Future Scenarios for E85 in California

SwRI® Project No. 03.29381

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POWERTRAIN ENGINEERING DIVISION

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1 INTRODUCTION

Concerns about greenhouse gas (GHG) emissions led to California's "Advanced Clean Cars II" (ACC II) regulations[1] which mandate that each year an increasing fraction of new light duty vehicle sales be "Zero Emissions Vehicles" (zero tailpipe emissions). However, about 90% of vehicles currently on the road[2] in California are powered by gasoline and diesel fuel. Sales of new gasoline and diesel vehicles will continue until 2035, and these vehicles will stay on the road[3] for about another 15 years.

To reduce CO_2 emissions from gasoline and diesel vehicles, the California Low Carbon Fuel Standard "is designed to decrease the carbon intensity of California's transportation fuel pool and provide an increasing range of low-carbon and renewable alternatives"[4]. Analysis by Argonne National Laboratory[5] indicates that conventional or hybrid vehicles powered by biofuels can achieve similar life cycle greenhouse gas (GHG) emissions to battery electric vehicles. Analysis by the U.S. Council for Automotive Research[6] concluded that "even with rapid electrification, transportation GHG emissions cannot reach carbon-neutral levels in 2050" without significant increases in biofuel production and use.

Ethanol is one of the most widely used biofuels in California[7] and nationwide[8]. According to a study[9] by Argonne, "corn ethanol in the transportation fuel market [in the U.S.] resulted in a total GHG emission reduction benefit of 544 MMT CO_2e during the period 2005 to 2019." Currently, most ethanol is used as E10, a blend of 10% ethanol in gasoline. Some ethanol is also used as E85 (nominally 85% ethanol) in flex-fuel vehicles (FFVs).

But many FFV owners do not refuel with E85, and thus the potential GHG emissions benefits are not achieved. The purpose of this study is to identify scenarios for increased consumption of E85 in California, and to quantify the potential future GHG emissions benefits using life cycle analysis.

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[1] California Air Resources Board, Advanced Clean Cars II, https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii
[2] California Department of Motor Vehicles, "Vehicle Fuel Type Count by Zip Code", https://data.ca.gov/dataset/vehicle-fuel-type-count-by-zip-code
[3] Table 8-1 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024, https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model
[4] California Air Resources Board, Low Carbon Fuel Standard, https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard/about
[5] Kelly, Elgowainy, Isaac, et al., "Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways", report ANL-22/27, June 2022, https://doi.org/10.2172/1875764
[6] USCAR (U.S. Council for Automotive Research), "Low-Carbon Liquid Fuels for U.S. Road Transportation", USCAR Whitepaper, October 2024, https://uscar.org/publications/
[7] California Air Resources Board, LCFS Data Dashboard, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard?keywords=2025
[8] U.S. Energy Information Administration, Biofuels explained, https://www.eia.gov/energyexplained/biofuels/
[9] Lee, Kwon, Wu, and Wang, "Retrospective analysis of the U.S. corn ethanol industry for 2005–2019: implications for greenhouse gas emission reductions", 2021, https://doi.org/10.1002/bbb.2225

2 ENGINE EFFICIENCY BENEFIT

When quantifying the effects of E85, it is important to account for changes in engine efficiency. Ford conducted back-to-back testing[10] of E85 and E0 gasoline at three speed-load operating points and measured relative thermal efficiency benefits of 3.8% to 4.6% for E85, as shown in Figure 1. The testing was conducted at light loads where the engine was not knock-limited, so the benefit was not due to octane (see the original SAE paper for further details).

The engine efficiency benefit of ethanol is now well accepted by experts. A literature review by authors from three major car companies[11] generalized the results from Ford and other studies as 0.5% engine efficiency improvement per 10% ethanol in the fuel (by volume). E85 sold in California is typically[12] 82% ethanol, resulting in 3.6% engine efficiency benefit versus E10 gasoline.

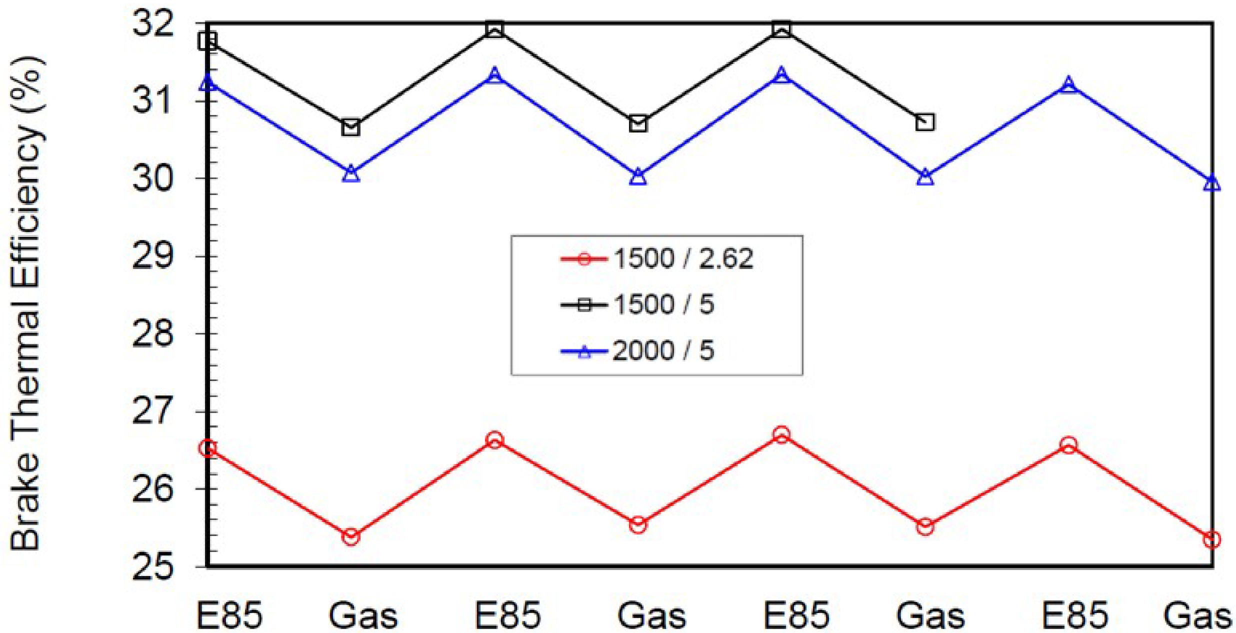

FIGURE 1: EFFECT OF E85 ON ENGINE EFFICIENCY

[10] Jung, Shelby, Stein, and Newman, "Effect of Ethanol on Part Load Thermal Efficiency and CO_2 Emissions of SI Engines," SAE Int. J. Engines 6(1):456-469, 2013, https://doi.org/10.4271/2013-01-1634

[11] Leone, Anderson, Davis, Iqbal, Reese, Shelby, and Studzinski, "The Effect of Compression Ratio, Fuel Octane Rating, and Ethanol Content on Spark-Ignition Engine Efficiency", Environmental Science & Technology paper 5b01420, 2015, https://doi.org/10.1021/acs.est.5b01420

[12] According to CARB: https://ww2.arb.ca.gov/resources/documents/substitute-pathways-and-default-blend-levels-lcfs-reporting-specific-fuel?keywords=2025

3 TRENDS IN CARBON INTENSITY OF ETHANOL

The life cycle greenhouse gas benefits of ethanol have been studied extensively. A critical review[13] of the literature by independent researchers from MIT, Tufts, and Harvard found a wide range of published values for the carbon intensity of ethanol, from 37.6 to 65.1 gCO_2e/MJ. The study noted a consistent decrease in the carbon intensity of farming and ethanol production over time, due to many factors including reduced use of nitrogen fertilizer and fossil fuel in farming and more efficient use of energy in ethanol production plants.

A widely used and authoritative tool for life cycle analysis is the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory. Key developers of this model studied[9] changes in the carbon intensity of corn ethanol, and found a 23% improvement from 2005 to 2019 (the black bars in Figure 2). The biggest contributor to the improvement was reduced natural gas consumption in ethanol production (the blue bars in Figure 2). The report states that "natural gas use in ethanol plants is subject to large variations, about ±40% of the median natural gas use in 2019, which means that there is the potential to further reduce GHG emissions if high natural gas consuming facilities can improve their efficiencies to levels closer to those of the low natural gas consuming ones" and that "renewable natural gas... can be an alternative option for... reduced CIs for ethanol".

