kWh electricity demand) which are then translated as inputs into the GOOD (electric sector simulation) model. The outputs of this model (operation of power plants across the western US are then used to determine the upstream emissions from charging which we evaluate and translate to health damages using the EASIUR model.

Travel Demand Data

In our study, we utilize the results from Sun et al. (30) which employs the California Statewide Travel Demand Model (CSTDM) Version 3.0 to forecast the travel demands and environmental impacts of various Connected and Automated Vehicle (CAV) deployment scenarios in California by the year 2050. CSTDM integrates a diverse array of data inputs, including zone systems, network properties, and socio-economic factors, essential for generating accurate travel demand forecasts across several modes and time periods. This model's calibration is grounded in the empirical data from the 2012 California Household Travel Survey (CHTS) that helps to ensure the reliability of travel pattern simulations.

To address the potential impacts of CAVs on travel demand and emissions, Sun et al. designed scenarios ranging from no automation to complete deployment of both private and shared CAVs, inclusive of zero-emission vehicles. These scenarios were crafted to assess shifts in vehicle miles traveled (VMT) and environmental outputs under different levels of technology adoption and regulatory frameworks. Emissions calculations within these scenarios rely on inputs from the EMission FACtor model (EMFAC) and Vision models, which are specifically adapted to project future impacts based on the varying levels of CAV penetration and vehicle electrification anticipated by 2050. The demand forecasts in Sun's paper combines outputs from short and long-distance private travel modes which are calibrated to observed travel according to the 2010-2012 California Household Travel Survey. While their paper conducts a wide range of different scenarios, we focus specifically on Scenarios 4a and 4b, which are meant to characterize the lower and upper-bound adoption of shared autonomous vehicles. The assumptions associated with these scenarios can be found in Table 1 below. The work specifically focuses on three aspects of impacts from SAVs in these scenarios: 1) increased number of trips due to lower travel costs and increased convenience, 2) shifts in travel modes from single-occupancy trips to shared trips as well as public transit trip shifts to auto trips, and 3) additional VMT from deadheading.

Table 1. Scenario options from Sun et al. (2023) used in this study.

<table>
<tr><th></th><th>CAV-a
Scenario 4a: Shared CAV (Lower Bound)</th><th>CAV-b
Scenario 4b: Shared CAV (Upper Bound)</th></tr>
<tr><td>Factor modifications to baseline</td><td>1. Operating cost -25%
2. Capacity +50%
3. Parking cost -25%
4. Driver's license relaxation
5. Auto VOT -50%</td><td>1. Travel behavior shifts:
• 10% single-occupancy to HOV2 (+6%) and HOV3+ (+4%)
• 40% private trips to HOV2 (+28%) and HOV3+ (+12%)
2. Short distance deadheading +10% HOV2, +10% HOV3+</td></tr>
<tr><td>Model post-process modifications</td><td>1. Operating cost -25%
2. Capacity +50%
3. Parking cost -25%
4. Driver's license relaxes to age 12
5. Auto VOT -50%</td><td>1. TAZ level OD trips +15% induced demand for all modes for SD and LD
2. Travel behavior shifts:
• 10% single-occupancy to HOV2 (+6%) and HOV3+ (+4%)
• 40% private trips to HOV2 (+28%) and HOV3+ (+12%)
3. Short distance deadheading +20% SOV, +20% HOV2, +20% HOV3</td></tr>
</table>

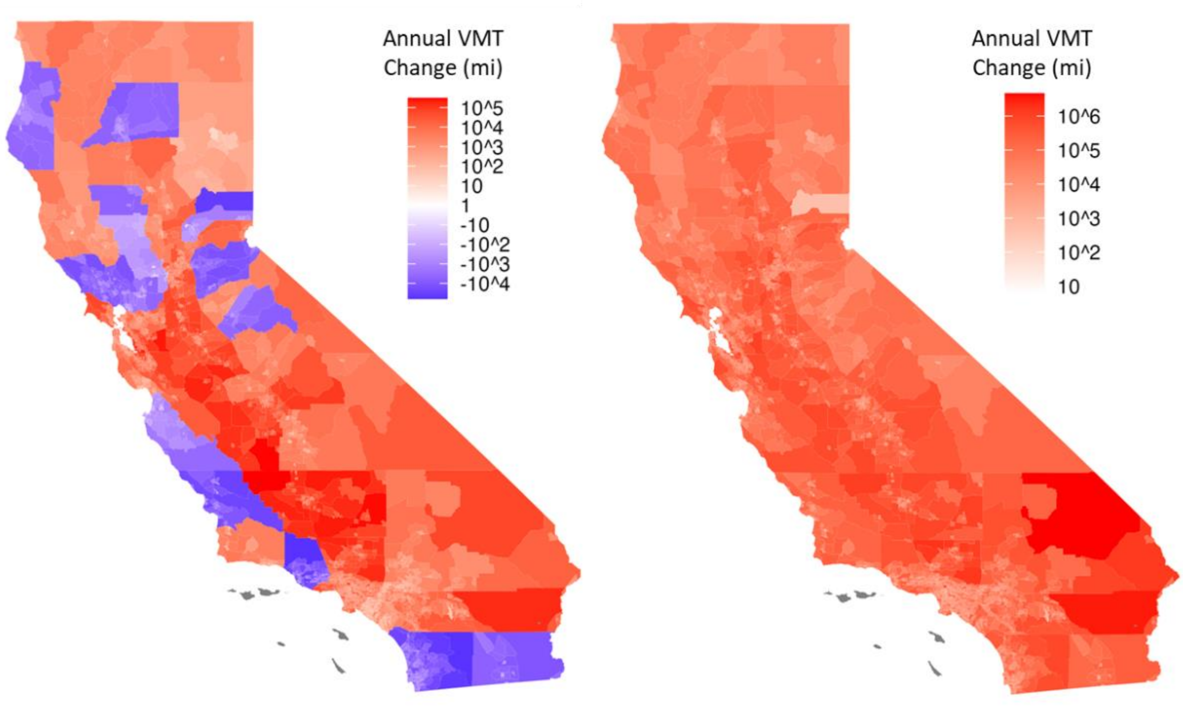

Figure 2. VMT differences between baseline scenarios and SAEV scenarios in 2050. (*left*) represents the change in VMT between the CAV-a scenario and BAU, (*right*) represents the change in VMT between the CAV-b scenario and BAU.

