Electric Vehicle Effects on Gasoline and Electricity Consumption

SwRI® Project No. 03.28490

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June 18, 2024

Benefiting government, industry and the public through innovative science and technology

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1 INTRODUCTION

Regulators and governments are encouraging the adoption of electric vehicles to replace liquid fueled vehicles. There are a range of policies including consumer tax credits for electric vehicle purchases and CO_2 regulations based only on tailpipe emissions. These policies have important implications for the future consumption of liquid fuels and electricity. But sales of electric vehicles will be affected by vehicle prices, fuel prices, customer acceptance, and other factors, so there is substantial uncertainty about the rate of adoption.

The purpose of this study is to quantify consumption of liquid fuels and electricity for a range of scenarios extending to 2035. The scenarios account for the possible effects of regulatory requirements and other relevant factors, and for the survival rates of vehicles in the on-road fleet.

To estimate future consumption of liquid fuels and electricity, for each scenario, the following quantities must be calculated:

1) How many electric and liquid-fueled vehicles will be sold each year.
2) How many electric and liquid-fueled vehicles from previous years will survive as part of the on-road fleet each year.
3) How much electricity and liquid fuel will be consumed by these vehicles.

2 REGULATORY PRESSURES FOR ELECTRIC VEHICLES

In the U.S., there are both federal and state regulatory pressures for electric vehicles which must be accounted for.

2.1 Federal

The primary federal pressure for electric vehicles is from the EPA emissions standards[1] which were finalized in March 2024. These standards only account for tailpipe emissions. Because electric vehicles have zero tailpipe emissions, they are expected to play a dominant role in meeting the aggressive EPA requirements for CO_2 emissions.

2.2 State

California's "Advanced Clean Cars II" (ACC II) regulations mandate that each year an increasing fraction of new light duty vehicle sales be "Zero Emissions Vehicles" (ZEVs). These regulations are also based on tailpipe emissions, so generally[2] only battery electric vehicles (BEVs) and hydrogen fuel cell vehicles qualify as ZEVs. Fuel cell vehicles are not expected to play a significant role in meeting ACC II requirements, due to an extremely limited supply of fuel cell

[1] "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles", 40 CFR Parts 85, 86, 600, 1036, 1037, 1066, and 1068, March 2024, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model

[2] Plug-in hybrid electric vehicles (PHEVs) are allowed to count for up to 20% of California ACC II ZEV requirements, but the "Max BEV" scenario in this study assumes no PHEVs will be used for ACC II.

vehicles and the hydrogen to refuel them. Many other states are also adopting ACC II mandates, which will be discussed later in this paper.

3 ESTIMATED SALES OF ELECTRIC VEHICLES

3.1 EPA Effects on BEV Sales

The EPA standards do not explicitly require the use of electric vehicles. The rules set targets for CO_2 emissions each year, within a complex framework of passenger car and truck fleets, "footprint" (vehicle size) based targets, off-cycle credits (the "adjusted" lines in Figure 1), trading of credits between manufacturers, etc. The overall result[3] is that light-duty vehicles in MY2032 would need to produce about 54% lower average CO_2 emissions than in MY2026:

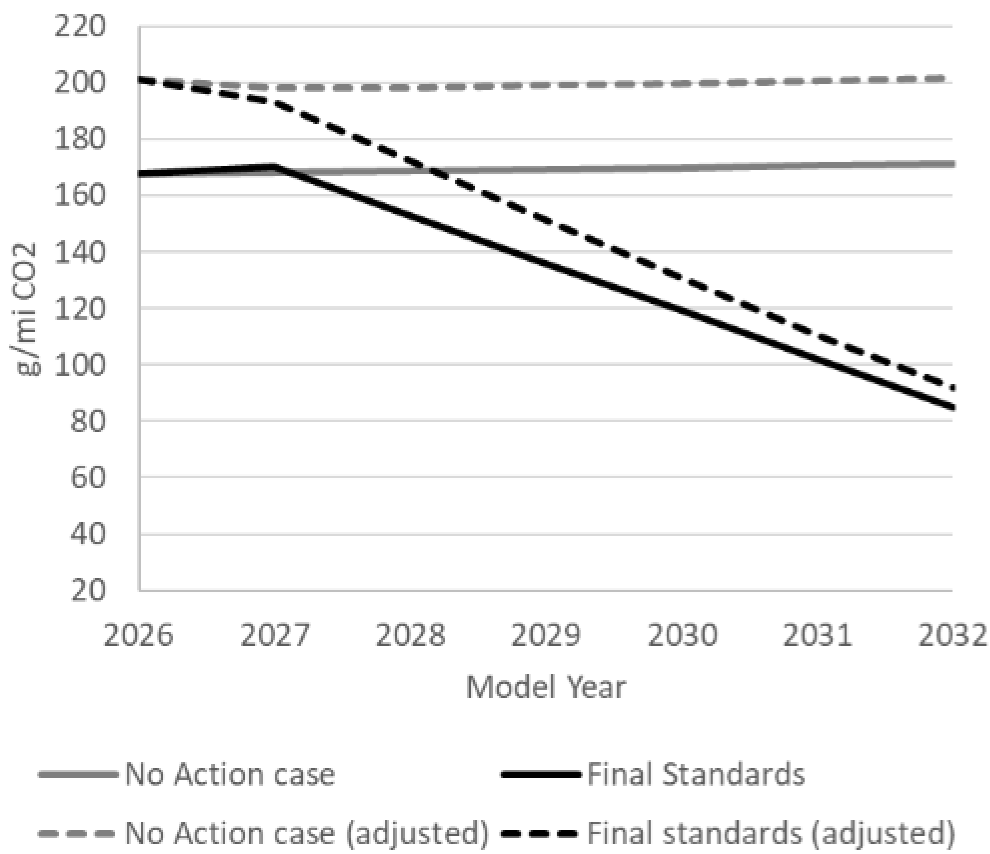

FIGURE 1: INDUSTRY AVERAGE CO_2 TARGETS FROM EPA

[3] Figure 9 and Table 22 of EPA "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles", 40 CFR Parts 85, 86, 600, 1036, 1037, 1066, and 1068, March 2024, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model

Such a rapid reduction in CO_2 emissions will be very challenging for automakers to achieve. The EPA uses models to estimate what technologies automakers would use to meet the standards. The models include assumptions for the tailpipe CO_2 benefit and the cost of each technology, the feasibility of implementing new technologies, and other factors. Based on these assumptions, EPA's modeling indicates that automakers will primarily rely on electric vehicles to meet the standards, while other individual technologies will play a much smaller role. As shown in Figure 2, EPA's "central analysis case" assumes[4] that new vehicle sales in 2032 will consist of 56% battery electric vehicles (BEVs). EPA evaluated two alternative "Pathways" to achieve the CO_2 targets with lower BEV sales, but higher sales of plug-in hybrid electric vehicles (PHEVs). The "No Action" scenario is EPA's estimate for BEV sales without any new CO_2 regulations after 2022, which shows 35% BEV sales for MY2032.