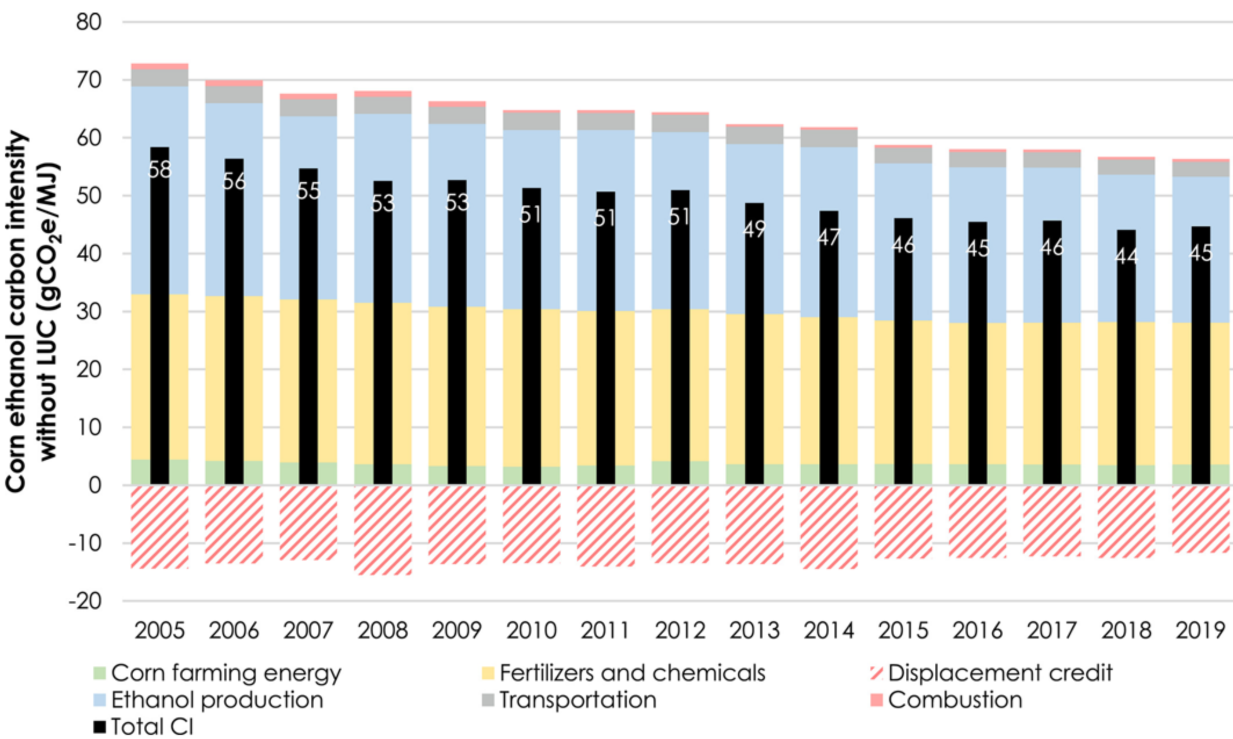

FIGURE 2: CARBON INTENSITY OF CORN ETHANOL, 2005 TO 2019

[13] Scully, Norris, Falconi and MacIntosh, "Carbon intensity of corn ethanol in the United States: state of the science", 2021, https://doi.org/10.1088/1748-9326/abde08

The second biggest factor for improved carbon intensity was reduced use of fertilizers and chemicals per bushel of corn (the yellow bars in Figure 2). The report states that "corn grain yield has increased continuously… while fertilizer inputs per acre have remained constant, resulting in decreased intensities of fertilizer inputs". It is important to note that corn yield[14] has been improving for many decades, as shown in Figure 3.

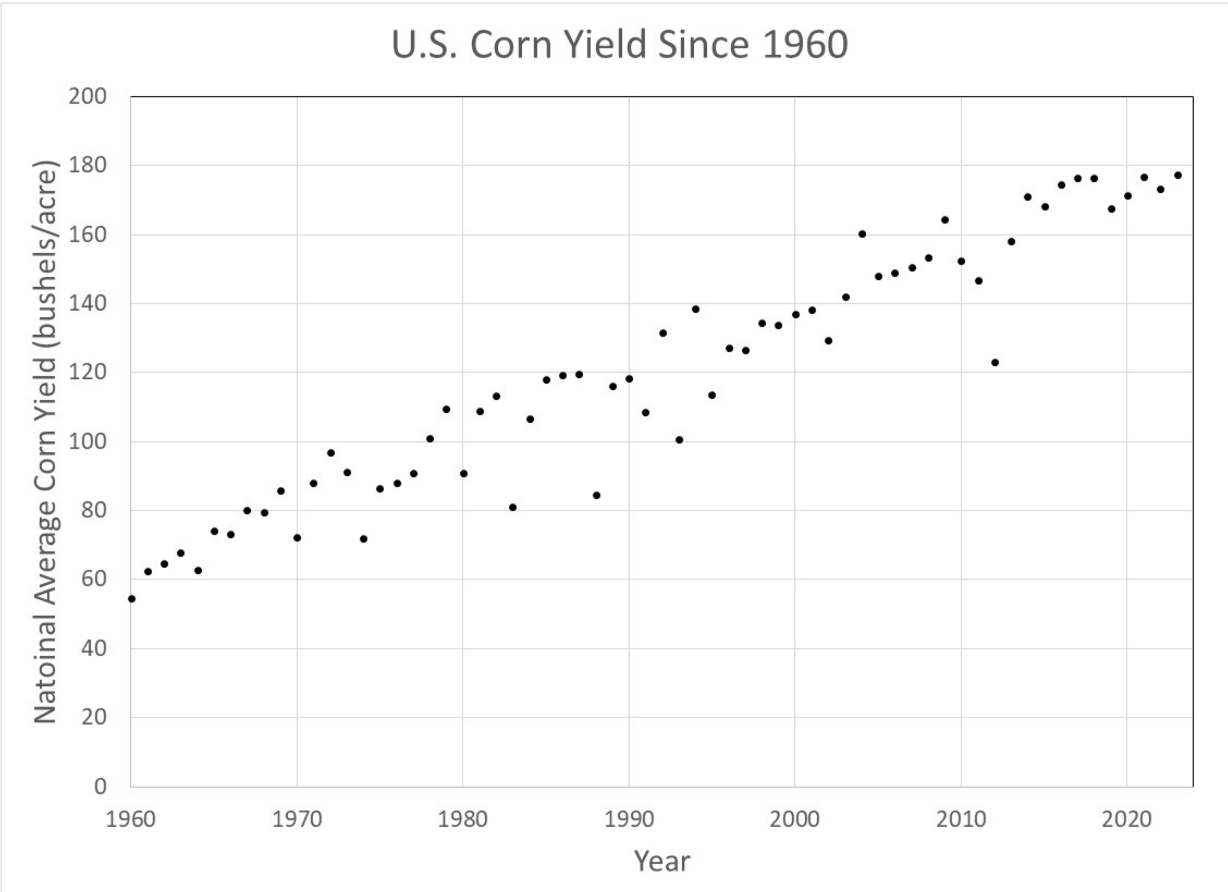

FIGURE 3: CORN YIELD SINCE 1960

[14] U.S. Department of Agriculture, National Agricultural Statistics Service, https://quickstats.nass.usda.gov/results/29260F67-A60C-3C6A-B323-8E5049510EBB

Historical improvements in the carbon intensity of ethanol have been driven primarily by economic factors; improved corn yield per acre of land, reduced use of fertilizers and chemicals per bushel of corn, and reduced natural gas consumption in ethanol production give direct economic benefits to farmers and ethanol producers. There are now additional incentives driven by the California Low Carbon Fuel Standard. Researchers from the U.S. Department of Agriculture analyzed[15] these incentives and stated "It is anticipated that ethanol refineries can achieve continued emission reductions through facility improvements. Some examples of ethanol refinery plant modifications include utilizing biogas as a substitute for natural gas, installing combined heat and power (CHP) systems to displace natural gas used for industrial heating purposes, and replacing grid electricity with electricity generated by on-site solar or wind power systems."

The California Air Resources Board (CARB) publishes quarterly reports[16] about fuels which qualify for credits under the Low Carbon Fuel Standard (LCFS). These reports include the average carbon intensity of ethanol based on volumes sold for each certified production pathway. As shown in Figure 4, the carbon intensity of ethanol sold in California has been improving by an average of 2.6 gCO_2e/mJ per year.

[15] Rosenfeld, Kaffel, Lewandrowski, and Pape, "The California Low Carbon Fuel Standard: Incentivizing Greenhouse Gas Mitigation in the Ethanol Industry", USDA Office of the Chief Economist, November 2020, https://www.usda.gov/sites/default/files/documents/CA-LCFS-Incentivizing-Ethanol-Industry-GHG-Mitigation.pdf
[16] California Air Resources Board, LCFS Data Dashboard, https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard?keywords=2025