Electricity Grid and Emissions Impact Modeling

The analysis of electric generation in California and its surrounding regions utilizes the Grid Optimized Operation Dispatch (GOOD) model (3,19,31–33). This model simulates the operation of power generation assets within the Western Interconnect, adhering to transmission constraints, to fulfill load demands. It operates akin to a system operator, prioritizing power plant dispatch based on marginal fuel costs, similar to the approach of the California Independent System Operator. The dispatch sequence starts with the lowest bidding plants, escalating to higher bidders until reaching the clearing price. The model also incorporates regional power flow considerations, adhering to specific transmission constraints, and factors in renewable energy generation constraints, such as California's Renewable Portfolio Standard (RPS), using representative daily generation profiles.

The formulation of the optimization model is provided below, following Table 2, which provides an overview of the sets, parameters, and decision variables employed in the GOOD model.

Table 2. Notations of Grid Optimized Operations Dispatch (GOOD) model.

Name	Type	Description
g	sets	Generators
gas_g	sets	Gas generators
t	sets	Time Period (hour)
d	sets	Time Period (day)
r	sets	Region
ca_r	sets	CA regions
$gtor_{g, r}$	sets	Generator to region mapping
r, o, p	sets	Alias sets of regions
$ttod_{t, d}$	sets	Hour to day mapping
$genCost_g$	parameters	Cost of generation [$ per MWh]
$demandLoad_{r,t}$	parameters	Baseload electricity demand [MWh]
$maxGen_g$	parameters	Capacity of dispatchable generation [MW]
$solarCap_r$	parameters	Capacity of solar generation [MW]
$windCap_r$	parameters	Capacity of wind generation [MW]
$solarCF_{r,t}$	parameters	Capacity factor of solar generation [unitless]
$windCF_{r,t}$	parameters	Capacity factor of wind generation [unitless]
$transCap_{r,o}$	parameters	Capacity of transmission line [MW]
$transCost_{r,o}$	parameters	Wheeling costs for transmission [$ per MW]
$percentRenew_r$	parameters	Renewable Portfolio Standards by region [unitless]
$windTransCost_r$	parameters	Wind transmission connection costs [$ per MW]
$storExisting_r$	parameters	Amount of storage from previous time period
$evHourlyLoad_{r,t}$	parameters	PEV hourly charging load [MWh]
$evDailyLoad_{r,d}$	parameters	PEV daily charging load [MWh]
transLoss	scalar	Transmission efficiency [unitless] /0.972/
storageLoss	scalar	Storage efficiency /0.85/
solarCost	scalar	Solar capacity cost [$ per MW] /80,000/
windCost	scalar	Wind capacity cost [$ per MW] /130,000/
storCost	scalar	Storage capacity cost [$ per MWh] /13,000/
importLimit	scalar	Transmission import limit [MWh] /80,000,000/
$generation_{g,t}$	positive variable	Generator operation [MW]
$trans_{r,t,o}$	positive variable	Transmission operation (from region r to o) [MW]
$evFlexibleLoad_{r,t}$	positive variable	PEV hourly charging load with smart charging [MWh]
$solarNew_r$	positive variable	New solar capacity built [MW]
$windNew_r$	positive variable	New wind capacity built [MW]
$storSOC_{r,t}$	positive variable	The storage state of charge [MWh]
$storIn_{r,t}$	positive variable	The input energy to and from the storage [MWh]
$storOut_{r,t}$	positive variable	The output energy to and from the storage [MWh]
$storCap_r$	positive variable	Storage capacity installed [MW]

Objective function: Minimizing total system cost

$$systemCost = \sum_{g,t}\left(generation_{g,t} \cdot genCost_g\right) + \sum_{r,t,o}\left(trans_{r,t,o} \cdot transCost_{r,o}\right) + \sum_{r}(solarCost \cdot solarNew_r + (windCost + windTransCost_r) \cdot windNew_r + (storCap_r - storExisting_r) \cdot storCost) \quad (1)$$

Constraint 1a: Generation should meet total load, including regular EV charging load

$$\sum_{g \in gtor(g,r)} generation_{g,t} + (solarCap_r + solarNew_r) \cdot solarCF_{r,t} + (windCap_r + windNew_r) \cdot windCF_{r,t} + \left(\sum_{o} trans_{o,t,r} \cdot transLoss - \sum_{p} trans_{r,t,p}\right) - storIn_{r,t} + storageLoss \cdot storOut_{r,t} - \left(demandLoad_{r,t} + evHourlyLoad_{r,t}\right) \geq 0 \quad (2)$$

Constraint 1b: Generation should meet total load, including flexible EV charging load under smart charging

$$\sum_{g \in gtor_{g,r}} generation_{g,t} + (solarCap_r + solarNew_r) \cdot solarCF_{r,t} + (windCap_r + windNew_r) \cdot windCF_{r,t} + \left(\sum_{o} trans_{o,t,r} \cdot transLoss - \sum_{p} trans_{r,t,p}\right) - storIn_{r,t} + storageLoss \cdot storOut_{r,t} - \left(demandLoad_{r,t} + evFlexibleLoad_{r,t}\right) \geq 0 \quad (3)$$

Constraint 2: Flexible EV charging load should match daily charging demand

$$\sum_{t \in ttod_{t,d}} evFlexibleLoad_{r,t} - evDailyLoad_{r,d} = 0 \quad (4)$$

Constraint 3: Renewable generation requirement under California's Renewable Portfolio Standards (RPS)

$$\sum_{t}\left((solarCap_r + solarNew_r) \cdot solarCF_{r,t} + (windCap_r + windNew_r) \cdot windCF_{r,t}\right) \cdot (1 - percentRenew_r) - percentRenew_r \cdot \sum_{t}\left(\sum_{g \in gtor_{g,r}} generation_{g,t}\right) \geq 0 \quad (5)$$

Constraint 4: Real-time energy balance of the grid storage

$$storSOC_{r,t} - storSOC_{r,t-1} - storIn_{r,t-1} \cdot storageLoss + storOut_{r,t-1} = 0 \quad (6)$$

Constraints 5&6: The charging/discharging energy per hour of storage is limited to be below 25% of the total capacity of the grid storage device according to the performance of current lithium-ion batteries.

$$storCap_r \cdot 0.25 - storIn_{r,t} \geq 0 \tag{7}$$

$$storCap_r \cdot 0.25 - storOut_{r,t} \geq 0 \tag{8}$$

Constraint 7: Storage capacity limit

$$storCap_r - storSOC_{r,t} \geq 0 \tag{9}$$

Constraint 8: Net balance for all storage

$$\sum_{r,t} \left(storIn_{r,t} - storOut_{r,t} \right) = 0 \tag{10}$$

Constraint 9: Import limit into CA

$$importLimit - \sum_{r,t,ca} trans_{r,t,ca} \geq 0 \tag{11}$$

The totality of the optimization system described by Table 2 and Equations (1) through (11) (collectively describing the objective function and constraints of the optimization), provide the framework for simulating the operation of power plants throughout our study region. The results from the model are at a high level of fidelity—providing both hourly results across an entire year as well as the exact spatial locations of power plants being used (thereby allowing for precise locations for emissions outcomes related to fossil fuel combustion for electricity generation). Emission estimates are derived from the power generation results by multiplying each power plant's production by their respective emission rates for both GHGs (CO_2, CH_4, and N_2O) and local air pollutants (NO_x, SO_x, and PM).