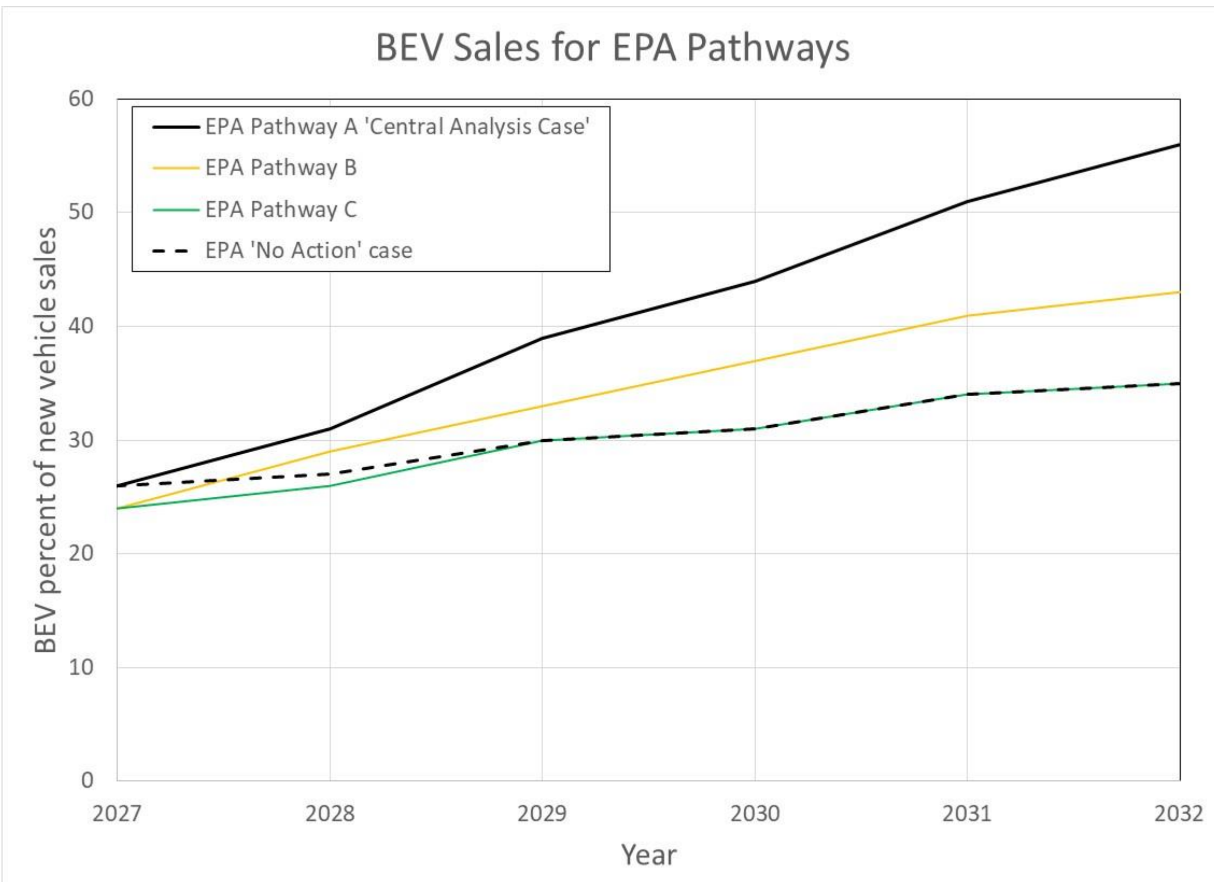

FIGURE 2: ELECTRIC VEHICLE SALES FOR EPA PATHWAYS

[4] Table 3 of EPA "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles", 40 CFR Parts 85, 86, 600, 1036, 1037, 1066, and 1068, March 2024, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model

3.2 ACC II Effects on BEV Sales

All or part of California's "Advanced Clean Cars II" (ACC II) regulations have been adopted by 17 other states,[5] which account for 40% of U.S. vehicle sales. ACC II requires[6] higher BEV sales than the national rates estimated by EPA, up to 82% in 2032 and 100% in 2035 (Figure 3):

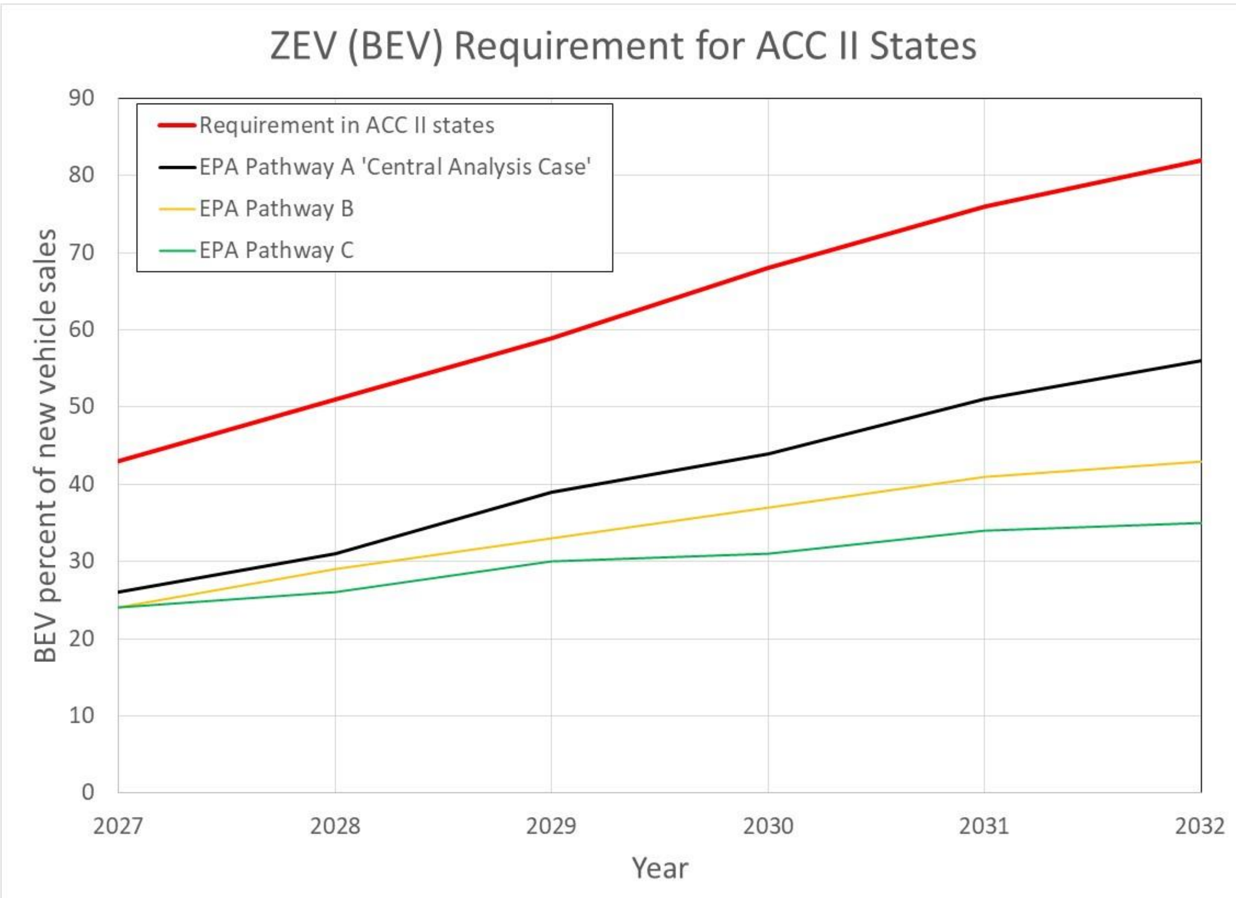

FIGURE 3: ZEV (BEV) REQUIREMENTS FOR ACC II

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[5] https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/states-have-adopted-californias-vehicle-regulations

[6] https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii

The EPA analysis included[7] the effects of ACC II ZEV requirements in California and 14 other states. The additional three potential ACC II states account for 6.0% of U.S. new vehicle sales[8]. The "Max BEV" scenario for the present study assumes ACC II in these three states, as shown in Figure 4.

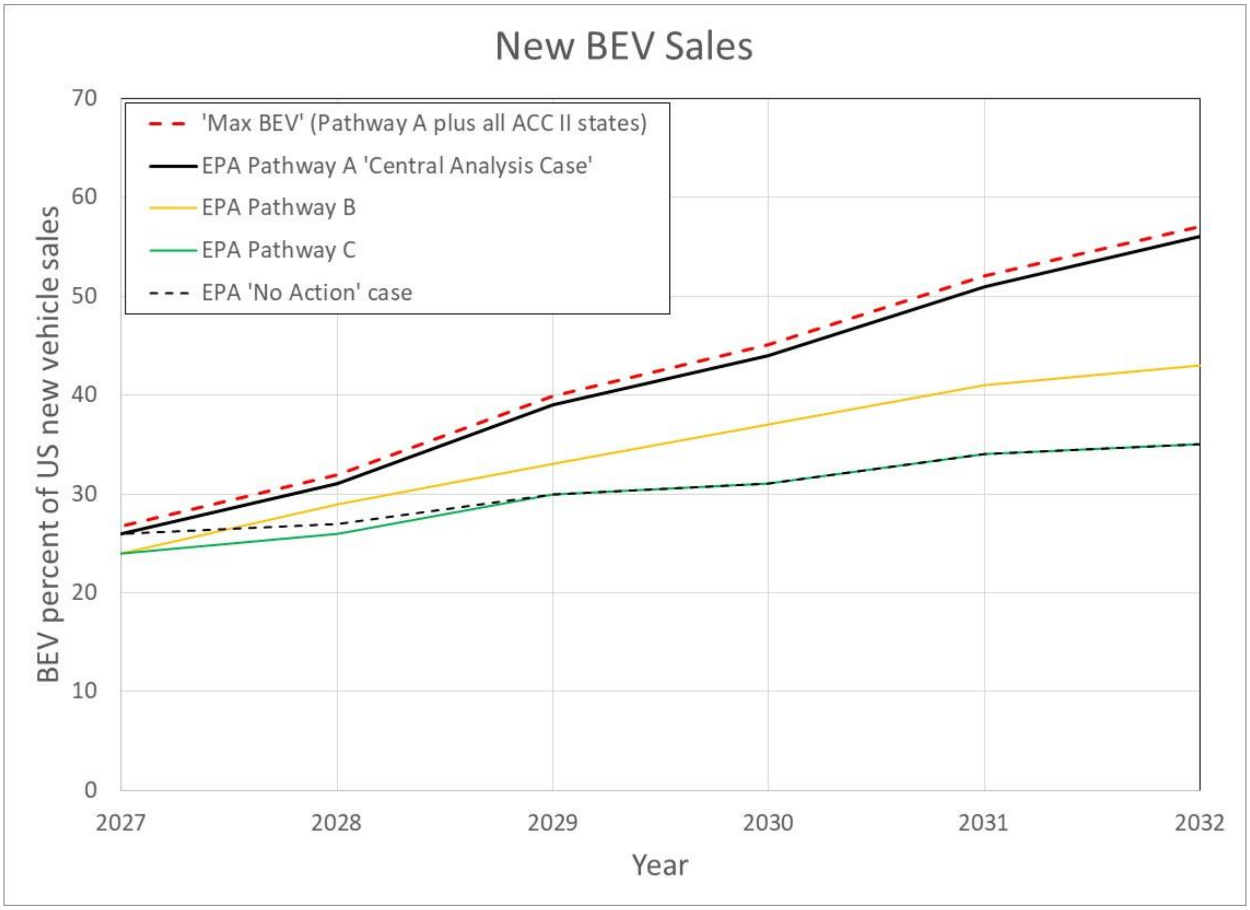

FIGURE 4: BEV SCENARIOS 2027 TO 2032

[7] The three ACC II states not in the EPA analysis are MN, NV, and PA - Table 112 of EPA "Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles", 40 CFR Parts 85, 86, 600, 1036, 1037, 1066, and 1068, March 2024, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model