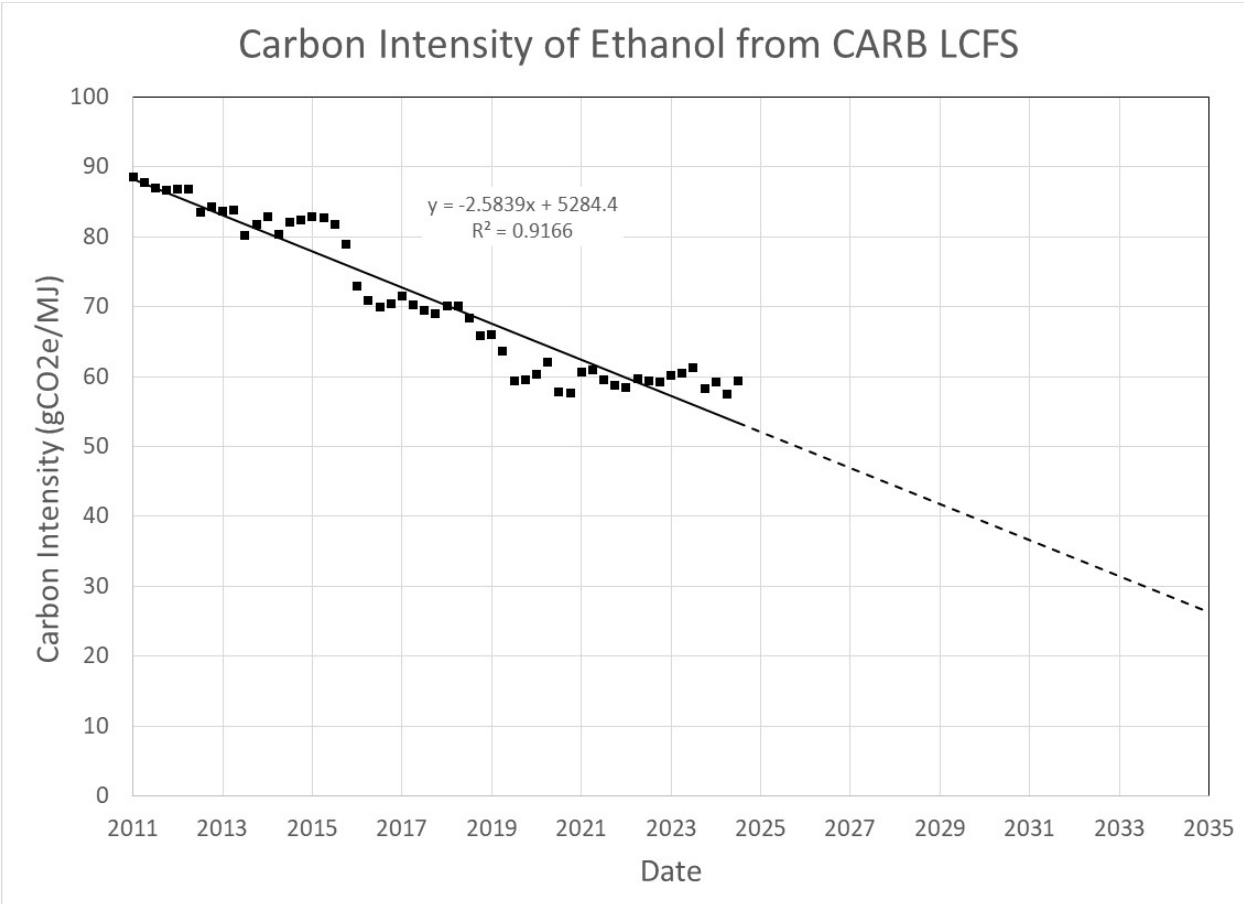

FIGURE 4: CARBON INTENSITY OF ETHANOL FROM CARB LCFS

To quantify the potential future greenhouse gas benefits of E85, it is necessary to estimate the future carbon intensity of ethanol. It is reasonable to extrapolate recent trends into the near future, and this is common practice[17,18] for estimating the future carbon intensity of electricity production. As described above, it is reasonable to expect that the trends contributing to recent improvements in ethanol carbon intensity will continue in future years, and that additional means of improvement will be implemented. For this study, the future carbon intensity of ethanol in California is assumed to continue the 2011-2024 trend, as shown by the dashed line in Figure 4.

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[17] Table 5-3 and Figure 8-12 of EPA Regulatory Impact Analysis, EPA-420-R-24-004, March 2024 https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-multi-pollutant-emissions-standards-model

[18] U.S. Energy Information Administration, Annual Energy Outlook, https://www.eia.gov/outlooks/aeo/

Based on the carbon intensity of ethanol from Figure 4 and a few other fuel properties[19,20,21,22], the carbon intensity of California E10 and E85 can be calculated for future years. As shown in Figure 5, both E10 and E85 improve over time as the carbon intensity of ethanol improves. Due to the higher ethanol content of E85, the CO_2 benefit of E85 vs. E10 improves from 34% in 2025 to 53% in 2035.

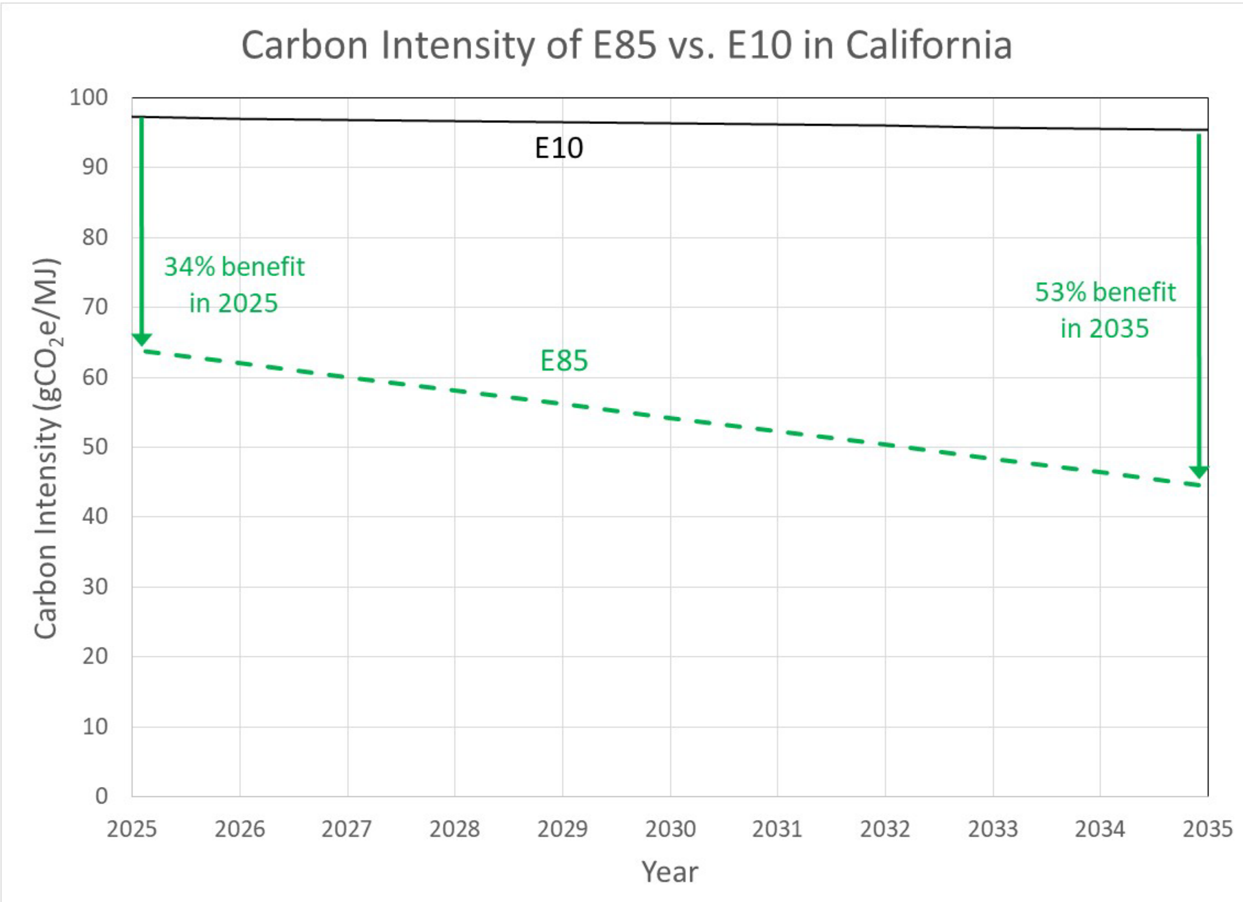

FIGURE 5: CARBON INTENSITY OF E85 VS. E10

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[19] Ethanol LHV = 21,274 MJ/m3 from GREET.NET 2024

[20] CARBOB gasoline blendstock 119.53 MJ/gal from California Air Resources Board, LCFS quarterly summary spreadsheet for Q3 2024, https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries?keywords=2025

[21] CARBOB gasoline blendstock 100.63 gCO2e/MJ from California Air Resources Board, Lookup Table Pathways Technical Support Documentation, August 12, 2024 https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/ca-greet/lut_update_v08122024.pdf

[22] Default ethanol blend level for E85 in CA is 82% according to California Air Resources Board, Substitute Pathways and Default Blend Levels for LCFS Reporting, https://ww2.arb.ca.gov/resources/documents/substitute-pathways-and-default-blend-levels-lcfs-reporting-specific-fuel?keywords=2025

4 USING RENEWABLE NAPHTHA IN E85

In addition to improving the carbon intensity of ethanol over time, the fossil gasoline portion of E85 (nominally 15%) can be replaced with renewable naphtha. The largest distributor of E85 in California has started using renewable naphtha and has announced plans to increase its use.[23,24,25] To illustrate the potential benefits, the future carbon intensity of E85 was recalculated assuming[26,27] use of renewable naphtha and the results are shown in Figure 6. The CO_2 benefit of E85 blended with renewable naphtha is estimated to be 45% in 2025, and 65% in 2035.

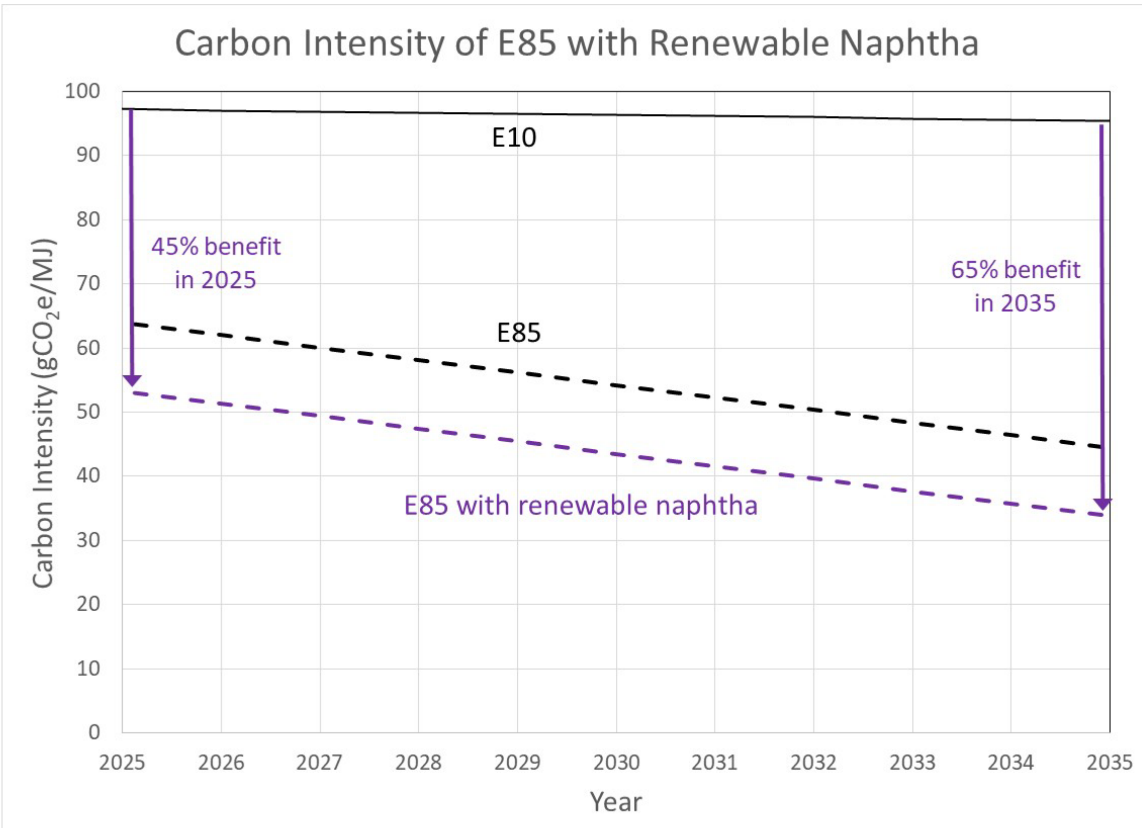

FIGURE 6: CARBON INTENSITY OF E85 WITH RENEWABLE NAPHTHA

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[23] Pearson Fuels, Comments on Potential Changes to the Low Carbon Fuel Standard, December 21, 2022, https://www.arb.ca.gov/lists/com-attach/77-lcfs-wkshp-nov22-ws-AXFXNANjV3YCdwBv.pdf