The dispersion of pollutants from point sources and translation to health damages are done via the "Estimating Air pollution Social Impact Using Regression" (EASIUR) model (34–36). This model is a reduced-form model of more complex air quality models and is able to take marginal pollution estimates and predict health costs associated with both morbidity and mortality outcomes from those local pollutants. In this study, we isolate the consequential emissions associated with SAEV use and identify the costs to society of the emissions changes associated with the adoption of the technology at a high spatial resolution. This resolution allows for differentiation of the effects of SAEV use across disadvantaged communities. We employ CalEnviroScreen 4.0 developed by the California Office of Environmental Health Hazard Assessment, which employs 21 indicators for pollution burdens and population demographics. These help to provide a scoring system to differentiate impacts across communities burdened by a comprehensive set of factors determined by CalEnviroScreen.

Scenarios

This study considers combinations of scenarios across travel demand, electric grid composition, and charging behavior. SAEV travel demand scenarios are described in the section “Travel Demand Data” and cover: 1) a baseline scenario with no changes in technology as it relates to electrification, shared-rides, and automation; 2) CAV-a: high SAEV adoption scenario alongside a lower bound estimate of deadheading, 3) CAV-b: similar to CAV-a, but with an upper bound estimate of deadheading. The construction of these scenarios provides a relatively robust bounding exercise of an SAEV saturated system compared to today’s single-occupancy, gas vehicle dominated system.

The scenarios regarding the composition of the electricity grid are broken down into 1) current power grid makeup in 2020 and 2) a heavily decarbonized 2050 grid. The two grid scenarios represent a “static” grid and a 100% renewable grid in accordance to California’s full decarbonization plans by 2045. The grid makeup is not exogenously determined, but rather a product of enforcing constraints to meet renewable generation targets set by the state. Again, this bookending provides insight into the differences in SAEV impacts from varying grid conditions.

The charging behavior scenarios assume that all SAEVs charge 1) via “regular” charging where vehicles charge based on patterns of public charging that are observed today from empirical data, and 2) employing “smart” charging where vehicles instead must fulfill a daily charge demand but within the day are free to charge (and they will choose to do so based off a price signal from the grid—hence allowing vehicles when the “best” times are to charge based on the cheapest times to do so).

To summarize, the analysis considers a total of 12 different scenarios across all combinations of described travel demand, electric grid composition, and charging behavior assumptions.

Results

Our results are broken into two primary categories: first are changes in mobility across the SAEV travel demand scenarios. These results provide some perspective on how assumptions of SAEV travel are ultimately input into the GOOD and subsequent EASIUR models to determine upstream emissions impacts. While we do not strictly provide quantification of mobility benefits in this work, the relative change in VMT across scenarios and regions allows for some insights on the distribution of the effects of SAEV adoption across different types of disadvantaged communities in California.

In the latter half of the Results section, we provide both aggregate and regionally sensitive emissions impacts from our analysis. The focus of this work is meant to highlight differences in SAEV adoption and use assumptions from a baseline scenario, both at an aggregate level but also taking into account disparities in populations across the state of California.

Mobility Impacts

The adoption of SAEV technology is a fundamental shift away from privately-owned gasoline vehicles—the primary mode of travel for the majority of the population in California. While we do not explicitly simulate travel demand in this study, we provide a deeper analysis of Sun et al.'s (2023) results on mobility travel pattern shifts with a specific focus on changes as they relate to disadvantaged communities. We differentiate impacts of emissions across different census tracts in California, specifically ranked by CalEnviroScreen. CalEnviroScreen is a tool developed by the California Office of Environmental Health Hazard Assessment (OEHHA) that identifies California communities by census tract that are disproportionately burdened by, and vulnerable to, multiple sources of pollution. It uses environmental, health, and socioeconomic information to produce scores for every census tract in the state, which reflect the relative burdens these communities face. The scores are derived from various indicators grouped into the following categories:

1. Pollution Burden: Includes indicators such as ozone, particulate matter, diesel emissions, pesticide use, toxic releases from facilities, and traffic density. This component measures the presence of harmful pollutants and their effects.
2. Population Characteristics: Includes socioeconomic and health indicators such as poverty, unemployment, educational attainment, housing burden, linguistic isolation, and incidence of asthma and cardiovascular disease. These factors influence how susceptible a population is to environmental health hazards.

Tracts with higher CalEnviroScreen scores are considered to be at higher risk, indicating greater environmental burdens and vulnerabilities. This scoring system is used to prioritize areas for environmental justice and help direct resources and efforts to reduce pollution and improve equity outcomes in the state of California. In Figure 3, we observe that in the CAV-a scenario, the magnitude of VMT change is relatively small but more this mileage difference consistently increases as the CalEnviroScreen scores increases—in other words, more "disadvantaged" communities experience a larger change compared to the baseline scenario. However, in the

CAV-b scenario, this trend is parabolic with an initial increase in the mileage difference between BAU and CAV-b followed by a decrease in the mileage difference around the median CalEnviroScreen score. It is important to note that the magnitude of the changes in the latter scenario comparison is almost tenfold larger than in the CAV-a versus BAU scenario.

