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Emissions Implications of Shared, Autonomous, and Electric Vehicle Fleets: A Case Study of California's Near Future

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Abstract

The transportation sector is a major source of greenhouse gas (GHG) emissions. Shared autonomous electric vehicles (SAEVs) have the potential to mitigate emissions, but the effect can be highly dependent on the growth and operation of the SAEV fleet as well as its interaction with the evolving power system. In this study, we simulate travel and charging behaviors of SAEVs based on empirical data of ride-hail service operations, and integrate SAEV charging with the Grid Optimized Operation Dispatch (GOOD) model, taking into account the expansion of renewable generation and charger capacity over time. Emissions from SAEVs are compared across different market adoption levels, occupancy rates, and charging strategies. We find that SAEVs are generally more than 6 times less carbon intensive than modern day ICVs on a per mile basis. The extent of aligning charging schedule with renewable generation is an essential determinant of the economic and emission savings from an SAEV fleet. At higher levels of renewable penetration, synergizing SAEV charging with grid operation can be the most impactful means to reduce emissions from an SAEV fleet, generating up to 95% less emissions than other charging strategies. We also examine the introduction of a carbon tax and find that it can further amplify the advantage of smart charging by approximately 1.5 times in the cost-effectiveness of emission mitigation.

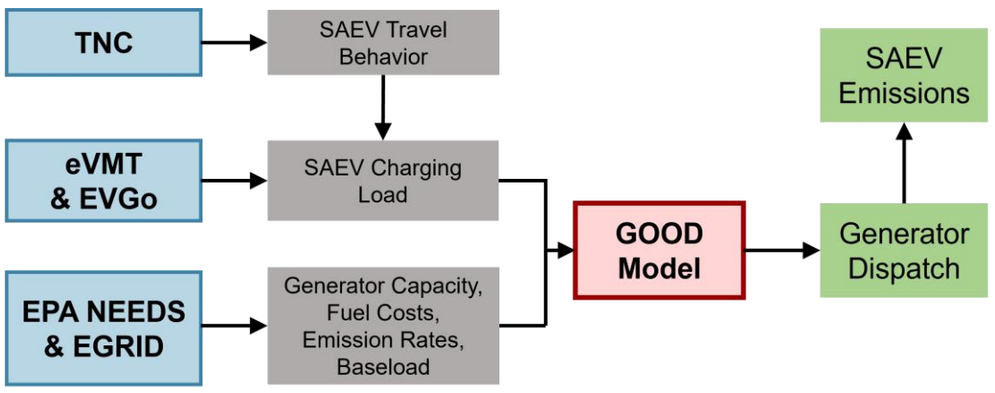

Figure 1: Data sources (blue), intermediate data (gray), model (red), and outputs (green) in the general research framework