[24] Melissa Anderson, "In Pursuit of Pure", Ethanol Producer Magazine, June 6, 2022, https://ethanolproducer.com/articles/in-pursuit-of-pure-19310

[25] Todd Neeley, "Ethanol Blog", Progressive Farmer Magazine, March 28, 2022, https://www.dtnpf.com/agriculture/web/ag/blogs/ethanol-blog/blog-post/2022/03/28/e85-continues-rapid-growth-latest

[26] Renewable naphtha carbon intensity of 58.04 gCO_2/MJ based on pathway B057303, California Air Resources Board, LCFS Certified Fuel Pathway Table, https://carbstage.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities

[27] Renewable naphtha energy density 117.66 MJ/gal from California Air Resources Board, LCFS quarterly summary spreadsheet for Q3 2024, https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries?keywords=2025

5 CAPTURE AND STORAGE OF CO_2 FROM ETHANOL

The life cycle greenhouse gas benefits of ethanol can be further improved by capturing CO_2 from fermentation of ethanol and sequestering it away from the atmosphere, for example by pumping it into stable geological formations underground. A summary report[28] from the Intergovernmental Panel on Climate Change (IPCC) states "if the geological storage site is appropriately selected and managed, it is estimated that the CO_2 can be permanently isolated from the atmosphere... The technical geological storage capacity is estimated to be on the order of 1000 $GtCO_2$, which is more than the CO_2 storage requirements through 2100 to limit global warming to 1.5°C."

There have been many proposals for capturing CO_2 emissions from power plants, and directly from the atmosphere. But the concentration of CO_2 in the atmosphere[29] is only 0.04%, and the concentration of CO_2 in the exhaust of a natural gas combined cycle power plant[30] is about 3%-4%. In contrast, "ethanol production generates a high purity (99%) stream of fermentation CO_2 containing only CO_2, H_2O, and small amounts of sulfur and organic compounds."[31] The high concentration and purity of CO_2 from ethanol production means that less energy and less capital investment is required to capture the CO_2, compared to carbon capture from power plants and direct air capture. IRS 45Q tax credits[32] are creating incentives to implement carbon capture and storage.

A study[33] by the U.S. Department of Agriculture concluded "when taking into account the energy requirements to capture, transport, and inject carbon dioxide into storage reservoirs, the net impact is likely a CI reduction of 20-25 gCO_2/MJ of ethanol". This reduction[34] was applied to the estimated future carbon intensity of ethanol from Figure 4, and the result is shown as the green line in Figure 7.

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[28] Intergovernmental Panel on Climate Change (IPCC), "Summary for Policymakers. In: Climate Change 2023: Synthesis Report", 2023, https://doi.org/10.59327/IPCC/AR6-9789291691647.001
[29] Sodiq et al., "A review on progress made in direct air capture of CO_2", Environmental Technology & Innovation, Volume 29, 2023, https://doi.org/10.1016/j.eti.2022.102991
[30] Baker, Freeman, Kniep, Wei, and Merkel, "CO_2 capture from natural gas power plants using selective exhaust gas recycle membrane designs", International Journal of Greenhouse Gas Control, Volume 66, November 2017, https://doi.org/10.1016/j.ijggc.2017.08.016
[31] Dees et al., "Cost and Life Cycle Emissions of Ethanol Produced with an Oxyfuel Boiler and Carbon Capture and Storage", Environmental Science & Technology, 2023, https://doi.org/10.1021/acs.est.2c04784
[32] U.S. Internal Revenue Service, "Required Procedures to Claim a Section 45Q Credit for Utilization of Carbon Oxide", Notice 2024-60, https://www.irs.gov/pub/irs-drop/n-24-60.pdf
[33] Rosenfeld, Kaffel, Lewandrowski, and Pape, "The California Low Carbon Fuel Standard: Incentivizing Greenhouse Gas Mitigation in the Ethanol Industry", USDA Office of the Chief Economist, November 2020, https://www.usda.gov/sites/default/files/documents/CA-LCFS-Incentivizing-Ethanol-Industry-GHG-Mitigation.pdf
[34] The average value of 22.5 gCO_2/MJ was assumed.

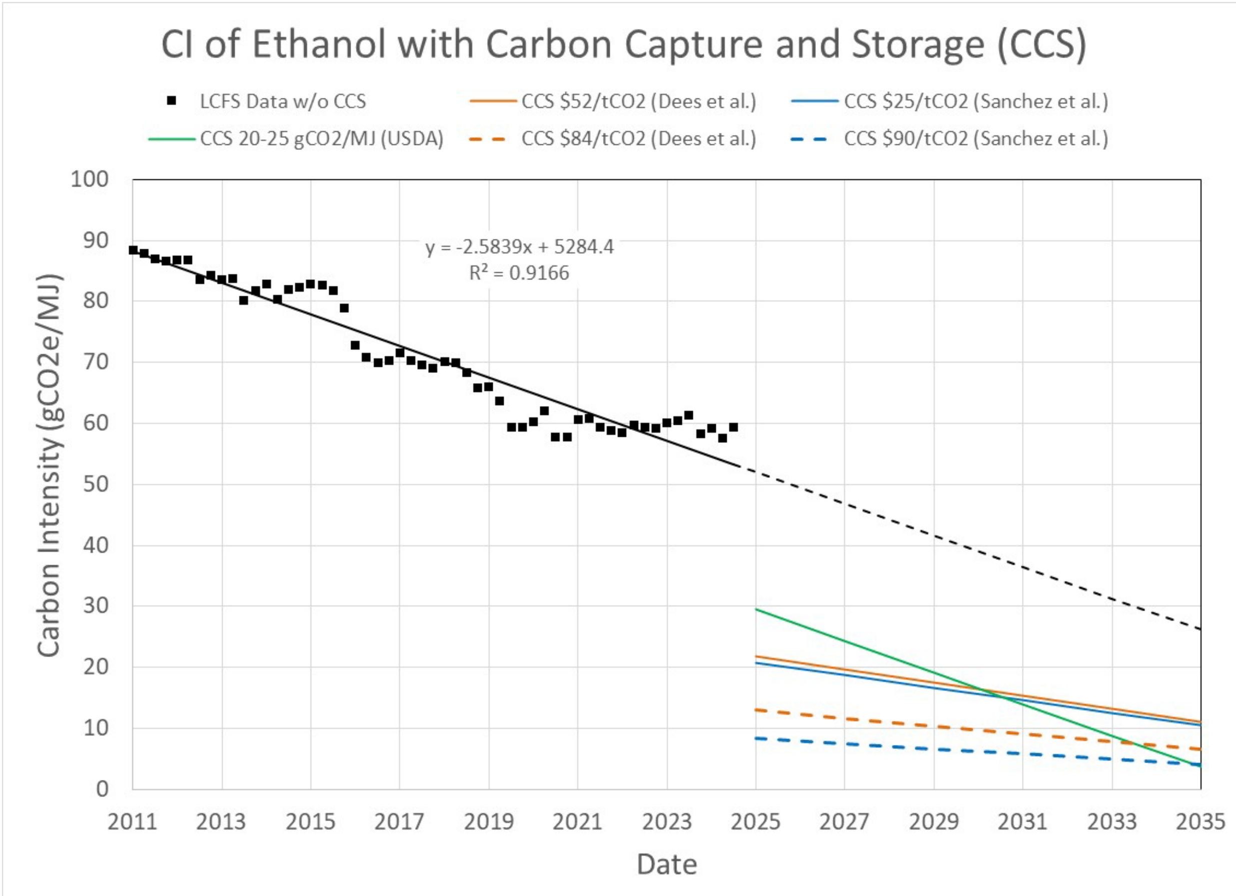

FIGURE 7: CI OF ETHANOL WITH CARBON CAPTURE AND STORAGE

An independent academic study[35] concluded that "existing US biorefineries emit 45 $MtCO_2$ annually from fermentation, of which 60% could be captured and compressed for pipeline transport for under $25/tCO_2$... [a credit] of $90/tCO_2$ can incent 38 Mt of abatement." An abatement of 38 MT from emissions of 45 MT is a carbon intensity reduction of 84%. Carbon intensity reductions of 60% and 84% are shown as the blue lines in Figure 7.

Another independent academic study[36] concluded that "capture and storage of CO_2 emissions from corn ethanol fermentation achieves ~58% reduction in the GHG intensity (CI) of ethanol at a levelized cost of 52 $/tCO_2e$ abated. The integration of an oxyfuel boiler enables further CO_2 capture at modest cost. This system yields a 75% reduction in CI at... 84 $/tCO2e." Carbon intensity reductions of 58% and 75% are shown as the orange lines in Figure 7. The study further concluded that "carbon-neutral or even carbon-negative ethanol can be achieved when oxyfuel carbon capture is stacked with low-CI alternatives to grid power and fossil natural gas."

