

Future Scenarios for E15 in the U.S.

SwRI® Project No. 03.28491

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1 INTRODUCTION

Concerns about greenhouse gas (GHG) emissions, and slower adoption of battery electric vehicles than previous forecasts, are leading to increasing interest in low-carbon fuels including renewable fuels, biofuels, and e-fuels. Analysis¹ by Argonne National Laboratory, in cooperation with industry experts, indicates that conventional or hybrid vehicles with renewable liquid fuels can achieve similar life cycle GHG emissions to battery electric vehicles.

The most widely used renewable fuel is ethanol. According to another study² by Argonne, "corn ethanol in the transportation fuel market 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 by volume. Some ethanol is used as E85 (nominally 85% ethanol), but only in flex-fuel vehicles.

Efforts have been announced to develop "drop-in" renewable gasoline which can be used in all vehicles, for example Chevron³ and ExxonMobil in cooperation with Toyota⁴. However, renewable gasoline is still under development, and it is not yet commercially available.

All vehicles produced from MY2001 onwards are EPA approved⁵ to use E15, a blend of 15% ethanol in gasoline. Analysis published by the Transportation Energy Institute⁶ showed large GHG emissions benefits for E15 but did not address how much time may be required to transition from E10 to E15.

The purpose of this study is to identify realistic scenarios for widespread adoption of E15, and to quantify the GHG emissions benefits using life cycle analysis.

¹ 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>

² 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>

³ "Chevron road trip demonstrates renewable gasoline blend", April 17, 2023, <https://www.chevron.com/newsroom/2023/q2/chevron-road-trip-demonstrates-renewable-gasoline-blend>

⁴ "ExxonMobil and Toyota Team Up to Test Fuels with a Lower Carbon Footprint", <https://pressroom.toyota.com/exxonmobil-and-toyota-team-up-to-test-fuels-with-a-lower-carbon-footprint/>

⁵ U.S. Federal Register 76 FR 44406, July 25, 2011, <https://www.govinfo.gov/content/pkg/FR-2011-07-25/pdf/2011-16459.pdf>

⁶ "Decarbonizing Combustion Vehicles: A Portfolio Approach to GHG Reductions", Transportation Energy Institute, July 2023, <https://www.transportationenergy.org/research/reports/decarbonizing-combustion-vehicles-a-portfolio-approach-to-ghg-reductions/>

2 VAPOR PRESSURE FOR E15 AND E10

The maximum vapor pressure of ethanol-gasoline blends⁷ occurs at 5% to 10% ethanol content, as illustrated in Figure 1.

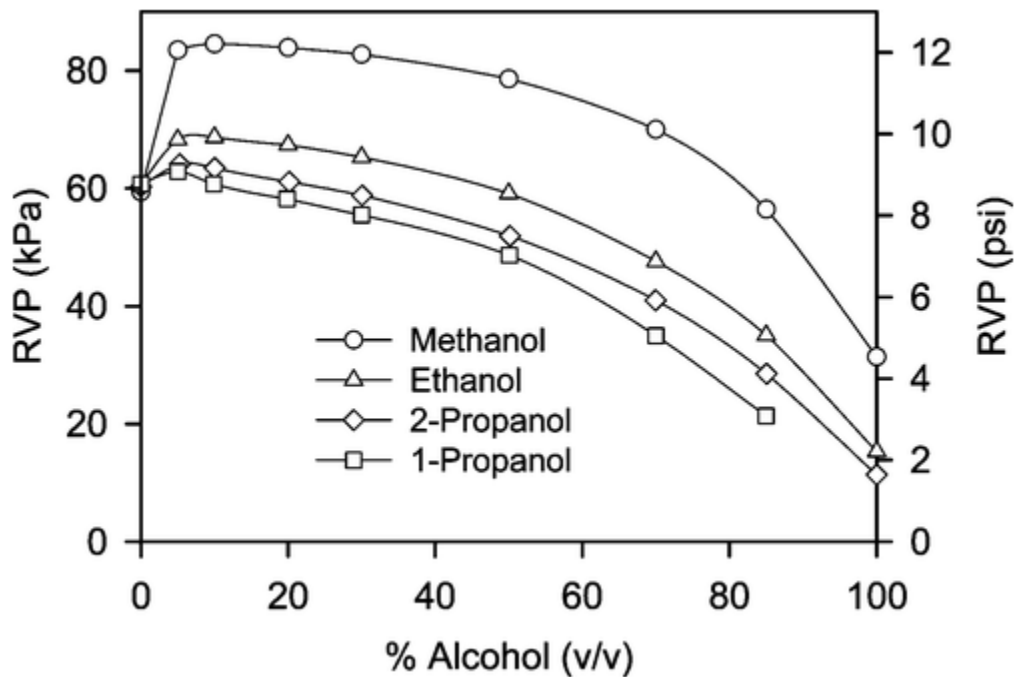


FIGURE 1: VAPOR PRESSURE VERSUS ALCOHOL CONTENT

⁷ Andersen, Anderson, Wallington, Mueller, and Nielsen, "Vapor Pressures of Alcohol-Gasoline Blends", <https://doi.org/10.1021/ef100254w>