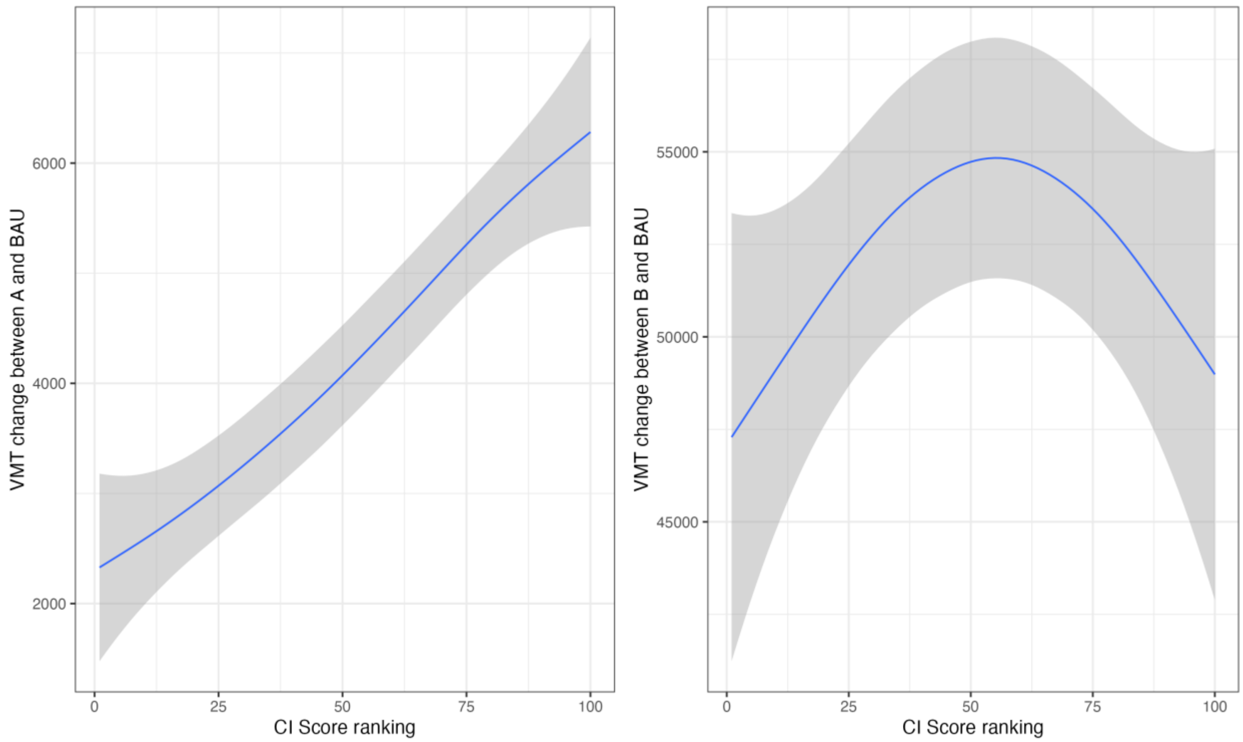

Figure 3. Change in mobility as a function of increasing CalEnviroScreen scores, the higher the ranking the more disadvantaged a community.

We also compare changes in the modality of travel from Sun et al. (2023) for the two SAEV scenarios (CAV-a and CAV-b) across different CalEnviroScreen score rankings (lower representing more advantaged communities versus higher representing more disadvantaged communities). While air travel isn't too different between the two scenarios, we find that for all other modes of travel there is a consistent increase in the number of trips occurring in the CAV-b scenario and that the pattern of these increases does not differ across CalEnviroScreen scores.

Generally speaking, we find that the results from Sun et al.'s (2023) work characterized in our SAEV scenarios are fairly consistent across different populations in California for the types of travel being taken. In other words, while there are differences in the way DACs travel, the changes resulting from SAEV technology adoption do not really affect the modalities of travel differently across the examined scenarios. The same cannot be said for the *amount* of travel done by SAEVs between the scenarios. Our analysis clearly demonstrates that the most disadvantaged communities experience the largest change in VMT in the CAV-a scenario whilst the median scored communities experience the largest changes in VMT in the CAV-b scenario.

While our work focuses on the emissions implications of these changes, it is important to note that these differences also has implications on costs and mobility accessibility across populations.

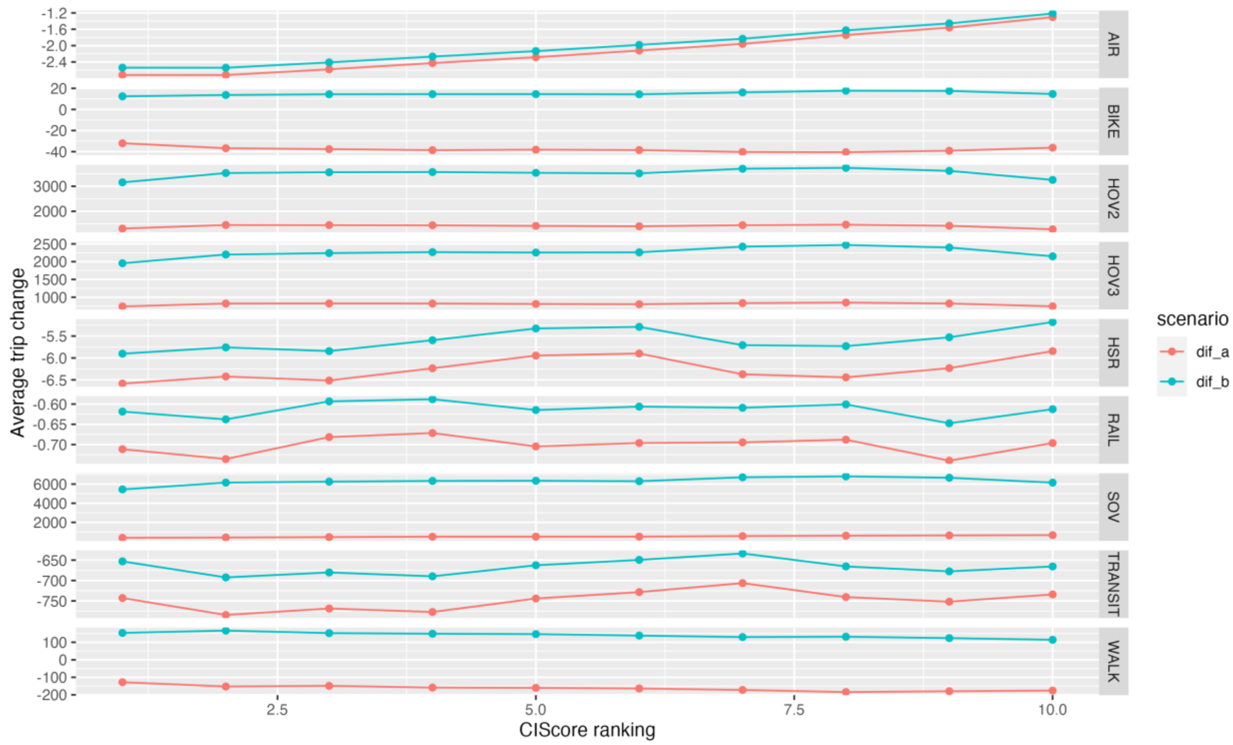

Figure 4. Changes in mobility behavior across different travel modes compared to the baseline scenario.

Emissions Impacts

While an abundance of studies have been conducted in research years regarding the emissions implications of SAEVs, it is important to note that this potential transition will likely occur heterogeneously across the population depending on socioeconomic and other demographic factors. Similarly, the emissions benefits will be influenced by spatial adoption patterns of SAEVs alongside existing and future grid infrastructure locations since local air pollutants will be heavily correlated to the location of fossil fuel plants generating electricity. In the following section on emissions impacts, we provide an overview of aggregate emissions, a spatial analysis of emission patterns across California, and lastly a translation of spatial impacts to DACs across the state.