[35] Sanchez et al., "Near-term deployment of carbon capture and sequestration from biorefineries in the United States", Proceedings of the National Academy of Sciences (PNAS), 2018, https://doi.org/10.1073/pnas.1719695115
[36] Dees et al., "Cost and Life Cycle Emissions of Ethanol Produced with an Oxyfuel Boiler and Carbon Capture and Storage", Environmental Science & Technology, 2023, https://doi.org/10.1021/acs.est.2c04784

Using the conservative estimate of 58% CI improvement for CO_2 capture (the solid orange line in Figure 7), the overall CI of E85 was recalculated. As shown by the dashed orange line in Figure 8, the CI benefit of E85 is estimated to be 69% in 2025, and 77% in 2035. Using the more optimistic estimate of 84% CI improvement for CO_2 capture (the dashed blue line in Figure 7), the CI benefit of E85 is estimated to be 79% in 2025, and 82% in 2035 (the dashed blue line in Figure 8).

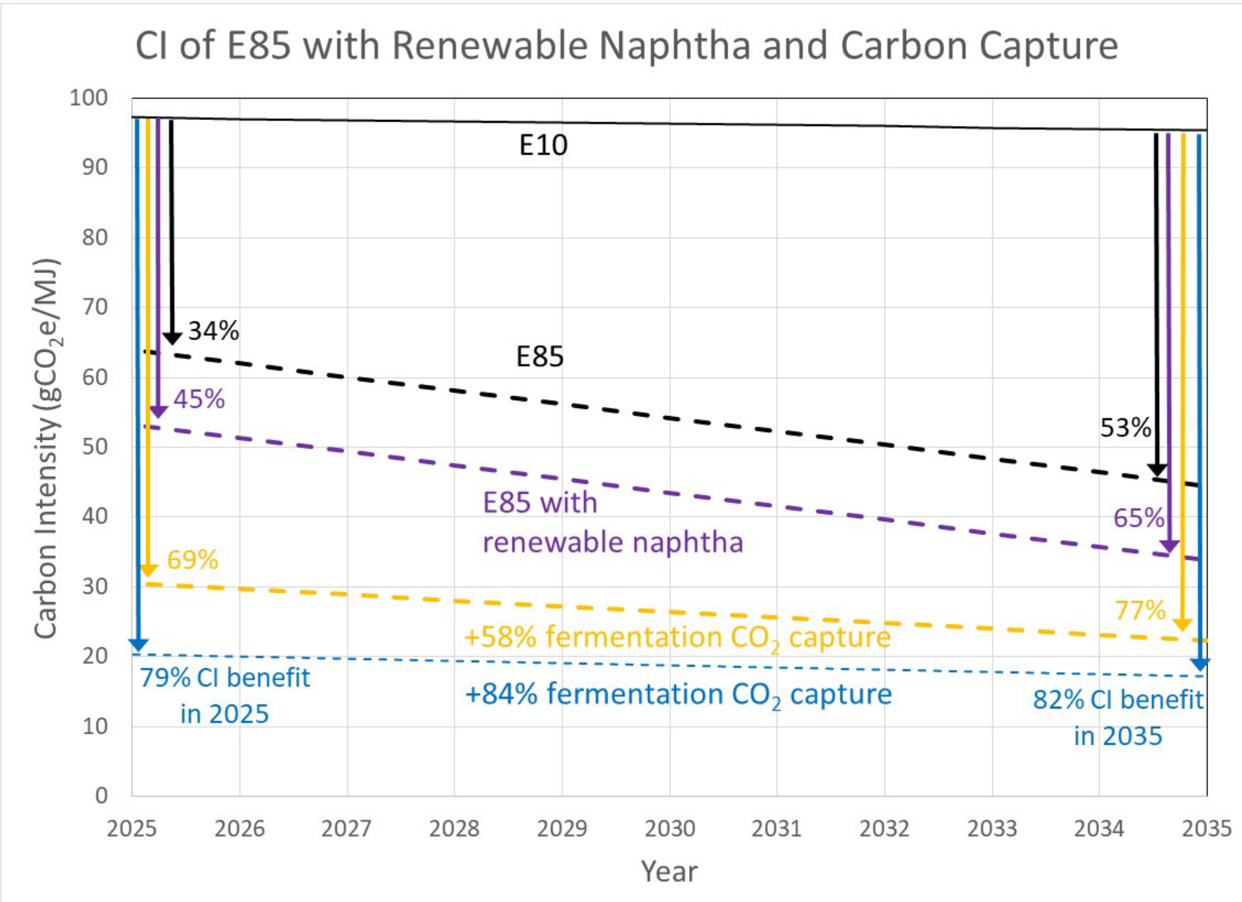

FIGURE 8: CI OF E85 WITH RENEWABLE NAPHTHA AND CARBON CAPTURE

6 RETAIL COST SAVINGS

The retail cost of E85 versus E10 in California was analyzed using data[37] from E85prices.com, which is "crowdsourced" price information contributed by individuals. There is significant variation from month to month, but as shown in Figure 9, the average price of E85 in California was 36% lower than E10 from January 2023 to March 2025.

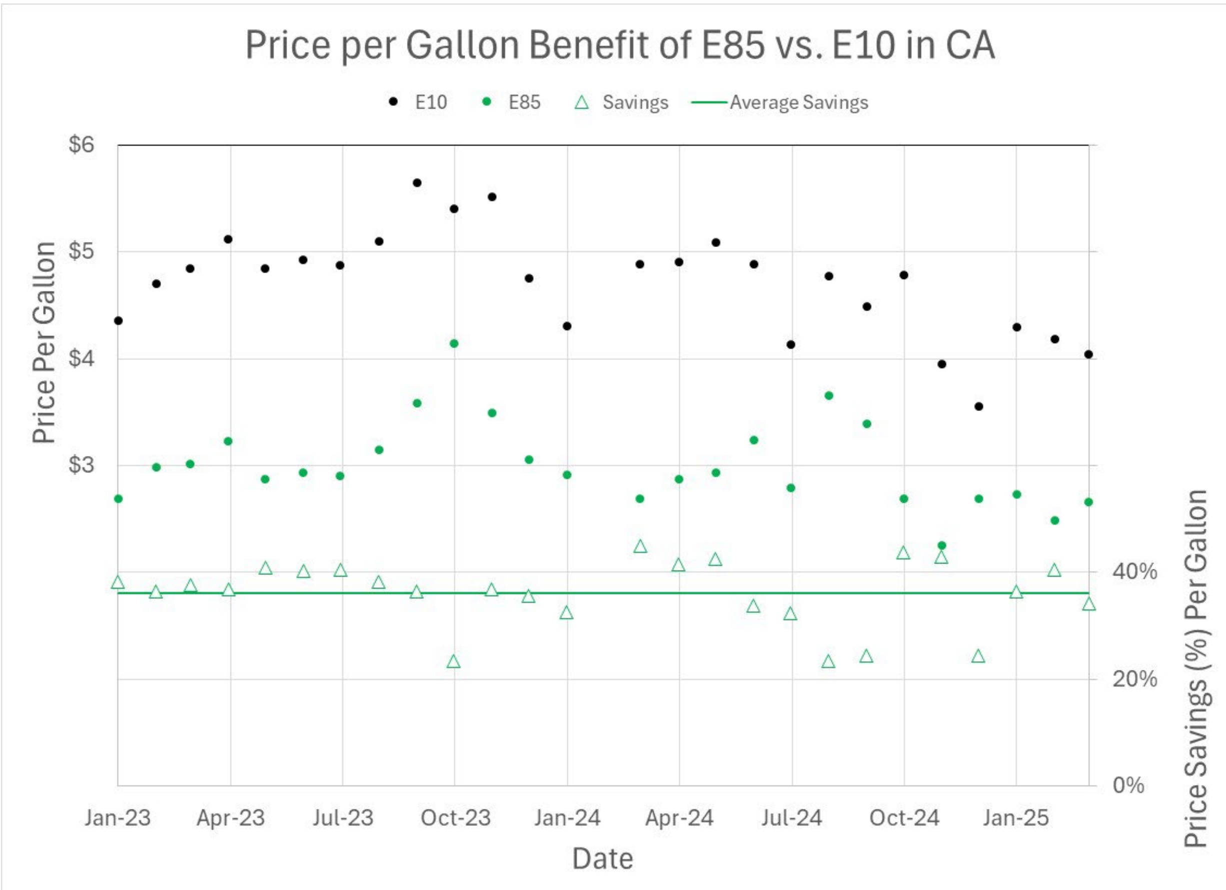

FIGURE 9: PRICE PER GALLON BENEFIT OF E85 VS. E10

[37] State average fuel price chart https://e85prices.com/california.html

The data was adjusted for the difference in volumetric energy content[19,20,22] between E85 and E10, and for the engine efficiency benefit described in section 2 of this paper. As shown in Figure 10, the average cost saving of E85 in California was 19% from January 2023 to March 2025.