[8] NADA DATA 2022 Annual Financial Profile of America's Franchised New-Car Dealerships, https://www.nada.org/media/4695/download?inline

3.3 Overall Scenarios for BEV Sales

The EPA standards cover MY2027 to MY2032, but this study covers 2022 to 2035. Therefore, the scenarios were interpolated back to 2022 data, and extrapolated to 2035 based on linear trends from 2029 to 2032. Figure 5 illustrates that even the EPA "No Action" case assumes large increases in BEV sales compared to 2022.

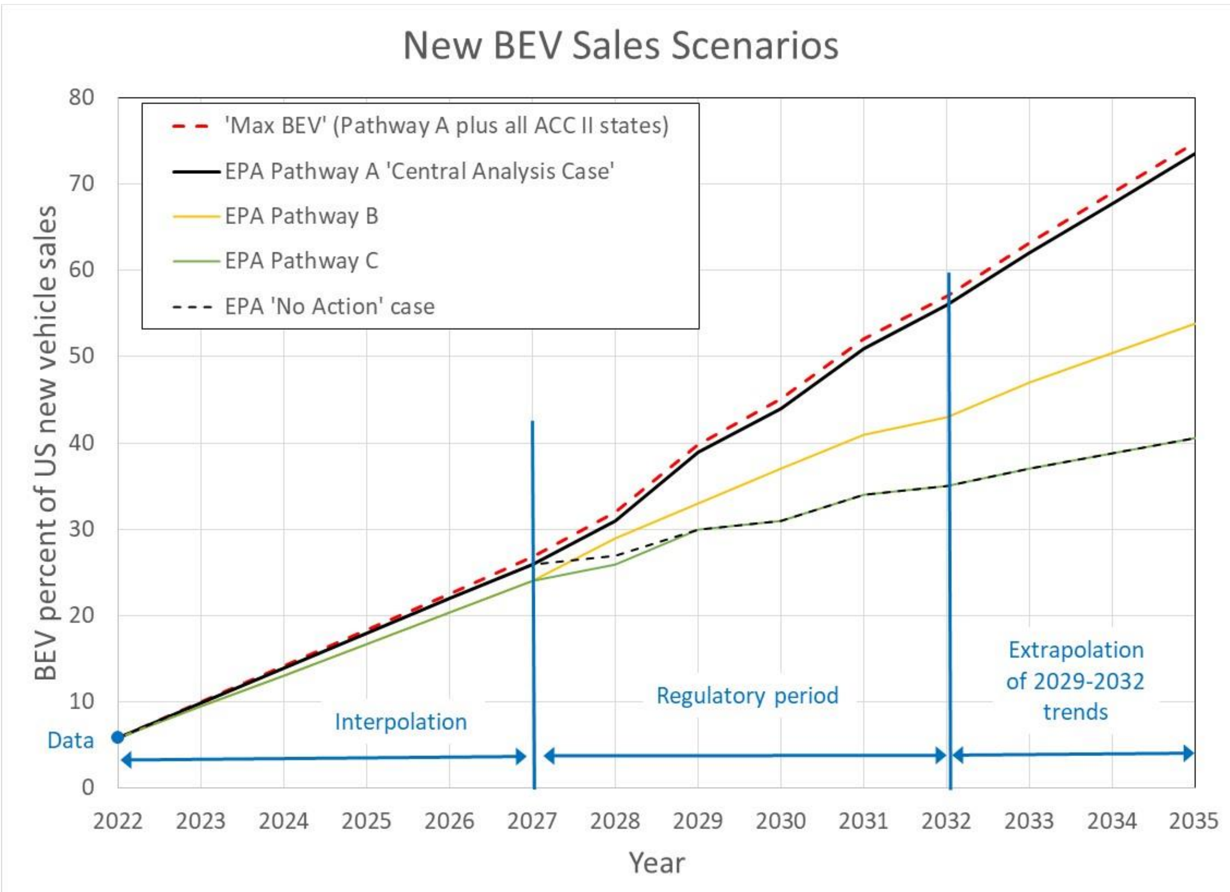

FIGURE 5: BEV SCENARIOS 2022 TO 2035

The U.S. Energy Information Administration (EIA) Annual Energy Outlook contains independent projections[9] of market share for BEVs, as shown in Figure 6. The EIA analysis indicates that oil price would have a large effect on future BEV sales, but even high oil prices would result in lower BEV sales than the EPA "No Action" case. This wide range of scenarios for BEV sales results in a large uncertainty in the future consumption of liquid fuels and electricity.

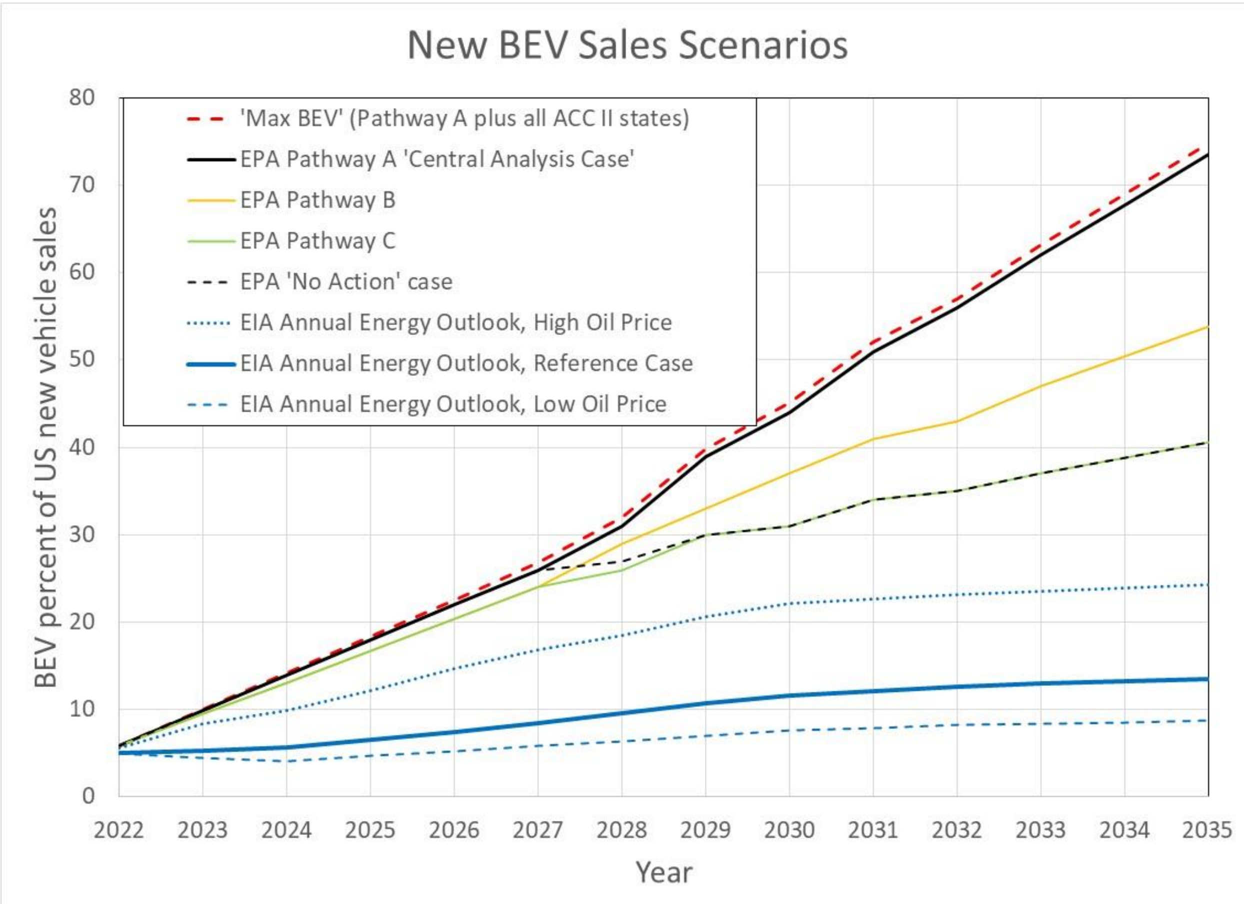

FIGURE 6: EPA AND EIA BEV SCENARIOS

[9] Table 38 of EIA Annual Energy Outlook, March 2023 (March 2024 edition not published) https://www.eia.gov/outlooks/aeo/data/browser

4 VEHICLE SURVIVAL AND ON-ROAD FLEETS

To quantify consumption of liquid fuels and electricity, an estimate is needed for the on-road fleet sizes of liquid-fueled and electric vehicles for each scenario. This requires estimates for new vehicles being added to the fleet each year (as described above) and estimates for older liquid-fueled and electric vehicles being removed from the fleet each year (as described below).