For a given gasoline blendstock, E15 has almost identical vapor pressure to E10, and therefore has essentially the same evaporative emissions. The National Renewable Energy Laboratory reviewed seven published papers and concluded⁸ that the "RVP impact of blending 10% and 15% ethanol is indistinguishable for all volatility classes" as shown in Figure 2.

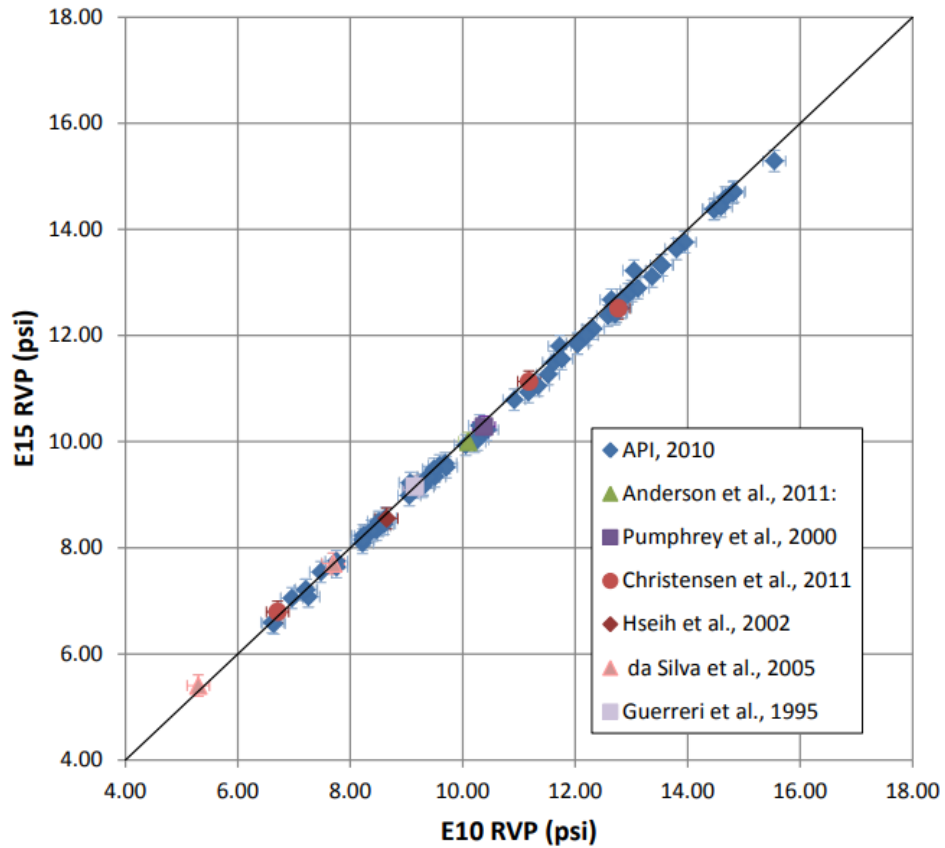


FIGURE 2: RVP OF E15 AND E10 BLENDED INTO SAME BASE FUEL

⁸ Robert L. McCormick (National Renewable Energy Laboratory) and Janet Yanowitz (Ecoengineering), "Discussion Document – Effect of Ethanol Blending on Gasoline RVP", 2012, https://d35t1syewk4d42.cloudfront.net/file/1410/RVP-Effects-Memo_03_26_12_Final.pdf

For historical reasons, E10 is allowed to have 1-psi higher vapor pressure than E0, E15, or any other ethanol-gasoline blend. Vapor pressure is a significant constraint on gasoline production, so this has been a contentious issue subject to multiple petitions⁹, temporary waivers¹⁰, and lawsuits¹¹. It is well known that the 1-psi waiver for E10 (but not E15) is a major obstacle to increased sales of E15. This is evident in the monthly E15 sales data for Minnesota¹² in Figure 3, where EPA rules and emergency 1-psi waivers for E15 were in force for the summer months of 2019 and later, but not for 2018 and earlier.