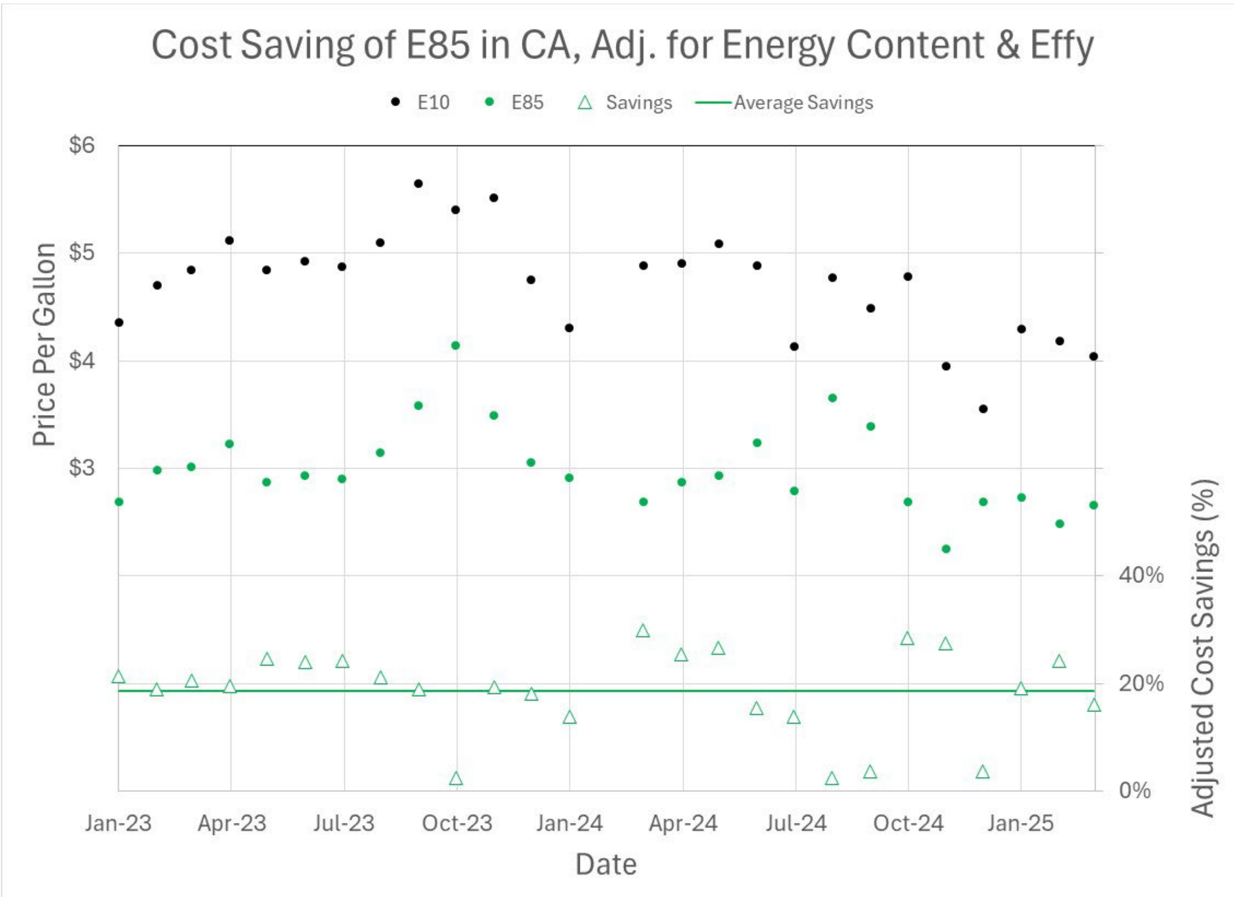

FIGURE 10: COST SAVINGS OF E85 VS. E10

7 TRENDS IN E85 CONSUMPTION

California has recently experienced large increases in E85 consumption. From 2016 to 2023, annual E85 sales volume[38] increased by more than a factor of five, while the number of FFVs[39] on the road declined slightly, as illustrated in Figure 11.

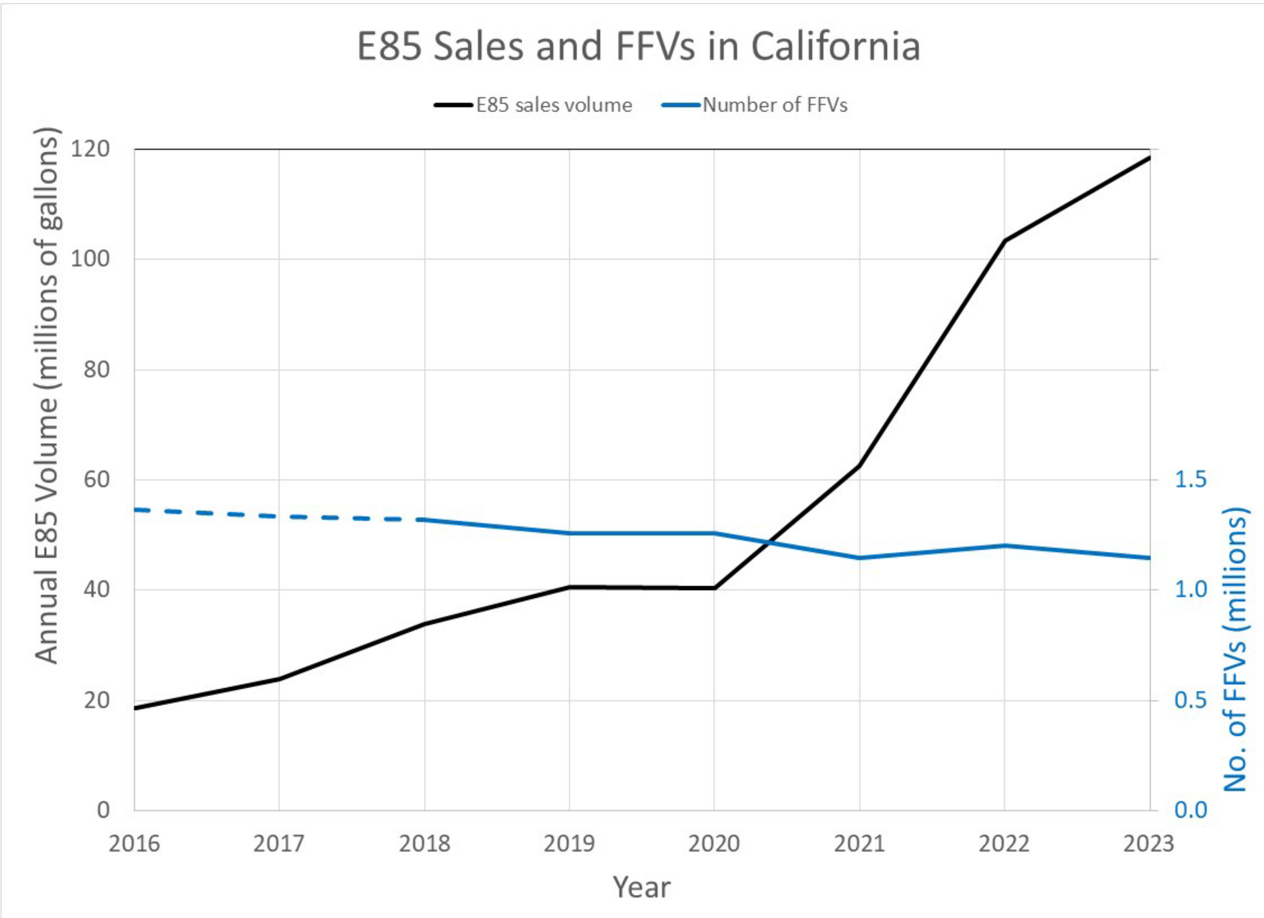

FIGURE 11: E85 SALES AND NUMBER OF FFVS

[38] From CARB reported Test Program Exemption data, https://ww2.arb.ca.gov/resources/documents/alternative-fuels-annual-e85-volumes

[39] 13% decline from 2018 to 2023 (no data available before 2018 or after 2023). Data from California Department of Motor Vehicles, "Vehicle Fuel Type Count by Zip Code", https://data.ca.gov/dataset/vehicle-fuel-type-count-by-zip-code

The California data was normalized[40] as annual E85 sales volume per registered FFV, as shown in Figure 12. Despite the recent significant increase in E85 sales, the average FFV consumed only 100 gallons of E85 in 2023. Clearly, there is room for continued growth in E85 sales. Extrapolation of the recent trend indicates that California could reach 228 gallons of E85 per FFV in 2028.