4.1 Vehicle Survival Rates

The EPA uses detailed models of the on-road fleet, which assume slightly different survival rates[10] for various types of vehicles. The present study assumes the average EPA survival rate for sedans, crossover vehicles, and pickup trucks, as shown in Figure 7.

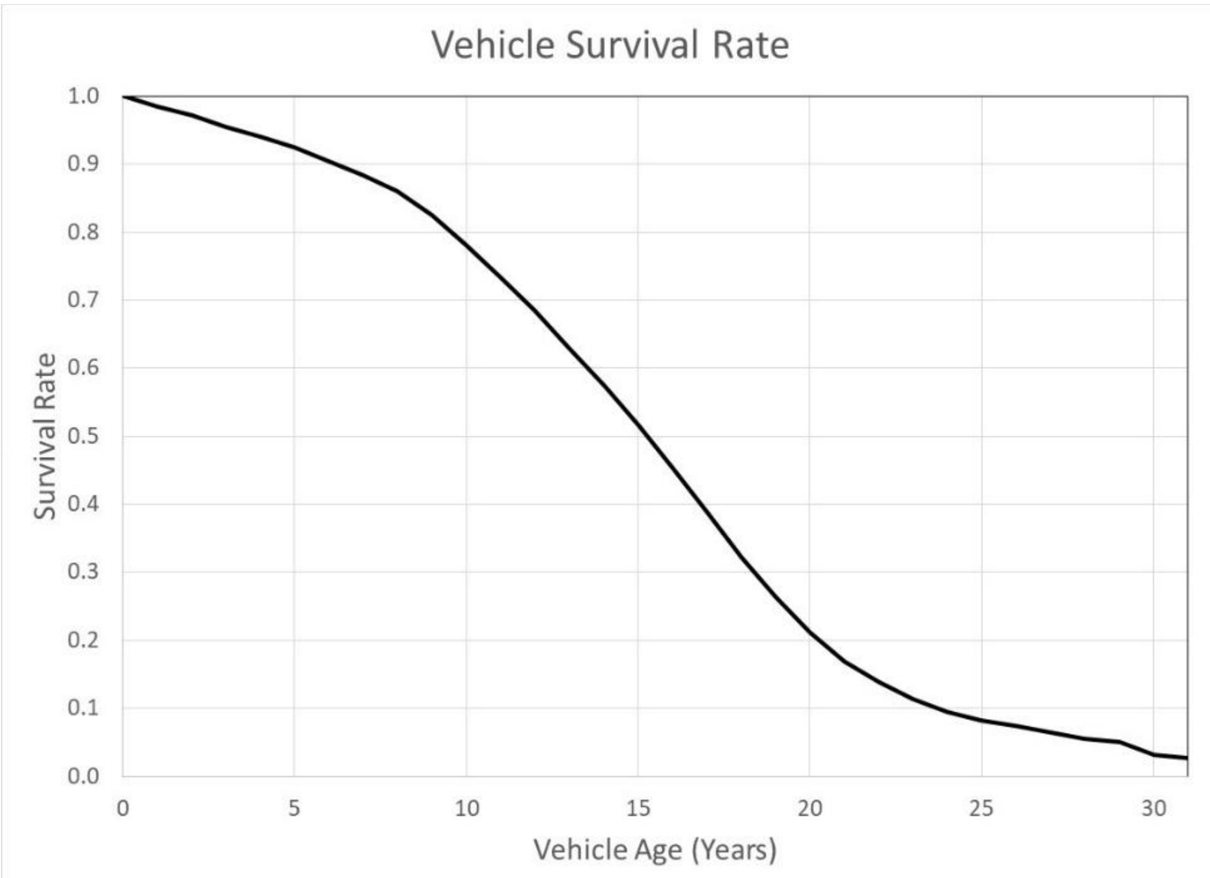

FIGURE 7: VEHICLE SURVIVAL RATE

[10] Table 8-1 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024, https://www.epa.gov/system/files/documents/2024-03/420r24004.pdf

4.2 On-Road ICE and BEV Fleets

EPA estimated[11] the size of the on-road fleets of liquid-fueled (internal combustion engine or ICE plus HEVs) and electric vehicles (BEVs and PHEVs) for various scenarios. The EPA estimate for Pathway A was adjusted to create a "Max BEV" scenario based on additional ACC II BEV sales, as described above. Vehicle survival rates were also used to convert the EIA Annual Energy Outlook scenarios for new BEV and ICE sales into scenarios for on-road fleets. On-road fleets for all scenarios are summarized in Figure 8.

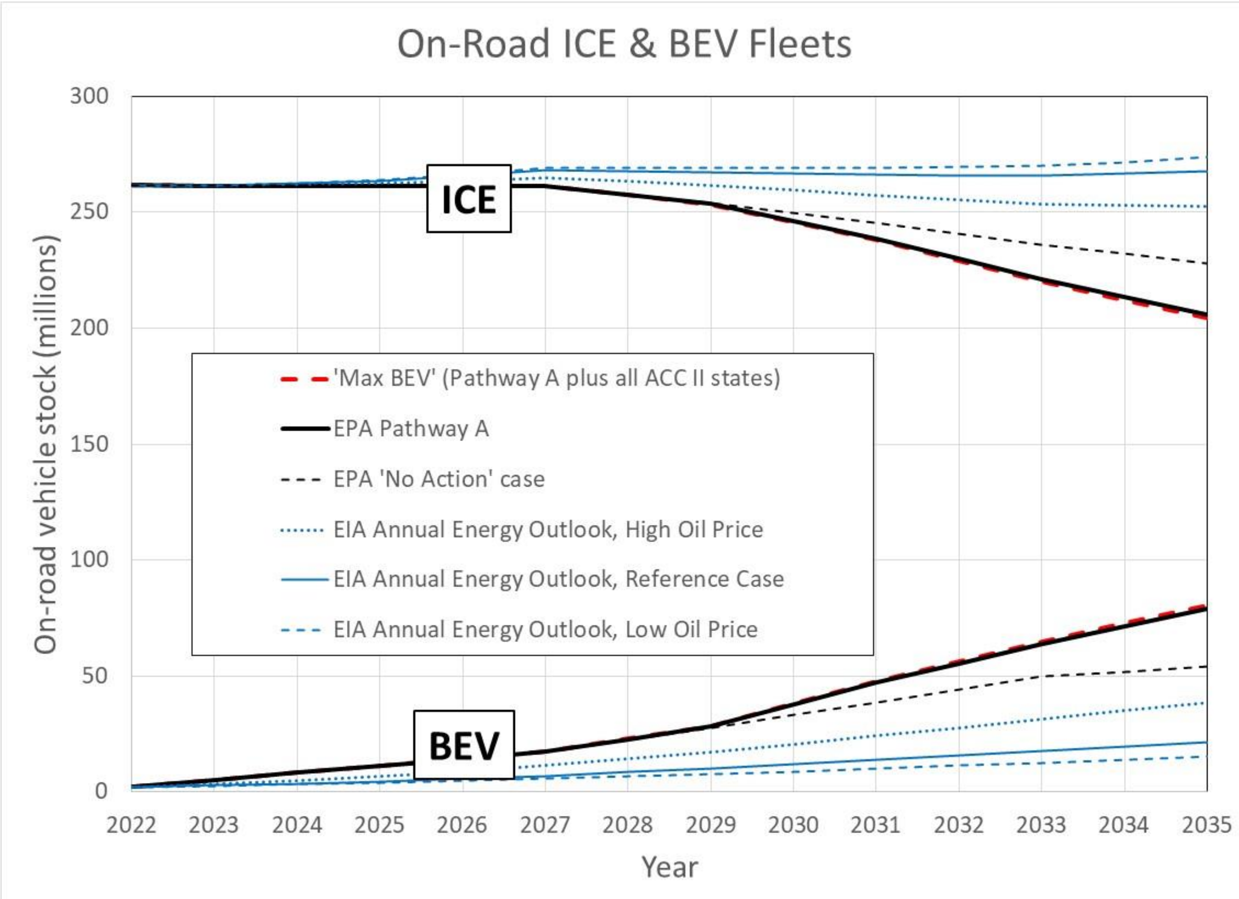

FIGURE 8: ON-ROAD ICE AND BEV FLEETS

[11] Figures 8-1 and 8-2 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024, https://www.epa.gov/system/files/documents/2024-03/420r24004.pdf

5 CHANGES IN ELECTRICITY CONSUMPTION

Increasing sales of battery electric vehicles (BEVs) will cause increases in electricity consumption. However, the magnitude of the increase varies dramatically for different scenarios of BEV sales.