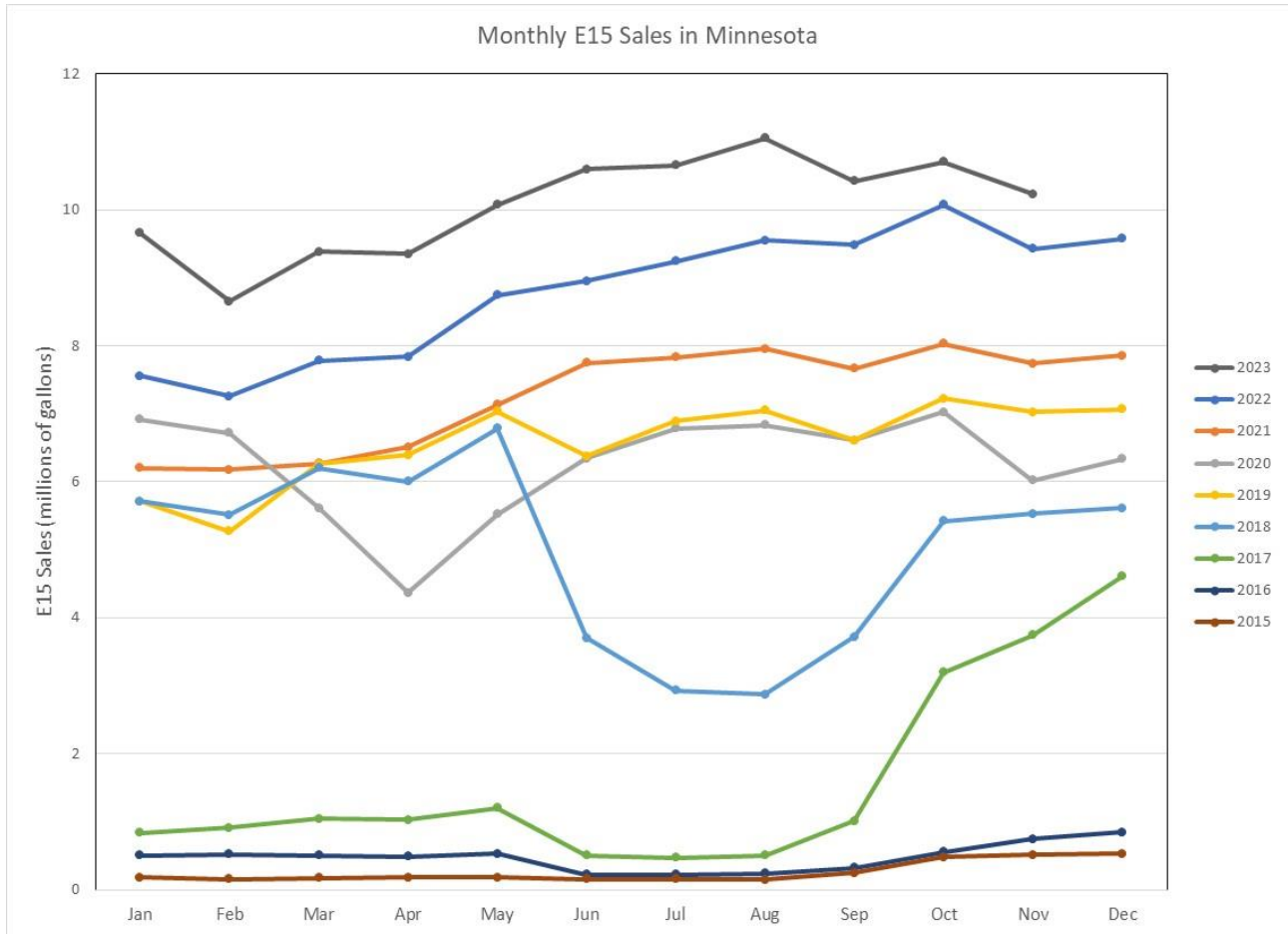


FIGURE 3: MONTHLY E15 SALES IN MINNESOTA, 2015 TO 2023

⁹ <https://www.epa.gov/gasoline-standards/proposed-rule-response-request-states-removal-gasoline-volatility-waiver>

¹⁰ <https://www.epa.gov/enforcement/fuel-waivers>

¹¹ <https://nationalaglawcenter.org/epa-delays-rescinding-gasoline-volatility-waivers-until-2025/>

¹² <https://mn.gov/commerce/business/weights-measures/fuel/biodiesel/ethanol.jsp>

The U.S. Environmental Protection Agency recently approved a rule¹³ which will remove the 1-psi waiver for E10 in eight Midwestern states, which account for¹⁴ 14.5% of US gasoline sales. This will create a stable environment for the growth of E15 sales in those states, in contrast to the uncertainty during recent years of petitions, temporary waivers, and lawsuits.