Table 3 shows the total emissions from private passenger vehicles across the 15 scenarios (12 scenarios plus 3 baseline scenarios assuming no vehicle electrification). When fixing the grid and charging scenarios, CAV-b always has the highest emissions due to the assumption of increased deadheading—around 25%-34% higher depending on the scenario. However, by far the largest benefit is simply electrification of the fleet, which results in a 63% up to 71% decrease even with the current grid mix. Additional benefits can be accrued with an 8% to 10%

decrease with the current grid. The largest benefits compared to the baseline private ICV fleet comes under a decarbonized grid, the SAEV fleet will emit 84%-87% less CO2 with regular charging compared to an ICEV non-shared fleet in 2050, and the SAEV fleet with smart charging will decrease the total CO2 emissions by 93.5% - 95%.

Table 3. Total CO_2 emissions [tonnes/year] across all scenarios.

Grid Scenario	Charging Scenario	*SAEV Scenario*		
		BAU	CAV-a	CAV-b
NA (all ICV)	NA (all ICV)	544,232	555,553	697,966
Current Grid	Regular Charging	154,606	157,984	199,873
Current Grid	Smart Charging	110,956	113,301	143,492
Decarbonized Grid	Regular Charging	67,888	69,371	87,738
Decarbonized Grid	Smart Charging	26,493	27,180	35,413

After spatially allocating local air pollutants throughout the state of California, we input point source emissions to the EASIUR model in order to translate the pollutants to health benefits/damages. Figure 5 immediately demonstrates that overall, there are very few locations that will experience health damages as a result of widespread SAEV use. Due to the correlation between generation dispatch pricing and emissions, when charging behavior is switched from regular public charging we observe today to smart charging (which is based on electricity price signals), this further reduces the number of locations that experience health damages. In fact, in a fully decarbonized grid, there are no health damages resulting from SAEVs when smart charging.

However, it is also important to point out that the benefits of reducing local air pollutants through SAEV adoption and use is not uniform throughout the state. There is a strong correlation in the size of health benefits and population density of different areas of California, but we later show that even per-capita the benefits are not evenly distributed.

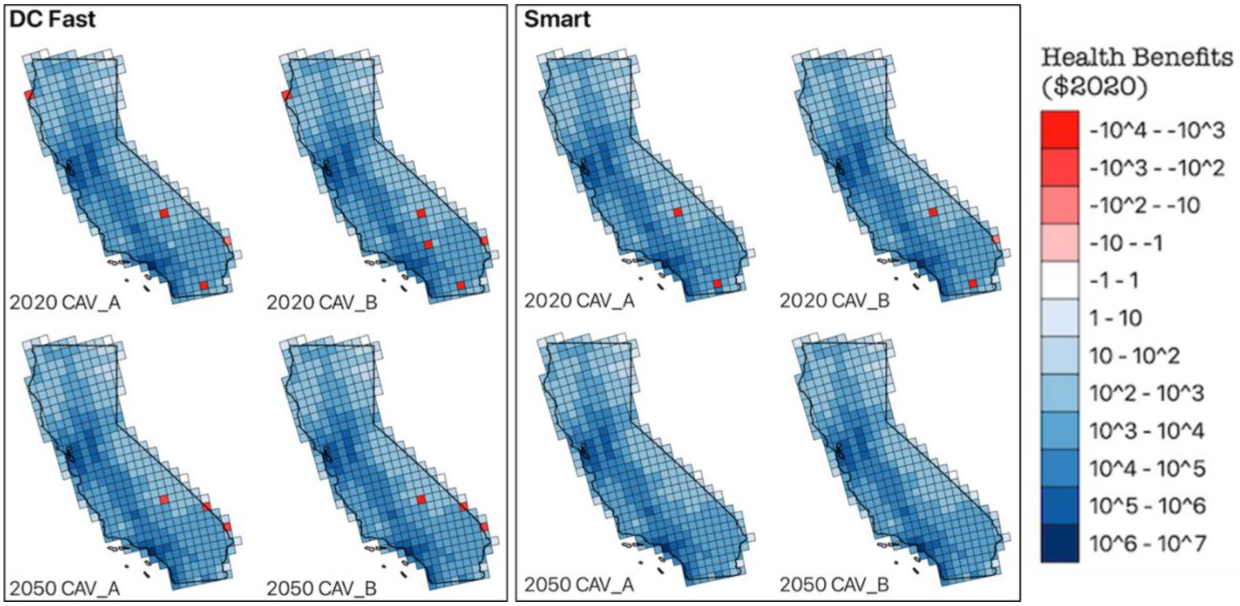

Figure 5. Monetized spatial health impacts from transitioning non-shared ICV fleet to SAEV fleet. The top row represents a current grid mix while the bottom row represents a fully decarbonized grid.

When considering CalEnviroScreen scores (indicators for environmental burdens as well as sociodemographic factors that characterize how "disadvantaged" a community is), we observe a clear trend where benefits decrease by about 15% between the "best" and "worst" disadvantaged communities in the state in Figure 6. Interestingly, the benefits between a full electrified fleet and an SAEV fleet are relatively small. In the current grid, the shared aspect of the CAV-a scenario is mostly offset by the lower efficiency of autonomous vehicles as well as the slightly higher mileage due to deadheading.