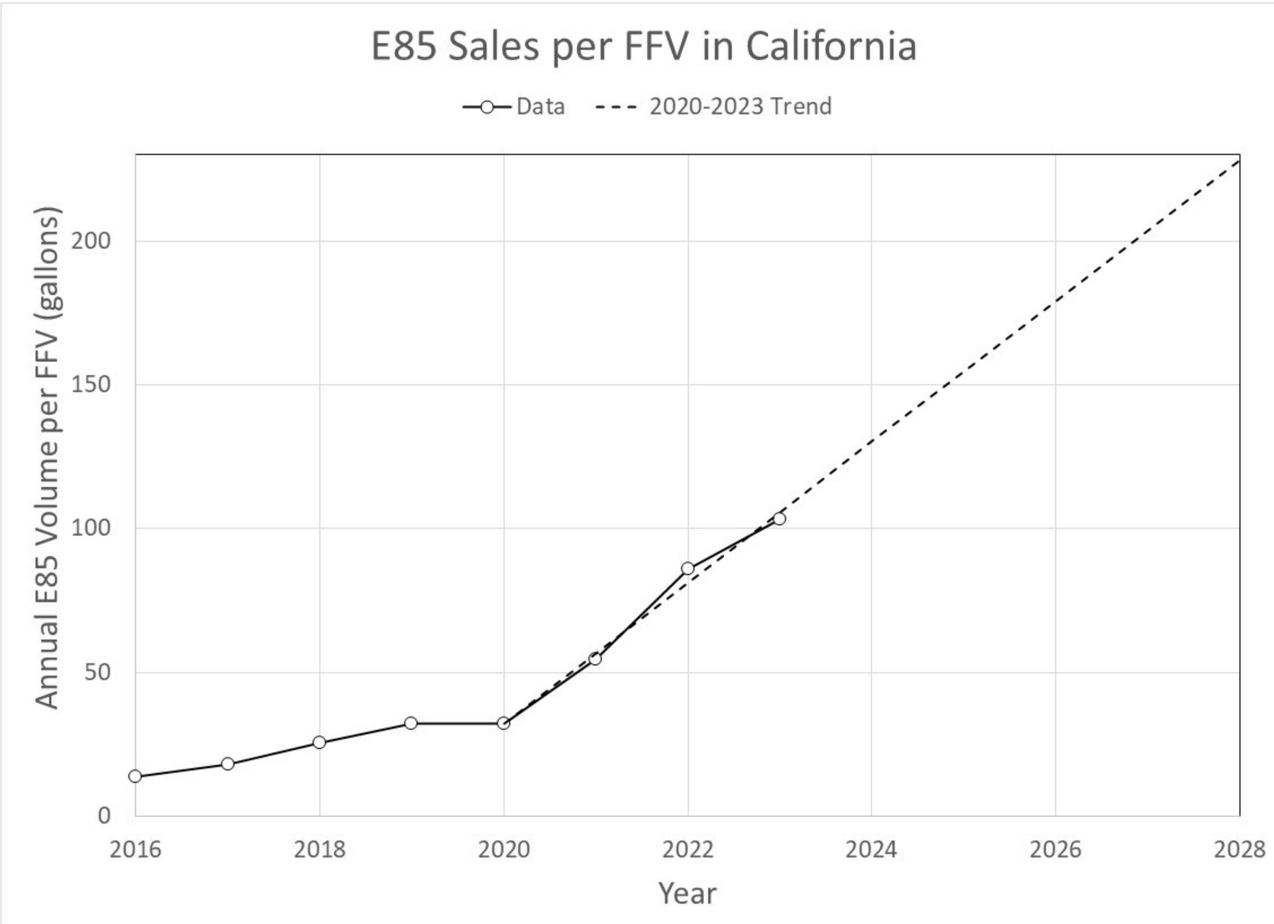

FIGURE 12: E85 SALES PER FFV

[40] The number of FFVs before 2018 was estimated using a linear fit to the 2018-2023 data, as illustrated by the dashed line in Figure 11.

8 FUTURE SCENARIOS FOR E85

This paper has identified and quantified recent trends which could influence the future greenhouse gas and cost benefits of E85 in California:

- Improving carbon intensity of ethanol (Figure 4)
- Increasing consumption of E85 per flex-fuel vehicle (Figure 12)
- Decreasing number of flex-fuel vehicles (Figure 11)
- Persistent cost benefit of E85 (Figure 10)

As shown in Figure 13, E85 offers substantial benefits if these trends[41] continue. In 2035 the estimated greenhouse gas benefit is 1.4 million tons CO_2e annually, while simultaneously saving $213 million annually. Note that estimated annual cost savings increase each year due to increasing consumption of E85 per flex-fuel vehicle, but the rate of increase slows down due to decreasing number of flex-fuel vehicles. Greenhouse gas benefits increase almost linearly, because the improving carbon intensity of ethanol offsets the decreasing number of flex-fuel vehicles.

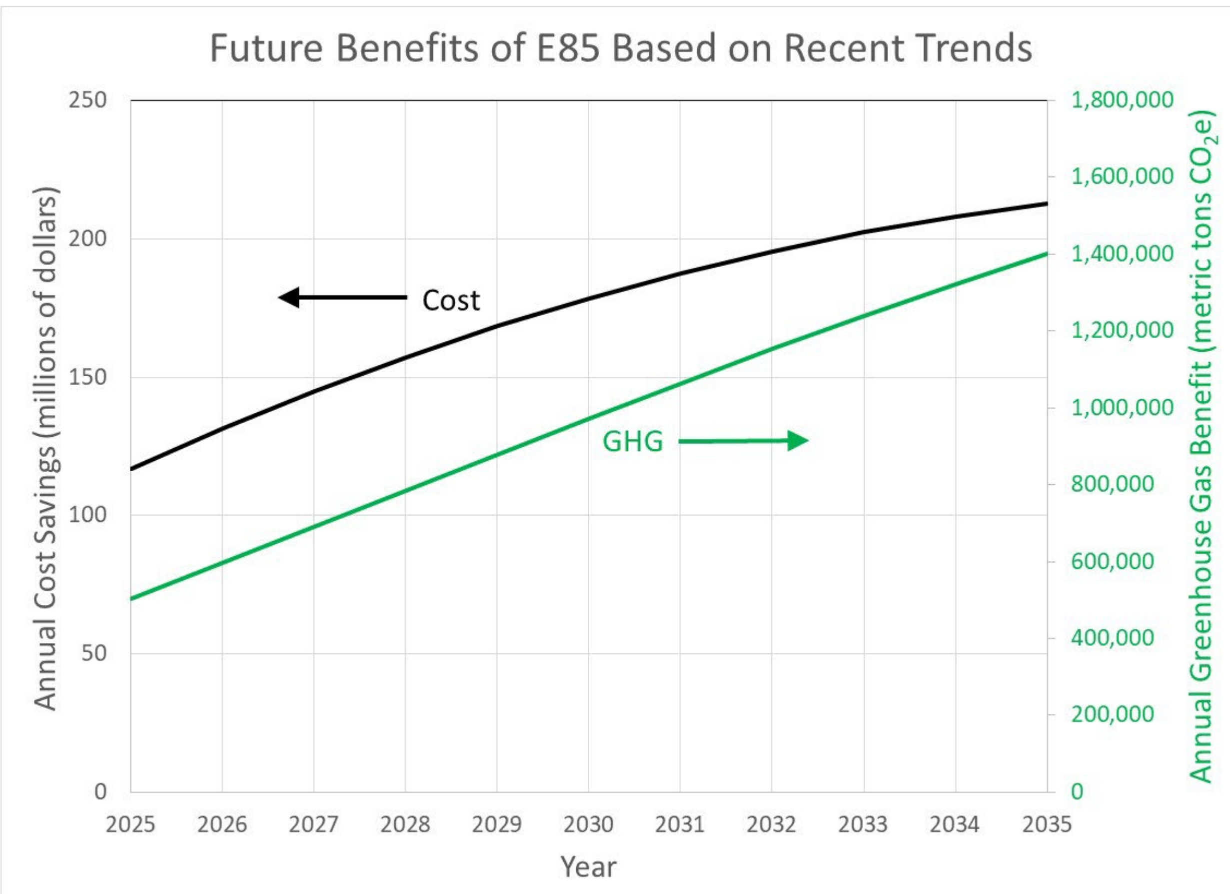

FIGURE 13: FUTURE BENEFITS OF E85 BASED ON RECENT TRENDS

[41] 2020 to 2023 trend for E85 per FFV in California, 2018 to 2023 trend for number of FFVs in California, and 2011 to 2024 trend for carbon intensity of ethanol in California

Figure 13 assumes that historical trends in carbon intensity of ethanol continue in the future. These trends are based on improved corn yield per acre of land, reduced use of fertilizers and chemicals per bushel of corn and reduced natural gas consumption in ethanol production. But as described in sections 4 and 5 of this paper, the future carbon intensity of E85 could be further improved if:

- The fossil gasoline portion of E85 is replaced with renewable naphtha, and/or
- CO_2 from fermentation of ethanol is captured and sequestered

As shown in Figure 14, the greenhouse gas benefit of E85 in 2035 could further improve from 1.4 to 2.1 million tons CO_2e annually with use of renewable naphtha and carbon capture.

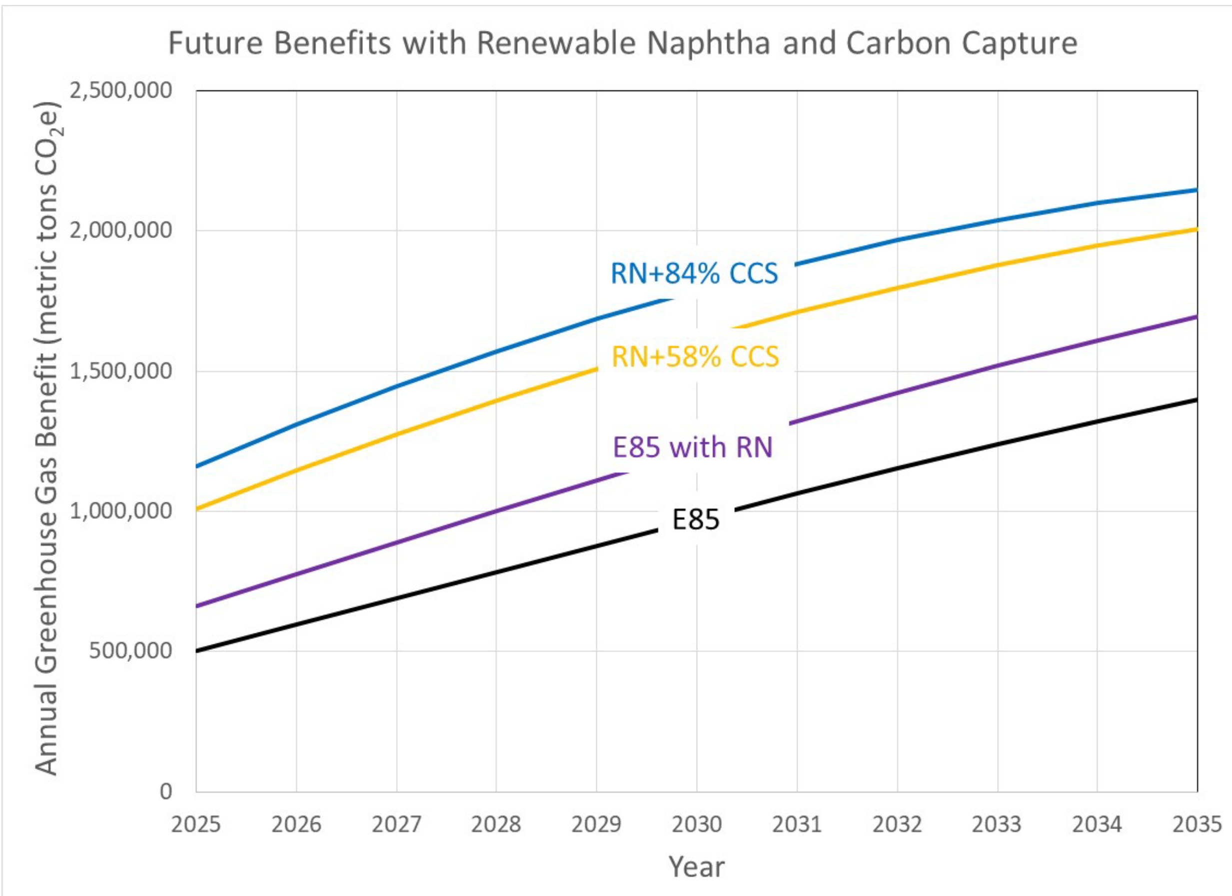

FIGURE 14: FUTURE BENEFITS OF E85 WITH RN AND CCS

The future greenhouse gas and cost benefits of E85 are limited by the number of flex-fuel vehicles (FFVs) on the road. Regulatory changes in the U.S. have decreased credits for FFVs, resulting in reduced availability[42] of new FFVs. Approximately 32,000 older FFVs are being taken off the road each year in California, as shown by the blue line in Figure 11. Compensating for this attrition (to maintain constant number of on-road FFVs) could be achieved if about 1.8% of new car sales in California[43] were FFVs.