5.1 Regulatory Scenarios

The EPA calculates changes in electricity consumption using modeling which tracks many details including a heterogenous fleet of vehicles of various sizes, ages, and powertrain technologies. The EPA results are published only as change in electricity consumption compared to the "No Action" case (no new CO_2 regulations after 2022).

The results of the EPA modeling show reasonably linear behavior (Figure 9) for change in electricity consumption versus change in the number of BEVs+PHEVs in the on-road fleet. The slope of this line is used to estimate electricity consumption for the "Max BEV" and "No Action" scenarios. The slope of the line is also used to estimate electricity consumption changes compared to a 2022 baseline, rather than to the EPA "No Action" case. This is an important part of the analysis, because the EPA "No Action" case assumes substantial BEV sales, e.g. 35% in 2032.

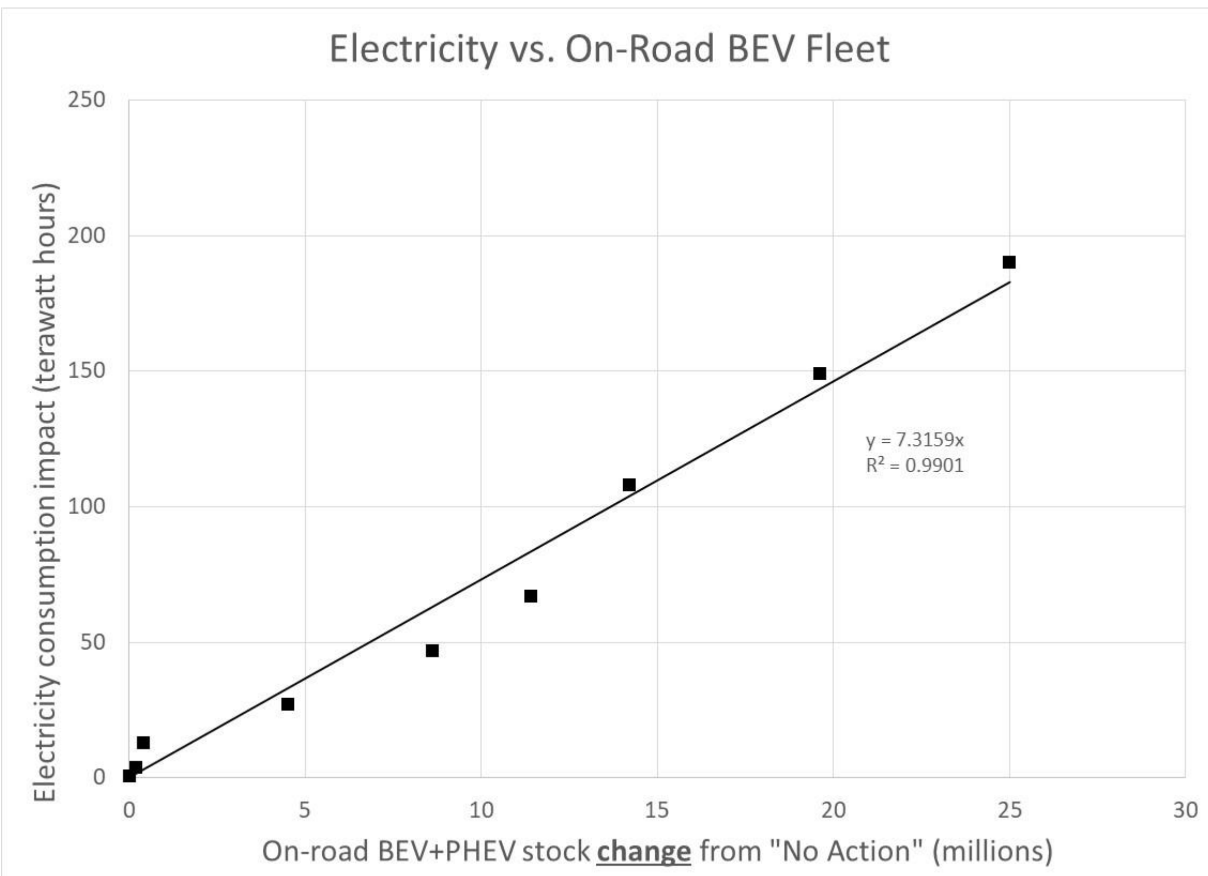

FIGURE 9: ELECTRICITY CONSUMPTION VS. ON-ROAD BEV FLEET

5.2 EIA Scenarios

The EIA Annual Energy Outlook contains independent projections of electricity consumption due to electric vehicles, which are lower than the EPA estimates due to lower assumed BEV sales. Figure 10 shows estimated changes in electricity consumption for all scenarios, in terawatt hours (TWh) and as a percent of total 2022 electricity consumption.

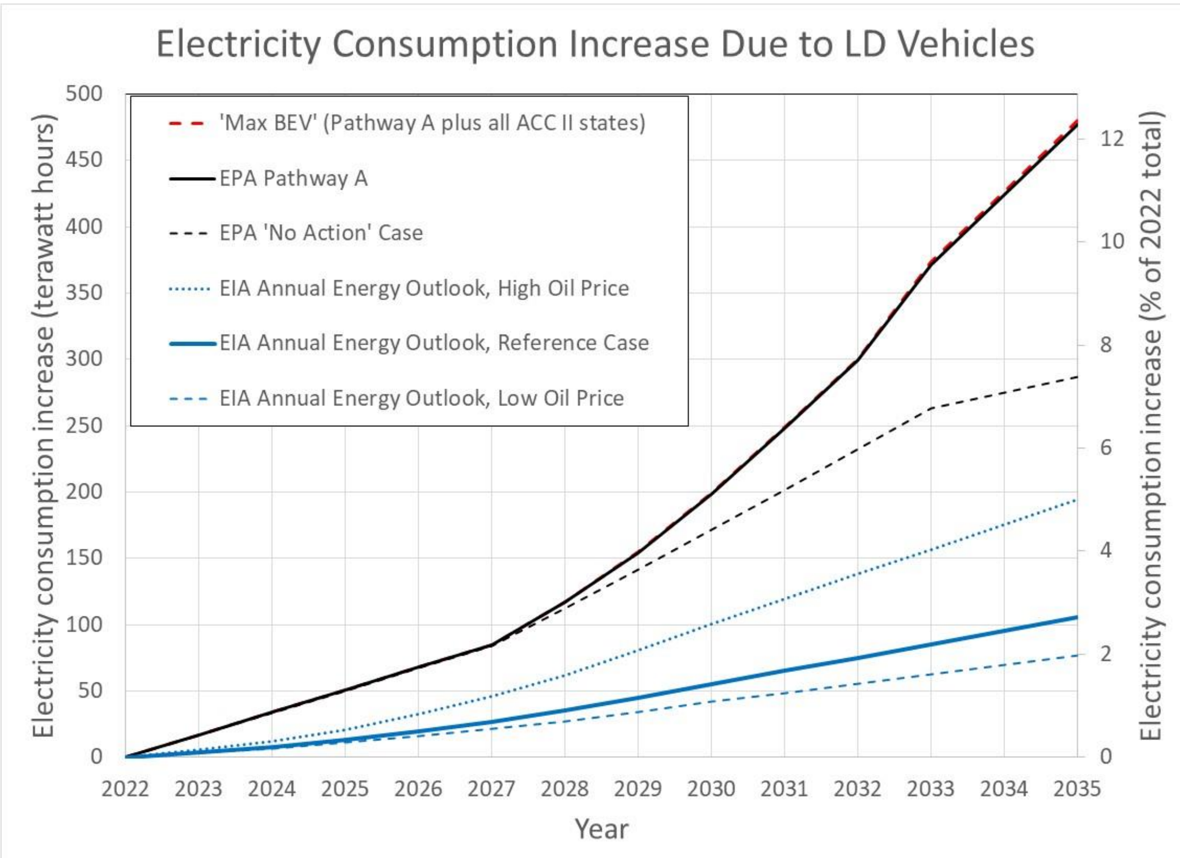

FIGURE 10: CHANGES IN ELECTRICITY CONSUMPTION

6 CHANGES IN LIQUID FUEL CONSUMPTION

Increasing sales of battery electric vehicles (BEVs) will ultimately cause decreases in liquid fuel consumption. However, the magnitude of the decrease varies dramatically with the range of different scenarios of BEV sales, and it also varies due to other factors discussed below.

6.1 Regulatory Scenarios

Like electricity consumption, EPA calculates changes in liquid fuel consumption for several scenarios, using modeling which tracks many details including a heterogenous fleet of vehicles of various sizes, ages, and powertrain technologies. The EPA results are published only as change in liquid fuel consumption compared to the "No Action" case (no new CO_2 regulations after 2022).