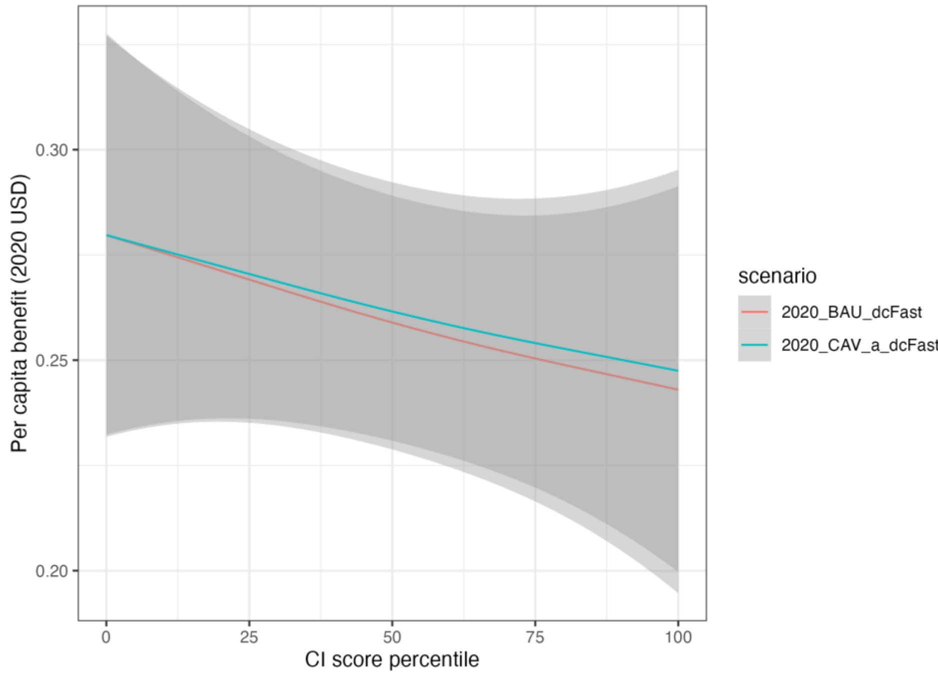

Figure 6. Total air quality health through 2050 from benefits of electrifying an ICV fleet compared to an SAEV fleet across an increasing percentile of CalEnviroScreen scores (indicator for environmental and social burdens).

In Figure 7, there is a more substantial per capita benefit of SAEV use when comparing charging scenarios of regular charging versus smart charging for CAV-a. The difference is negligible for the wealthiest and most advantaged communities in California, but smart charging provides relatively more benefits for the most disadvantaged communities—though the overall benefit level consistently decreases with higher CalEnviroScreen scores. Nevertheless, smart charging technology will help alleviate air pollution related health disparities across communities to a greater extent than the baseline regular charging scenarios.

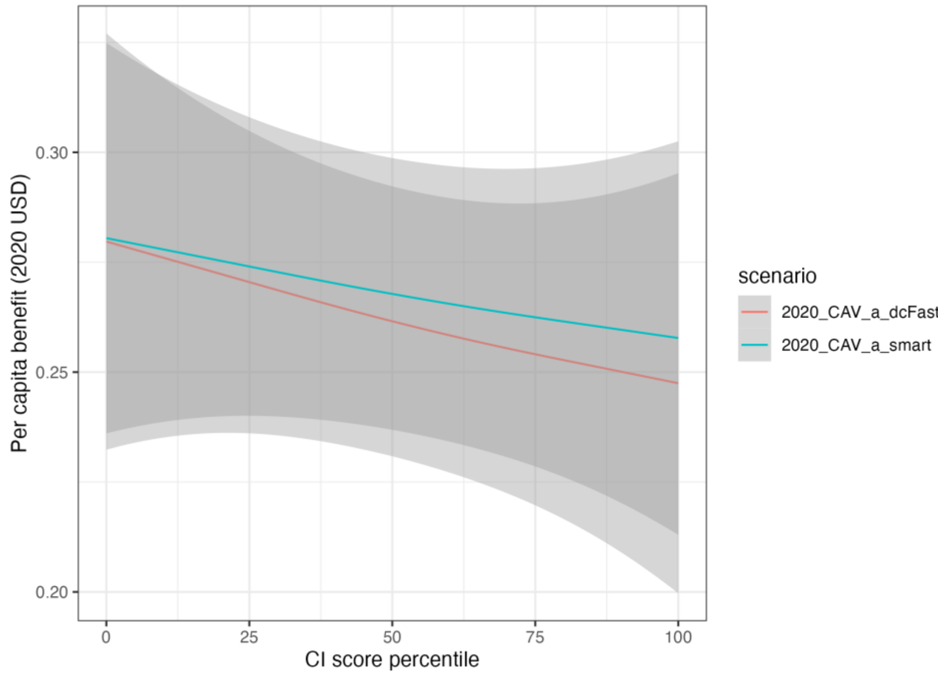

Figure 7. Total air quality health benefits through 2050 of regular public DC fast charging an SAEV fleet compared to smart charging an SAEV fleet across an increasing percentile of CalEnviroScreen scores (indicator for environmental and social burdens).

As can be seen in Figure 8, the largest difference in benefits come from decarbonizing the electricity grid. The same trend observed in Figure 6 and Figure 7 holds true for disadvantaged communities, which tend to capture a relatively smaller proportion of the emissions reduction benefits compared to more advantaged communities. Nevertheless, this particular comparison shows the largest difference in benefits comes from grid decarbonization in the CAV-a SAEV scenarios.

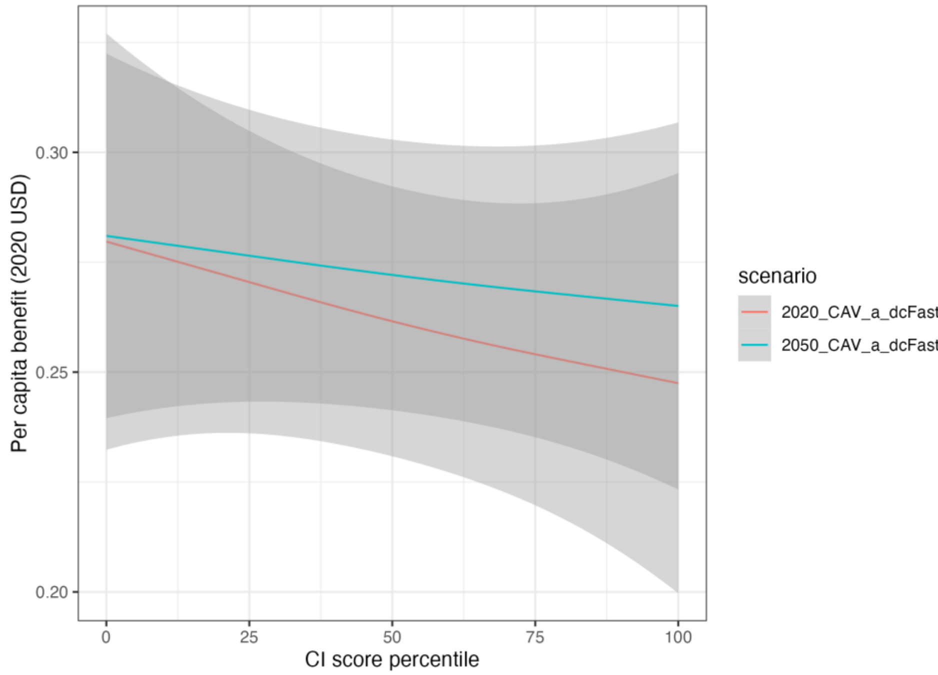

Figure 8. Total air quality health benefits of SAEVs in 2020 compared to SAEVs in 2050 across an increasing percentile of CalEnviroScreen scores (indicator for environmental and social burdens).

It is important to emphasize the fact that our modeling results show that SAEVs are almost universally beneficial from an emissions standpoint. However, our findings clearly indicate that the distribution of benefits will be felt differently across the population—and particularly troubling is the fact that benefits are consistently lowest amongst the most disadvantaged communities in the state.