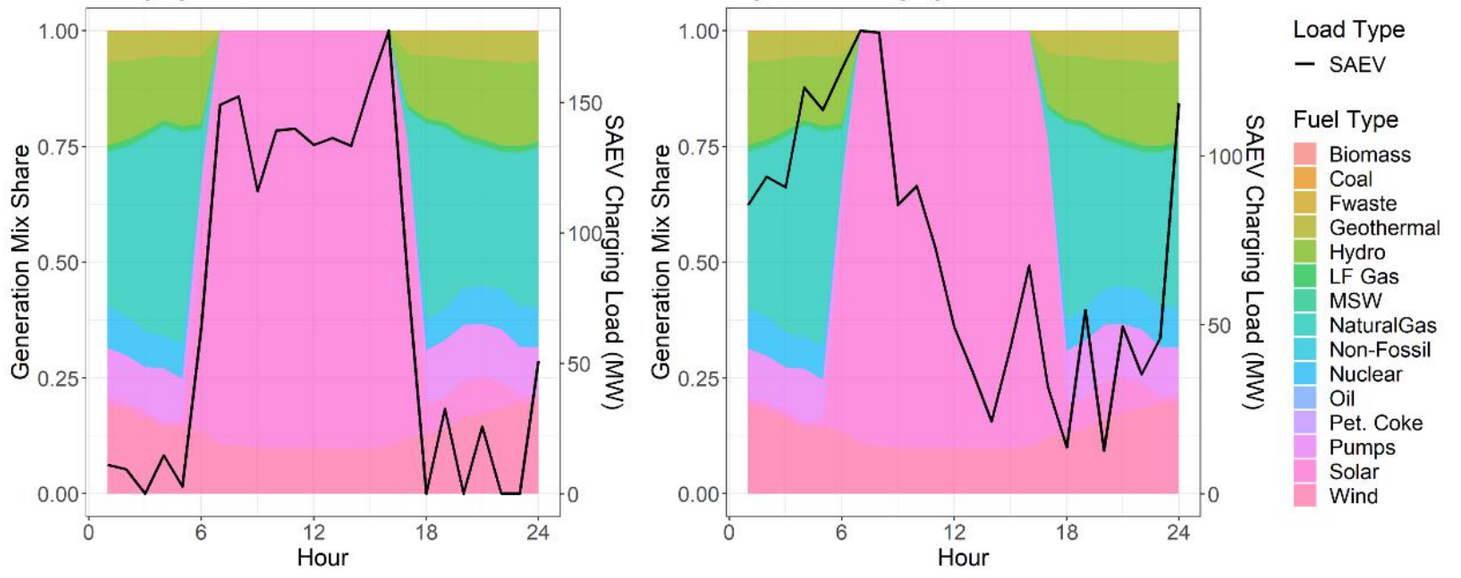

Figure 2: Hourly generation mix in California and SAEV charging load of different charging strategies, on a typical spring day of 2030, with medium SAEV adoption level, occupancy rate of 1 passenger, and without applying carbon tax

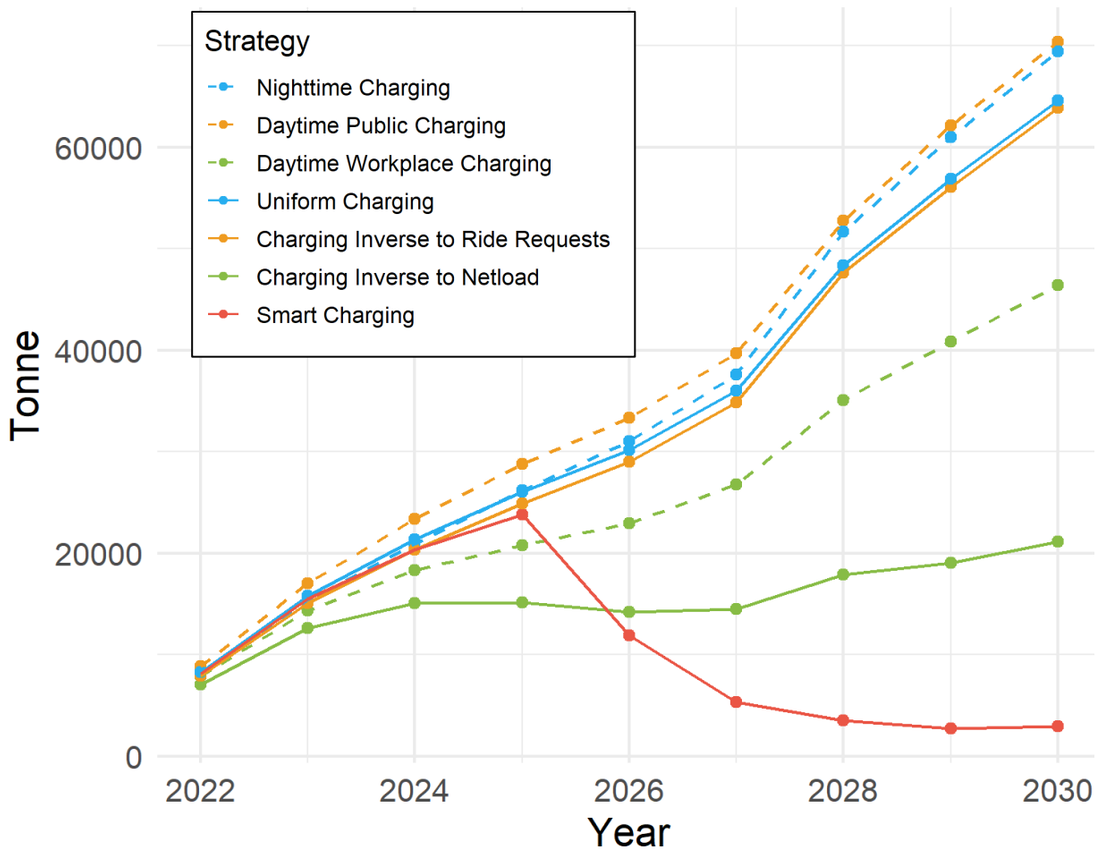

Figure 3: Total annual CO2 emission caused by SAEVs in California, under different charging strategies, with medium adoption level and occupancy rate of 1 passenger, without applying carbon tax