The results of the EPA modeling show reasonably linear behavior (Figure 11) for change in liquid fuel consumption versus change in the number of ICE+HEV vehicles in the on-road fleet. The slope of this line is used to estimate liquid fuel consumption for the "Max BEV" and "No Action" scenarios. The slope of the line is also used to estimate liquid fuel consumption changes compared to a 2022 baseline, rather than to the EPA "No Action" case. This is an important part of the analysis, because the EPA "No Action" case assumes substantial BEV sales, e.g. 35% in 2032, which would significantly reduce the number of on-road ICE vehicles.

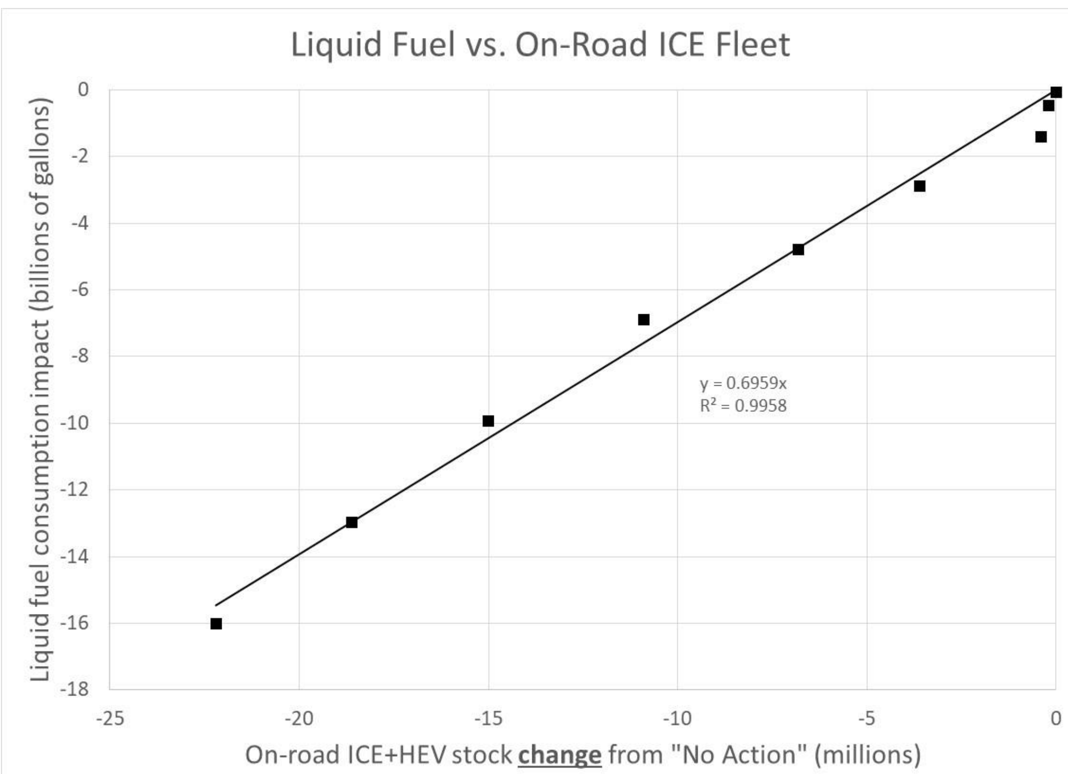

FIGURE 11: LIQUID FUEL CONSUMPTION VS. ON-ROAD ICE FLEET

6.2 EIA Scenarios

The EIA Annual Energy Outlook contains independent projections of liquid fuel consumption, which are substantially different from the EPA estimates. The plots below show estimated decreases in liquid fuel consumption for all scenarios, in gallons and as a percent of total 2022 gasoline consumption.

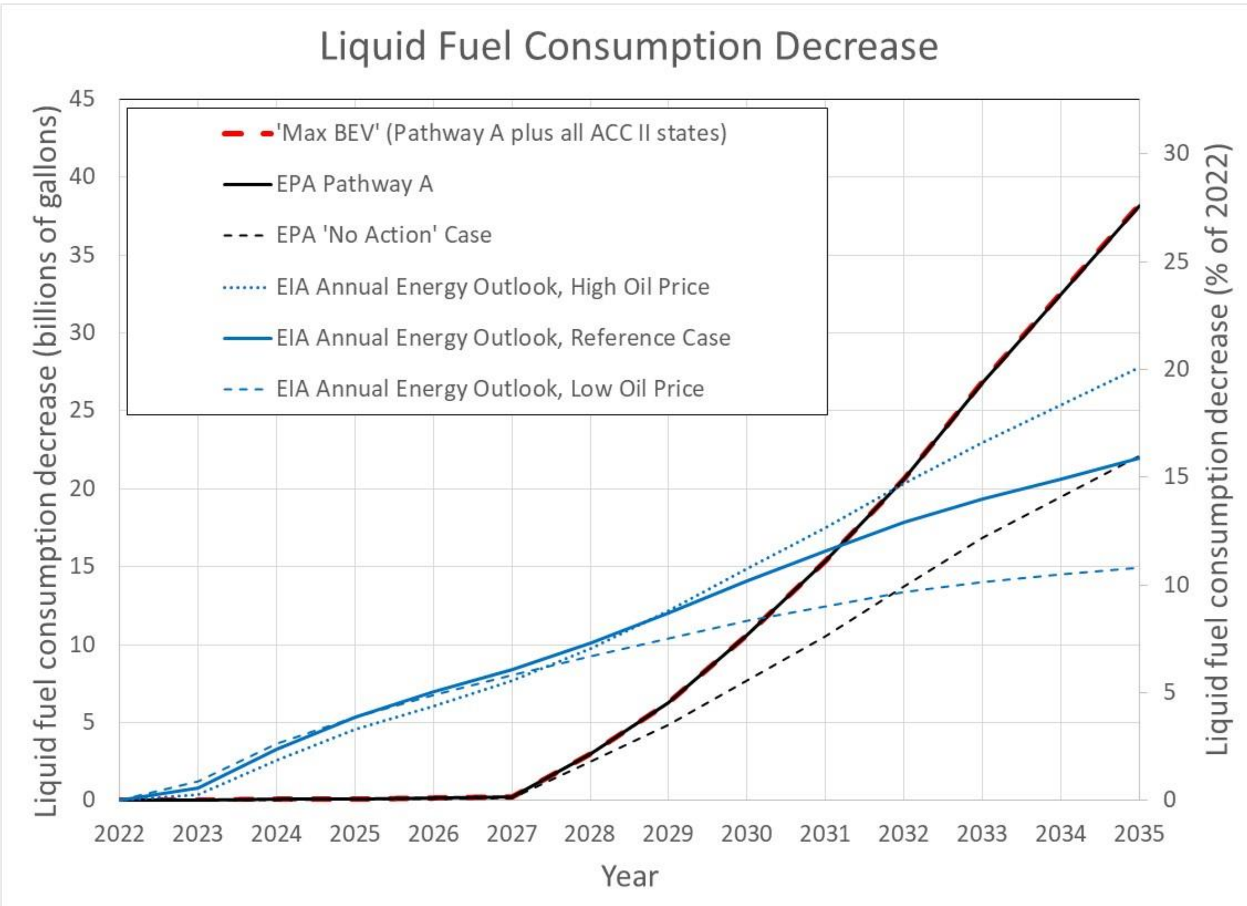

FIGURE 12: CHANGES IN LIQUID FUEL CONSUMPTION

Note that the EIA estimate shows a steady change in liquid fuel consumption, while the EPA estimate shows a non-linear trend. EPA assumes that almost all changes in liquid fuel consumption will be from increasing BEV sales. EPA's modeling indicates that other technologies will play very minor roles, for example HEV sales[4] are estimated to decrease to 3% market share by 2032.

In contrast, EIA assumes steady changes in the number of on-road BEVs (Figure 8), and assumes steady increases in HEV sales and other improvements in the efficiency of liquid-fueled vehicles.

6.3 Low-Carbon Fuel Scenario

The EPA standards assume that all light duty vehicle tailpipe CO_2 improvements will be achieved with vehicle technology improvements. Although EPA counts BEVs as "zero emissions" for regulatory purposes, it estimates upstream CO_2 emissions for electricity generation when quantifying[12] net CO_2 benefits[13] of the regulations, as shown in Figure 13.