Conclusion and Discussion

This study is anchored in the context of California's evolving transportation landscape, marked by the potential rise of Shared Autonomous and Electric Vehicles (SAEVs). We aim to analyze the broader implications of SAEV adoption, particularly concerning energy consumption, emissions reduction, and the socio-economic impacts on disadvantaged communities. This research is essential in understanding how technological advancements in mobility can align with environmental and societal objectives, such as enhancing sustainable transportation and ensuring equitable access. The focus on disadvantaged communities highlights a commitment to integrating environmental justice into transportation policies and innovations, ensuring that the benefits and burdens of emerging technologies are distributed fairly. This comprehensive analysis offers crucial insights into the potential reshaping of personal mobility and its implications for California's future.

Our study provides several important insights in the first novel examination of equity of benefits from SAEV adoption and use. We find that the adoption of Shared Autonomous and Electric Vehicles (SAEVs) in California results in predominantly positive air quality (AQ) benefits statewide. However, the distribution of these benefits is uneven, with more disadvantaged communities typically receiving a lower proportion of the overall improvements. The most significant benefits are derived from vehicle electrification, underscoring its importance in reducing emissions. Grid decarbonization also contributes significantly, followed by charging behavior influencing emissions outcomes. Notably, assumptions regarding deadheading (SAEVs traveling empty) can lead to a substantial increase in relative emissions, highlighting the need for strategic management of SAEV operations to maximize environmental benefits.

While research in this area is still fairly preliminary—especially as it pertains to understanding the equity implications of SAEVs, we provide several of the following policy recommendations based on the findings of this work:

1. Equitable Access to SAEVs: Develop policies ensuring that Shared Autonomous and Electric Vehicles (SAEVs) are accessible to all, especially in disadvantaged communities. This includes infrastructure development like equitable distribution of charging stations and affordability schemes.
2. Incentivization of SAEV Adoption: Create incentives for adopting SAEVs, focusing on reducing emissions and promoting energy efficiency. These could include financial incentives such as tax credits, subsidies, or discounted rates for using renewable energy for charging.
3. Integration with Renewable Energy: Encourage policies that facilitate the integration of SAEVs with renewable energy sources. This can be achieved through support for renewable energy projects and mandates for SAEVs to use a certain percentage of renewable energy.
4. Data-Driven Policymaking: Implement policies that encourage the collection and analysis of data on SAEV usage. This data should be used to continually refine policies, ensuring they effectively address social, economic, and environmental impacts.

5. Community Engagement: Prioritize community engagement in policy formulation, ensuring that the voices of those in disadvantaged communities are heard. This could include public forums, surveys, and collaborative policy workshops.
6. Environmental and Health Impact Assessments: Regularly conduct comprehensive assessments to understand the environmental and health impacts of SAEVs, focusing on air quality and public health in disadvantaged areas.

References

1. Kamargianni M, Li W, Matyas M, Schäfer A. A Critical Review of New Mobility Services for Urban Transport. Transportation Research Procedia. 2016;14:3294–303.

2. Storme T, Casier C, Azadi H, Witlox F. Impact Assessments of New Mobility Services: A Critical Review. Sustainability. 2021 Mar 11;13(6):3074.

3. Sheppard CJR, Jenn AT, Greenblatt JB, Bauer GS, Gerke BF. Private versus Shared, Automated Electric Vehicles for U.S. Personal Mobility: Energy Use, Greenhouse Gas Emissions, Grid Integration, and Cost Impacts. Environ Sci Technol. 2021 Mar 2;55(5):3229–39.

4. Sheppard CJR, Bauer GS, Gerke BF, Greenblatt JB, Jenn AT, Gopal AR. Joint Optimization Scheme for the Planning and Operations of Shared Autonomous Electric Vehicle Fleets Serving Mobility on Demand. Transportation Research Record. 2019 Jun;2673(6):579–97.

5. Chen TD, Kockelman KM, Hanna JP. Operations of a shared, autonomous, electric vehicle fleet: Implications of vehicle & charging infrastructure decisions. Transportation Research Part A: Policy and Practice. 2016 Dec;94:243–54.

6. Kovačić M, Mutavdžija M, Buntak K. New Paradigm of Sustainable Urban Mobility: Electric and Autonomous Vehicles—A Review and Bibliometric Analysis. Sustainability. 2022 Aug 3;14(15):9525.

7. Olayode IO, Du B, Severino A, Campisi T, Alex FJ. Systematic literature review on the applications, impacts, and public perceptions of autonomous vehicles in road transportation system. Journal of Traffic and Transportation Engineering (English Edition). 2023 Dec;10(6):1037–60.

8. Dikshit S, Atiq A, Shahid M, Dwivedi V, Thusu A. The Use of Artificial Intelligence to Optimize the Routing of Vehicles and Reduce Traffic Congestion in Urban Areas. EAI Endorsed Trans Energy Web [Internet]. 2023 Dec 15 [cited 2024 Sep 9];10. Available from: https://publications.eai.eu/index.php/ew/article/view/4613

9. Omamode Henry Orieno, Ndubuisi Leonard Ndubuisi, Valentine Ikenna Ilojianya, Preye Winston Biu, Beryl Odonkor. THE FUTURE OF AUTONOMOUS VEHICLES IN THE U.S. URBAN LANDSCAPE: A REVIEW: ANALYZING IMPLICATIONS FOR TRAFFIC, URBAN PLANNING, AND THE ENVIRONMENT. Eng sci technol j. 2024 Jan 15;5(1):43–64.

10. Dicianno BE, Sivakanthan S, Sundaram SA, Satpute S, Kulich H, Powers E, et al. Systematic review: Automated vehicles and services for people with disabilities. Neuroscience Letters. 2021 Sep;761:136103.

11. Kassens-Noor E, Cai M, Kotval-Karamchandani Z, Decaminada T. Autonomous vehicles and mobility for people with special needs. Transportation Research Part A: Policy and Practice. 2021 Aug;150:385–97.

12. Kim K, Kim JS, Jeong S, Park JH, Kim HK. Cybersecurity for autonomous vehicles: Review of attacks and defense. Computers & Security. 2021 Apr;103:102150.

13. Onat NC, Mandouri J, Kucukvar M, Sen B, Abbasi SA, Alhajyaseen W, et al. Rebound effects undermine carbon footprint reduction potential of autonomous electric vehicles. Nat Commun. 2023 Oct 6;14(1):6258.