As an alternative or supplement to sales of new FFVs, some vehicles not originally designed as FFVs can be converted to FFVs using commercially available kits, which must meet standards[44] instituted by the U.S. Environmental Protection Agency (EPA), the National Highway Traffic Safety Administration (NHTSA), and state agencies like the California Air Resources Board (CARB). In France, hundreds of thousands of conversion kits have been sold, FFVs based on conversion kits now outnumber vehicles originally sold as FFVs[45], and annual sales of conversion kits are about 1.7% of new car sales[46,47].

It is possible that attrition of older on-road FFVs in California could be offset by sales of FFV conversion kits and/or by sales of new FFVs. As shown in Figure 15, this would increase the annual greenhouse gas benefit to 2.0 million metric tons CO_2e, while simultaneously saving \$302 million annually. If these FFVs were refueled only with E85, the annual greenhouse gas benefit would be 3.0 million metric tons CO_2e in 2035, while saving \$461 million annually.

[42] U.S. Department of Energy, Alternative Fuels Data Center, Flexible Fuel Vehicle Availability, https://afdc.energy.gov/vehicles/flexible-fuel-availability
[43] In California from 2016 to 2024, new vehicle sales averaged 1.82 million per year based on data from Experian Automotive, as published by California New Car Dealers Association, California Auto Outlook, April 2025, https://www.cncda.org/wp-content/uploads/Cal-Covering-1Q-25.pdf
[44] U.S. Department of Energy, Alternative Fuels Data Center, Conversion and Tampering Regulations, https://afdc.energy.gov/vehicles/conversions-regulations
[45] Approximately 252,000 on-road vehicles with E85 conversion kits and 148,000 on-road vehicles originally sold as FFvs per Bioethanol France, Données Superéthanol-E85, February 2025, https://bioethanolfrance.fr/wp-content/uploads/2025/03/Donnees-Superethanol-E85-fevrier-2025.pdf
[46] Approximately 29,000 E85 conversion kits sold last year per Bioethanol France, Conférence de presse Collective du Bioéthanol, January 2025, https://www.bioethanolcarburant.com/wp-content/uploads/2025/01/Conf-de-Presse-Bilan-BIOETHANOL-28-01-2025-VF-1_compressed.pdf
[47] New car sales in France were 1,682,065 per ACEA report “Vehicles on European Roads”, January 2025, https://www.acea.auto/publication/report-vehicles-on-european-roads-2025/

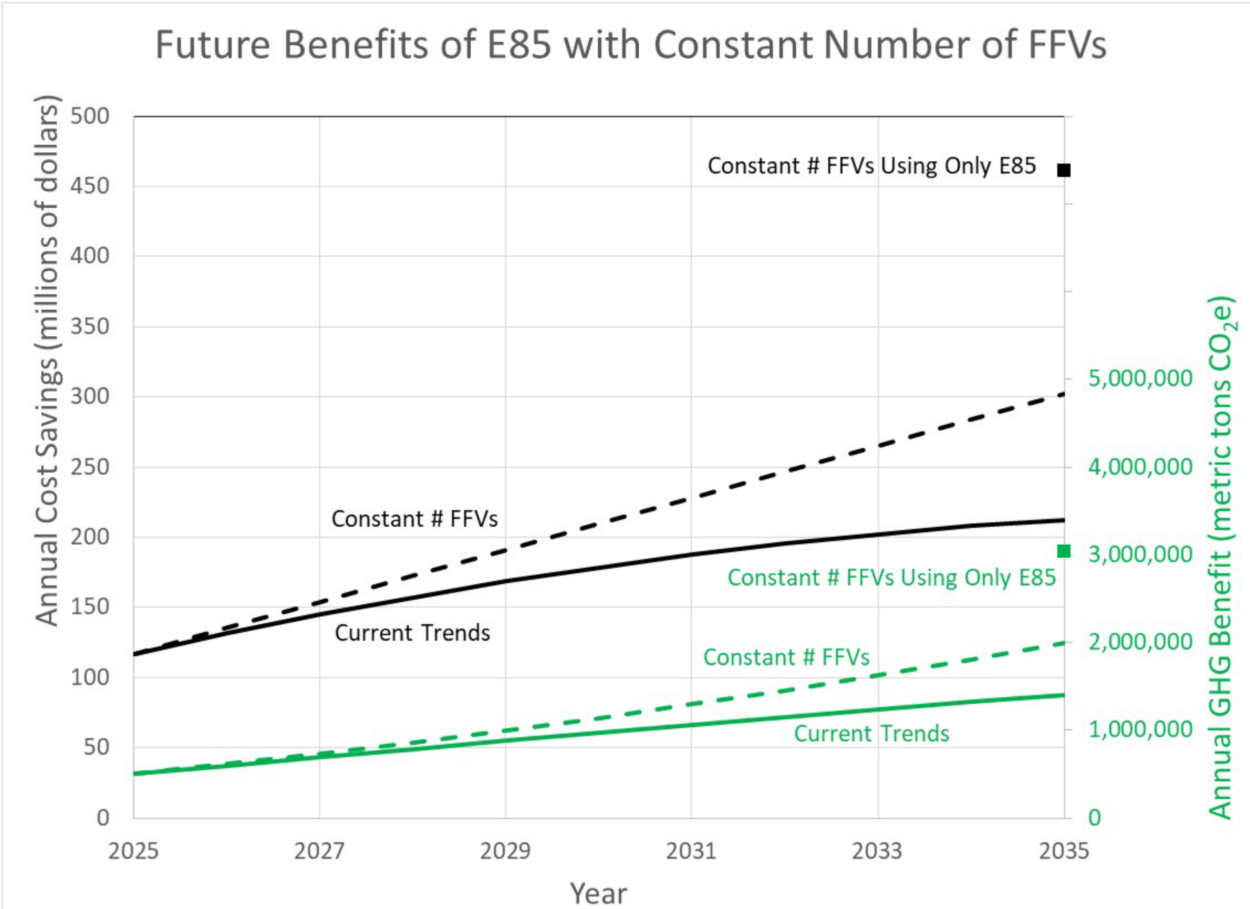

FIGURE 15: FUTURE BENEFITS OF E85 WITH CONSTANT # FFVS

8.1 DISCUSSION AND CONCLUSIONS

Greater use of E85 (fuel with nominally 85% ethanol and 15% gasoline) would have significant greenhouse gas emissions benefits and cost savings. This study identified possible scenarios for greater use of E85 in California and quantified the greenhouse gas benefits using life cycle analysis.

E85 can only be used in flex-fuel vehicles (FFVs). About 3.7% of all vehicles on the road[2] in California are FFVs. But many FFV owners do not refuel with E85, and thus the full potential emissions benefits are not currently achieved. In recent years, E85 sales have increased dramatically in California. Annual E85 consumption per FFV increased from 14 gallons in 2016 to 103 gallons in 2023. If this trend continues, Californians will use 400 gallons of E85 per FFV in 2035.

The greenhouse gas benefits of E85 depend on the carbon intensity of ethanol, which has been improving steadily for many years. This trend is based on improved corn yield per acre of land, reduced use of fertilizers and chemicals per bushel of corn, and reduced natural gas consumption in ethanol production. If recent trends in carbon intensity and E85 consumption continue, California is on track to achieve annual greenhouse gas reductions of 1.4 million metric tons CO_2e in 2035.

Historical improvements in the carbon intensity of ethanol have been driven primarily by economic factors. There are now additional incentives driven by the California Low Carbon Fuel Standard. The future carbon intensity of E85 could be further improved if the fossil gasoline portion of E85 is replaced with renewable naphtha, and/or if CO_2 from fermentation of ethanol is captured and sequestered. If these changes are implemented, California could achieve annual greenhouse gas reductions up to 2.1 million metric tons CO_2e in 2035.

In addition to the greenhouse gas benefits, E85 consistently offers a cost advantage, which averaged 19% in California[48] from January 2023 to March 2025. If recent trends in E85 consumption continue, California is on track to achieve annual savings of $213 million in 2035.

The future greenhouse gas and cost benefits of E85 are limited by the number of flex-fuel vehicles (FFVs) on the road, which is decreasing due to attrition of older vehicles. It is possible that attrition of older on-road FFVs could be offset by sales of FFV conversion kits, and/or by sales of new FFVs. This would increase the annual greenhouse gas benefit to 2.0 million metric tons CO_2e (with current trends in carbon intensity of ethanol), while simultaneously saving $302 million annually. If this is combined with renewable naphtha and carbon capture, the annual greenhouse gas benefit would be up to 3.1 million metric tons CO_2e in 2035.

[48] The price per gallon was 35% lower for E85 versus E10. After adjusting for differences in volumetric energy content and engine efficiency as described in section 6 of this paper, the net cost benefit was 19%.