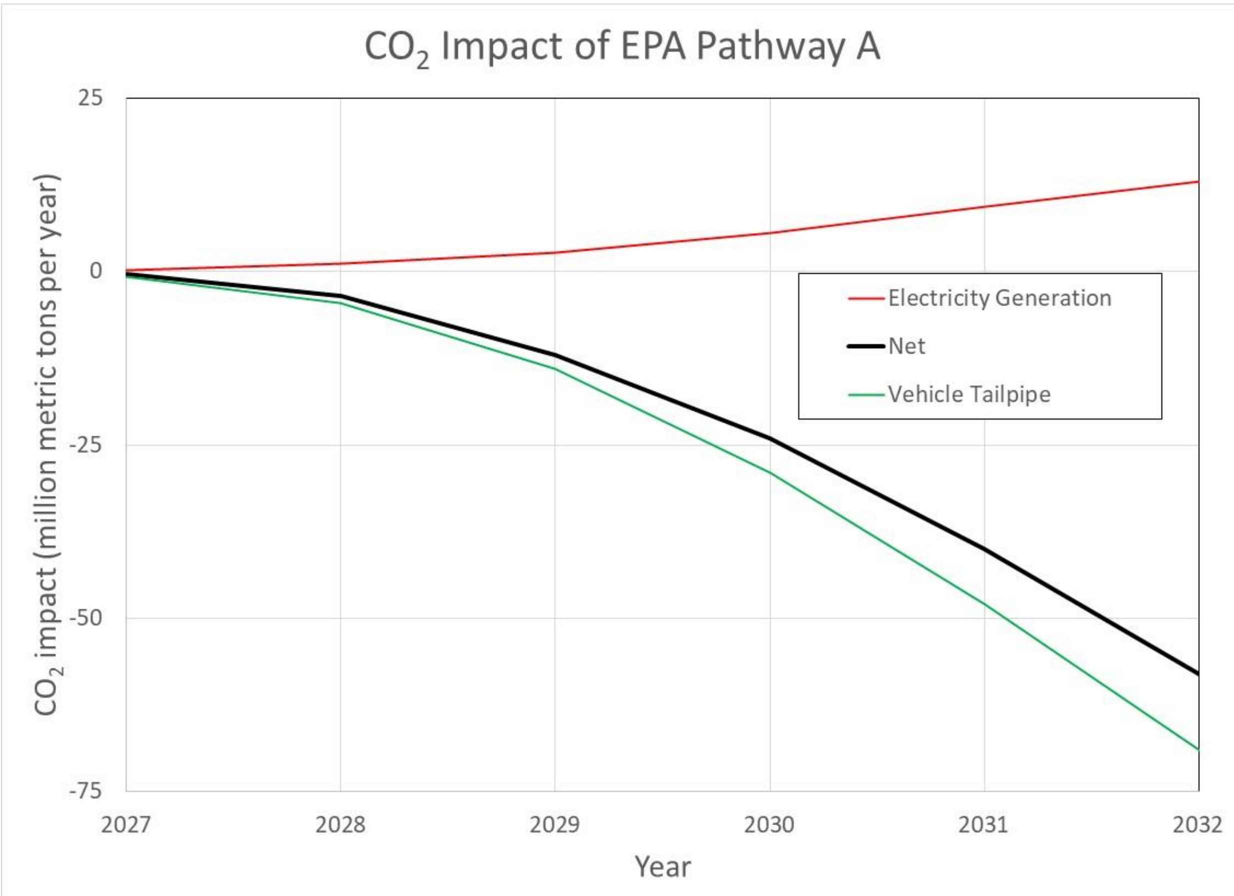

FIGURE 13: CO_2 IMPACT OF EPA STANDARDS

[12] Tables 8-22 and 8-25 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024, https://www.epa.gov/system/files/documents/2024-03/420r24004.pdf

[13] These numbers do not include CO_2 emissions from vehicle and battery manufacturing

The EPA calculations for CO_2 emissions of electricity generation assume a grid carbon intensity[14] of 278 gCO_2/kWh in 2028, and 135 $gCO_2/kWhr$ in 2035. These values are 29% and 65% better than the 2022 U.S. average according to EIA data[15]. While EPA assumes continuous improvement in carbon intensity of electricity generation, it does not assume any future improvement in carbon intensity of liquid fuels. But the California Low-Carbon Fuel Standard (LCFS) has already achieved[16] over 12% improvement in fuel carbon intensity since 2010, and it requires ongoing improvements of 1.25% per year[17], as shown in Figure 14. The Oregon Clean Fuels Program requires[18] a 37% reduction in carbon intensity by 2035. New Mexico recently enacted[19] a Clean Fuel Standard, although quantitative targets have not yet been determined.

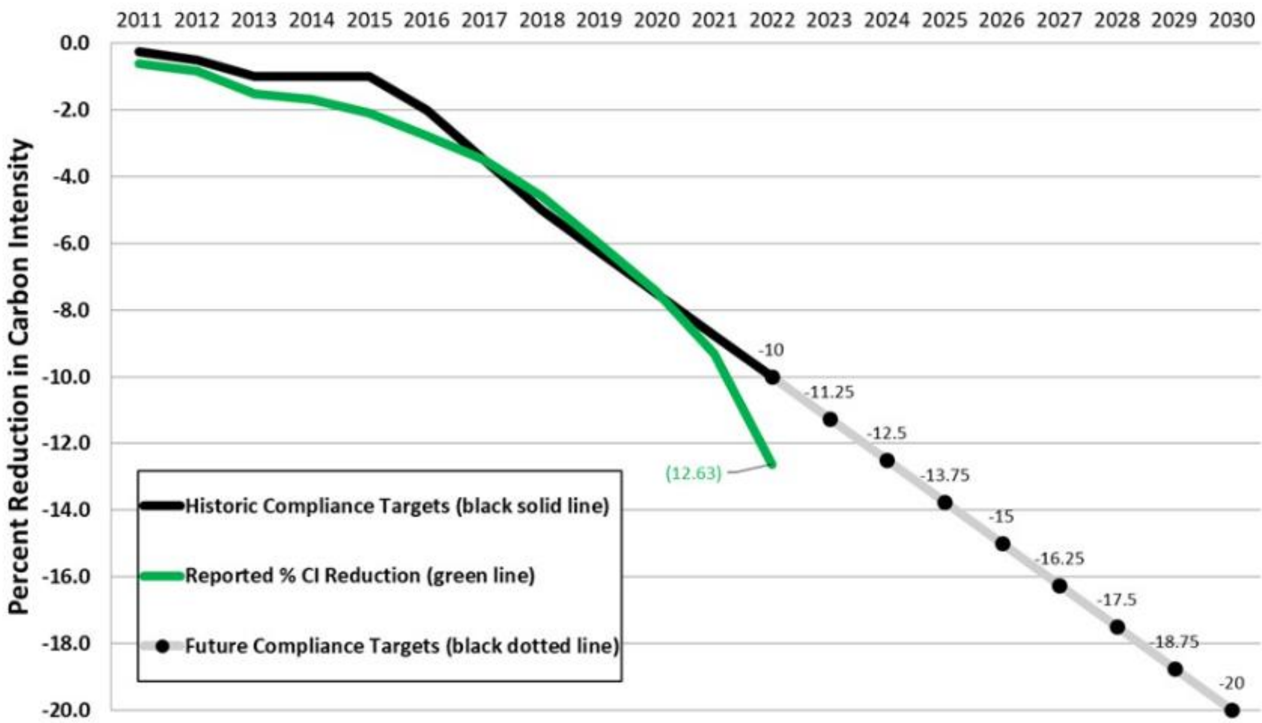

FIGURE 14: CALIFORNIA LOW-CARBON FUEL STANDARD

[14] Calculated from Tables 5-2 and 5-3 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024, https://www.epa.gov/system/files/documents/2024-03/420r24004.pdf
[15] U.S. Energy Information Administration State Electricity Profiles, https://www.eia.gov/electricity/state/
[16] California Air Resources Board LCFS Data Dashboard, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard
[17] The California Air Resources Board is considering amendments which would require even greater improvements, https://ww2.arb.ca.gov/rulemaking/2024/lcfs2024
[18] Oregon Clean Fuels Program Overview, https://www.oregon.gov/deq/ghgp/cfp/Pages/CFP-Overview.aspx
[19] New Mexico Clean Fuel Standard https://www.env.nm.gov/climate-change-bureau/clean-fuel-standard/

Lowering the carbon intensity of liquid fuels can reduce CO_2 emissions faster than new vehicles can displace the existing fleet. Even with aggressive targets for BEV adoption, the on-road fleet will be dominated by liquid fueled internal combustion engine vehicles for a very long time (Figure 8).

To illustrate this point, a Low-Carbon Fuel Scenario was created. It assumes nationwide annual 1.25% reduction in liquid fuel carbon intensity (like the California requirements in Figure 14), starting in 2027, with the same ICE and BEV sales as the EPA "No Action" case (no new CO_2 requirements after MY2022). For the regulatory period of 2027 to 2032, this scenario shows larger annual CO_2 benefits than EPA Pathway A (Figure 15).