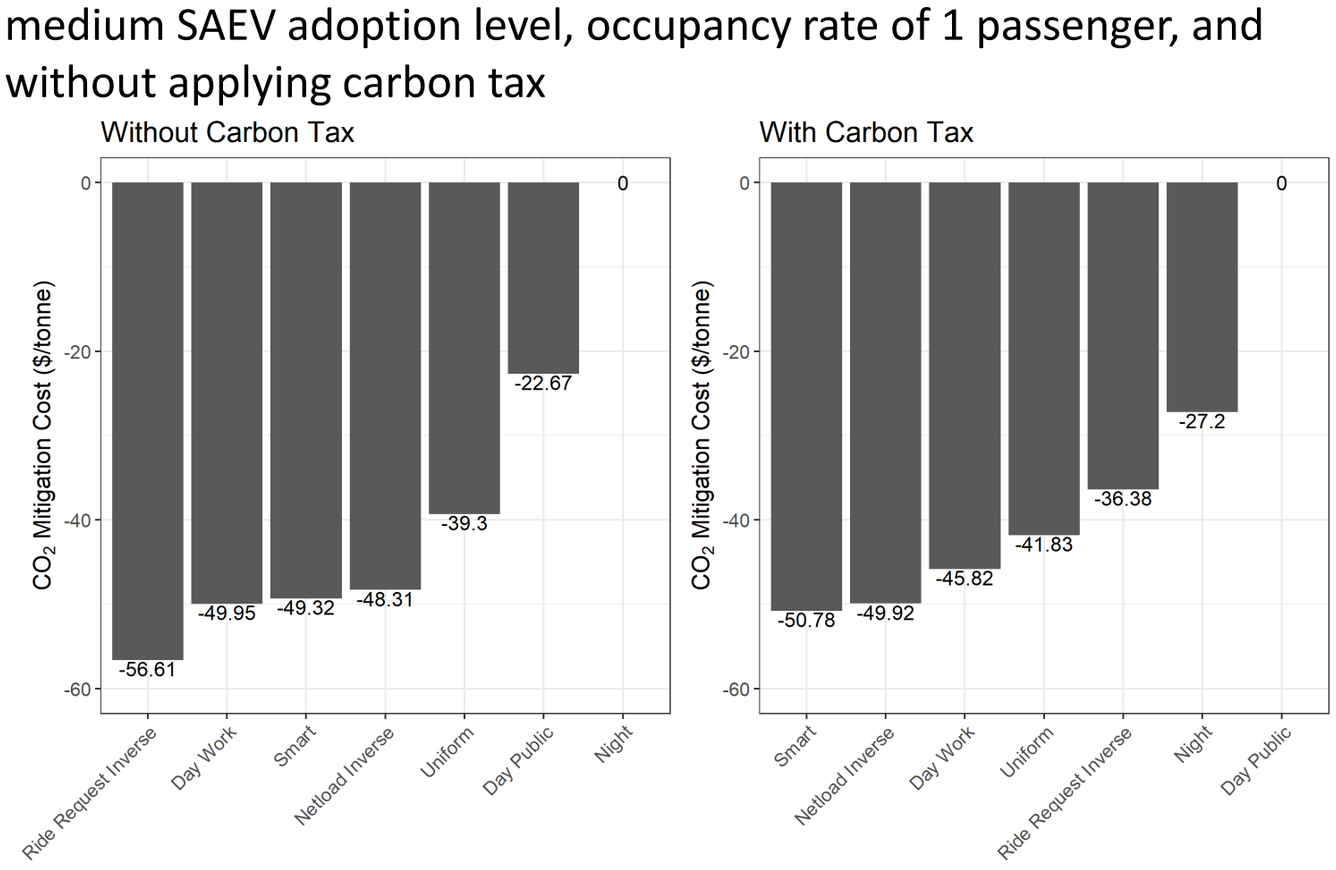

Figure 4: Relative CO2 mitigation cost by switching from the most carbon-intensive charging strategy to other charging strategies for SAEVs, under medium adoption level and occupancy rate of 1 passenger, 2030, California