14. Elizabeth Deakin JH. Examining the Potential for Uber and Lyft to be Included in Subsidized Mobility Programs Targeted to Seniors, Low Income Adults, and People with Disabilities. 2020 [cited 2024 Sep 9]; Available from: https://escholarship.org/uc/item/0mw7h24f

15. Qiao S, Gar-On Yeh A. Is ride-hailing competing or complementing public transport? A perspective from affordability. Transportation Research Part D: Transport and Environment. 2023 Jan;114:103533.

16. Nair GS, Bhat CR, Batur I, Pendyala RM, Lam WHK. A model of deadheading trips and pick-up locations for ride-hailing service vehicles. Transportation Research Part A: Policy and Practice. 2020 May;135:289–308.

17. Sperling D. Three Revolutions: Steering Automated, Shared, and Electric Vehicles to a Better Future. Island Press; 2018. 234 p.

18. McCauley D, Heffron R. Just transition: Integrating climate, energy and environmental justice. Energy Policy. 2018 Aug;119:1–7.

19. Li Y, Li X, Jenn A. Evaluating the emission benefits of shared autonomous electric vehicle fleets: A case study in California. Applied Energy. 2022 Oct;323:119638.

20. Liao Z, Taiebat M, Xu M. Shared autonomous electric vehicle fleets with vehicle-to-grid capability: Economic viability and environmental co-benefits. Applied Energy. 2021 Nov;302:117500.

21. Loeb B, Kockelman KM. Fleet performance and cost evaluation of a shared autonomous electric vehicle (SAEV) fleet: A case study for Austin, Texas. Transportation Research Part A: Policy and Practice. 2019 Mar;121:374–85.

22. Saleh M, Milovanoff A, Daniel Posen I, MacLean HL, Hatzopoulou M. Energy and greenhouse gas implications of shared automated electric vehicles. Transportation Research Part D: Transport and Environment. 2022 Apr;105:103233.

23. Iacobucci R, McLellan B, Tezuka T. Modeling shared autonomous electric vehicles: Potential for transport and power grid integration. Energy. 2018 Sep;158:148–63.

24. Morfeldt J, Johansson DJA. Impacts of shared mobility on vehicle lifetimes and on the carbon footprint of electric vehicles. Nat Commun. 2022 Oct 27;13(1):6400.

25. Akimoto K, Sano F, Oda J. Impacts of ride and car-sharing associated with fully autonomous cars on global energy consumptions and carbon dioxide emissions. Technological Forecasting and Social Change. 2022 Jan;174:121311.

26. Ercan T, Onat NC, Keya N, Tatari O, Eluru N, Kucukvar M. Autonomous electric vehicles can reduce carbon emissions and air pollution in cities. Transportation Research Part D: Transport and Environment. 2022 Nov;112:103472.

27. Zhong S, Liu A, Jiang Y, Hu S, Xiao F, Huang HJ, et al. Energy and environmental impacts of shared autonomous vehicles under different pricing strategies. npj Urban Sustain. 2023 Feb 25;3(1):8.

28. Jones EC, Leibowicz BD. Contributions of shared autonomous vehicles to climate change mitigation. Transportation Research Part D: Transport and Environment. 2019 Jul;72:279–98.

29. Ahmed AA, Nazzal MA, Darras BM, Deiab IM. Global warming potential, water footprint, and energy demand of shared autonomous electric vehicles incorporating circular economy practices. Sustainable Production and Consumption. 2023 Mar;36:449–62.

30. Sun R, Circella G, Jaller M, Qian X, Alemi F. Impacts of Connected and Automated Vehicles on Travel Demand and Emissions in California. Transportation Research Record: Journal of the Transportation Research Board. 2023 Aug 22;03611981231186984.

31. Jenn A. Emissions of electric vehicles in California's transition to carbon neutrality. Applied Energy. 2023 Jun;339:120974.

32. Jenn A, Clark-Sutton K, Gallaher M, Petrusa J. Environmental impacts of extreme fast charging. Environ Res Lett. 2020 Sep 1;15(9):094060.

33. Tong F, Jenn A, Wolfson D, Scown CD, Auffhammer M. Health and Climate Impacts from Long-Haul Truck Electrification. Environ Sci Technol. 2021 Jul 6;55(13):8514–23.

34. Gilmore EA, Heo J, Muller NZ, Tessum CW, Hill JD, Marshall JD, et al. An inter-comparison of the social costs of air quality from reduced-complexity models. Environ Res Lett. 2019 Jul 1;14(7):074016.

35. Heo J, Adams PJ, Gao HO. Reduced-form modeling of public health impacts of inorganic PM 2.5 and precursor emissions. Atmospheric Environment. 2016 Jul;137:80–9.

36. Heo J, Adams PJ, Gao HO. Public Health Costs of Primary $PM_{2.5}$ and Inorganic $PM_{2.5}$ Precursor Emissions in the United States. Environ Sci Technol. 2016 Jun 7;50(11):6061–70.

Data Summary

This data repository includes a wide array of datasets designed to support this research project. The repository is a compilation of multidimensional data that spans demographic profiles, environmental quality indices, socioeconomic factors vehicle specifications, and travel demand estimations. It serves as a foundational resource for analyzing the effects of Shared Autonomous Electric Vehicles (SAEVs) on mobility, energy consumption, and emissions within disadvantaged communities across California. The datasets are structured to facilitate comprehensive analyses, offering insights into the current state and potential future scenarios of SAEV integration into these communities. Each dataset within the repository is accompanied by rich metadata, ensuring clarity, context, and ease of use for researchers and policymakers.

Data Format and Content

1. Demographic Data:

Population statistics of disadvantaged communities in California including income levels, employment rates, and education levels are derived from employ CalEnviroScreen 4.0 developed by the California Office of Environmental Health Hazard Assessment: https://oehha.ca.gov/calenviroscreen/report/calenviroscreen-40

2. Vehicle Data:

The fleet average vehicle energy efficiencies and on-road emission rates of light-/heavy-duty ICEVs and PEVs are estimated through the CARB EMission FACtor (EMFAC) model: https://arb.ca.gov/emfac/emissions-inventory

Temporal charging patterns of SAEVs are simulated from empirical data from observed charging patterns collected from a previous research project of the Electric Vehicle Research Center at UC Davis: https://ev.ucdavis.edu/project/evmt

3. Travel Demand Data:

Sun, Ran et al. (2021). Emissions impact of connected and automated vehicle deployment in California - model results [Dataset]. Dryad. https://doi.org/10.25338/B86926

4. Grid Emission Factor Data:

The emission factors of power plants are derived from EPA'S Emissions & Generation Resource Integrated Database (eGRID): https://www.epa.gov/egrid

Data Access and Sharing

All data is publicly available in the links provided above.

Reuse and Redistribution

No restrictions on the reuse and redistribution of data.