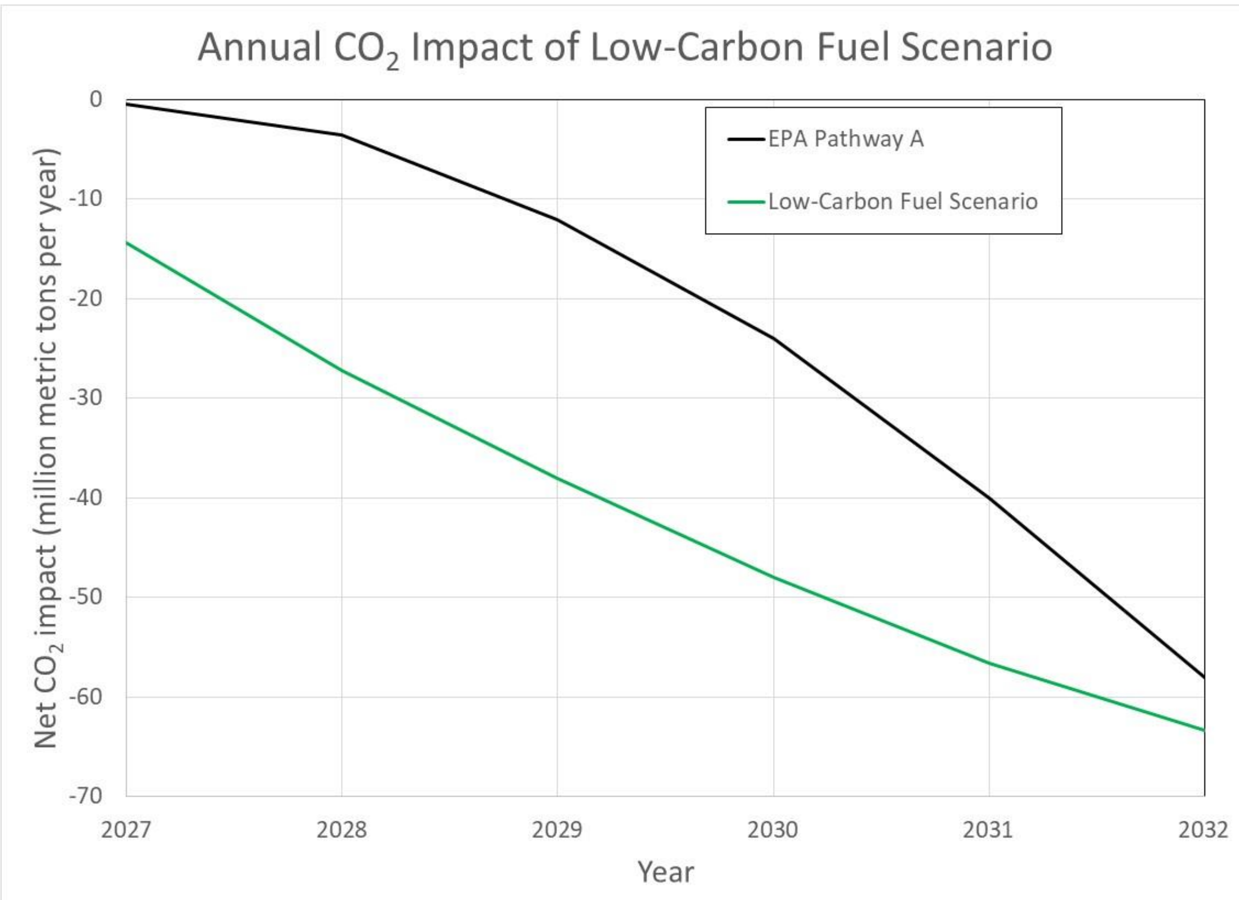

FIGURE 15: ANNUAL CO_2 IMPACT OF LOW-CARBON FUEL SCENARIO

As shown in Figure 16, the Low-Carbon Fuel Scenario achieves 77% more cumulative CO_2 benefit than EPA Pathway A during the 2027 to 2032 regulatory period, despite having a substantially smaller on-road BEV fleet. Because the Low-Carbon Fuel Scenario assumes the same BEV sales as the EPA "No Action" case, future consumption of liquid fuels would also be the same (black dashed line in Figure 12). But lowering the carbon intensity of liquid fuels for the large on-road fleet can offer better CO_2 benefits than new BEVs entering the fleet.

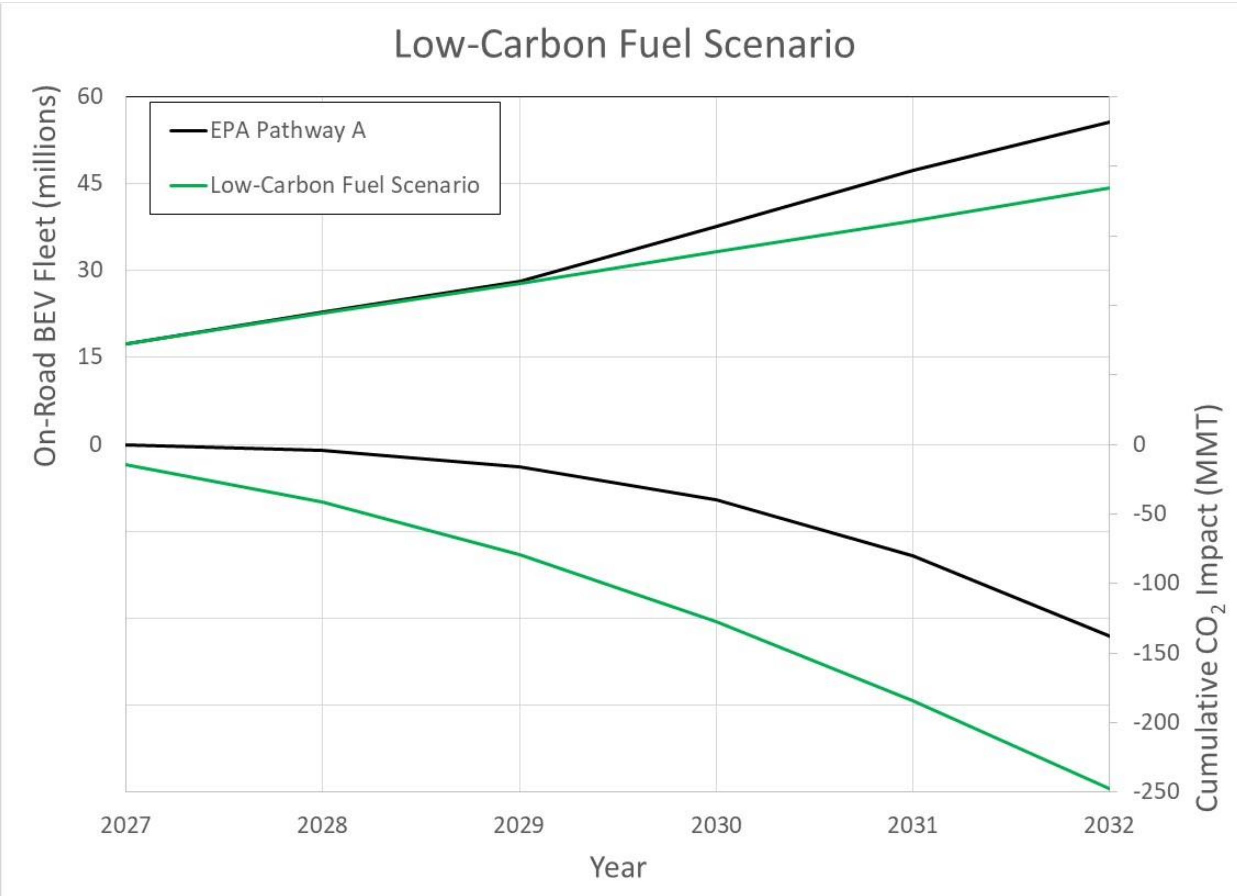

FIGURE 16: CUMULATIVE CO_2 IMPACT OF LOW-CARBON FUEL SCENARIO

7 CONCLUSIONS

Increasing sales of battery electric vehicles (BEVs) will increase electricity consumption and decrease consumption of liquid fuels. But there is substantial uncertainty about the rate of BEV adoption. This study quantified results for a wide range of scenarios.

The "max BEV" scenario assumed a combination of two factors:

1) EPA tailpipe CO_2 requirements achieved primarily with high BEV sales rather than a mix of BEVs, PHEVs, and HEVs
2) Adoption of California's "Advanced Clean Cars II" (ACC II) sales mandates of "Zero Emissions Vehicles" in all 17 other potential ACC II states

Under the "max BEV" scenario, electricity consumption in 2035 would increase by 480 terawatt hours (12% of 2022 total consumption), and liquid fuel consumption in 2035 would decrease by 38 billion gallons (29% of 2022 total consumption). In this scenario, the decrease in liquid fuel consumption is driven almost entirely by BEV sales.

At the opposite extreme, under the "Low Oil Price" scenario from the U.S. Energy Information Administration, electricity consumption in 2035 would increase by 72 terawatt hours (2% of 2022 total consumption), and liquid fuel consumption in 2035 would decrease by 15 billion gallons (11% of 2022 total consumption). In this scenario, much of the liquid fuel consumption decrease is due to increasing sales of hybrid electric vehicles and other efficiency improvements in liquid-fueled vehicles.

Lowering the carbon intensity of liquid fuels can reduce CO_2 emissions faster than new vehicles can displace the existing fleet. If the future carbon intensity of liquid fuel were reduced 1.25% per year nationwide, the cumulative CO_2 benefit from 2027 to 2032 would be 77% larger than required by the EPA standards. This CO_2 benefit could be achieved with a dramatically smaller on-road BEV fleet - 44 million in 2032, versus 56 million for EPA "Pathway A".