To provide similar benefits nationwide, the Consumer and Fuel Retailer Choice Act of 2023 would¹⁵ apply the same vapor pressure requirements to E10, E15, and higher blends of ethanol. This would enable larger scale use of E15, and therefore greater greenhouse gas benefits.

The legislation would also allow retailers of E15 to use the same gasoline blendstock as retailers of E10, resulting in the same vapor pressure (Figure 2). Without this legislation or other action, E10 generally qualifies for a 1-psi waiver and can thus use a higher volatility blendstock. Producing and distributing two separate blendstocks adds cost, which is a major obstacle to the growth of E15 sales.

The analysis presented in this paper quantifies potential benefits of future E15 scenarios which rely on this legislation or other action to equalize vapor pressure regulation for E15 and E10, permanently and nationwide.

3 OTHER CONSTRAINTS ON E15

Expansion of E15 sales may be constrained by compatibility of the fuel distribution system. A 2015 study¹⁶ by the National Renewable Energy Laboratory suggested that ethanol compatibility was not a significant risk and found no negative impacts due to the rapid transition from E0 to E10. But the report noted the importance of materials compatibility, and documented the resources available for fuel retailers to determine E15 compatibility of underground storage tanks, dispensers, valves, etc. The U.S. Environmental Protection Agency now requires¹⁷ "an affirmative statement of compatibility" before a retailer can sell E15.

To assist fuel retailers in transitioning to E15, the U.S. Department of Agriculture provided \$100 million in grants through the Biofuel Infrastructure Partnership¹⁸, and another \$200 million through the Higher Blends Infrastructure Incentive Program¹⁹. More recently, the Inflation Reduction Act²⁰ is providing an ongoing \$67.5 million per quarter for transportation fuel retailers and \$18 million per quarter for fuel distribution facilities. These funds, combined with routine

¹³ Final Rule in Response to Request From States for Removal of Gasoline Volatility Waiver,

<https://www.epa.gov/gasoline-standards/final-rule-response-request-states-removal-gasoline-volatility-waiver>

¹⁴ U.S. Department of Transportation, Federal Highway Administration, Motor Fuel & Highway Trust Fund, https://www.fhwa.dot.gov/policyinformation/motorfuelhwy_trustfund.cfm

¹⁵ <https://www.congress.gov/bill/118th-congress/house-bill/1608?s=1&r=271>

¹⁶ Moriarty and Yanowitz, "E15 and Infrastructure", NREL/TP-5400-64156, 2015, <https://doi.org/10.2172/1215238>

¹⁷ U.S. Environmental Protection Agency, "E15 Compatibility with UST Systems Statement", January 2020, https://19january2021snapshot.epa.gov/ust/e15-compatibility-ust-systems-statement_.html

¹⁸ Biofuels Infrastructure Partnership Frequently Asked Questions, https://www.fsa.usda.gov/Assets/USDA-FSA-Public/usdafiles/Energy/FAQs_Biofuel_Infrastruct_Prtnrship.pdf

¹⁹ "What is the Higher Blends Infrastructure Incentive Program?", <https://www.rd.usda.gov/hbiip>

²⁰ Biden-Harris Administration Announces Funding for Homegrown Biofuels as Part of Investing in America Agenda, <https://www.usda.gov/media/press-releases/2023/06/26/biden-harris-administration-announces-funding-homegrown-biofuels>

replacement of old equipment, will continue to improve E15 compatibility of the fuel distribution system.

Compatibility of the fuel distribution system may constrain future sales of E15. Recent trends of E15 sales were used to guide projections of future E15 sales. Only two states track E15 sales, and year-round sales of E15 have only been allowed since 2019. As shown in Figure 4, E15 sales appear to be growing non-linearly. However, for forecasting purposes the most conservative assumption would be to assume linear growth based on Minnesota data¹² which indicates that since 2019 E15 market share grew by 1.1 percentage points per year. The Iowa data²¹ shows a faster growth rate of 2.5 points of market share per year since 2020.

In both states, the growth was a combination of increased volume per station selling E15, and increased number of stations selling E15. From 2019 to 2022, the number of stations selling E15 grew by 33% in Iowa and 23% in Minnesota. Both data sets are from a time of great uncertainty for E15 due to the petitions, temporary waivers, and lawsuits mentioned previously.⁹
¹⁰ ¹¹ Therefore recent trends of E15 market growth give strong evidence that fuel infrastructure compatibility can be overcome at least this quickly.

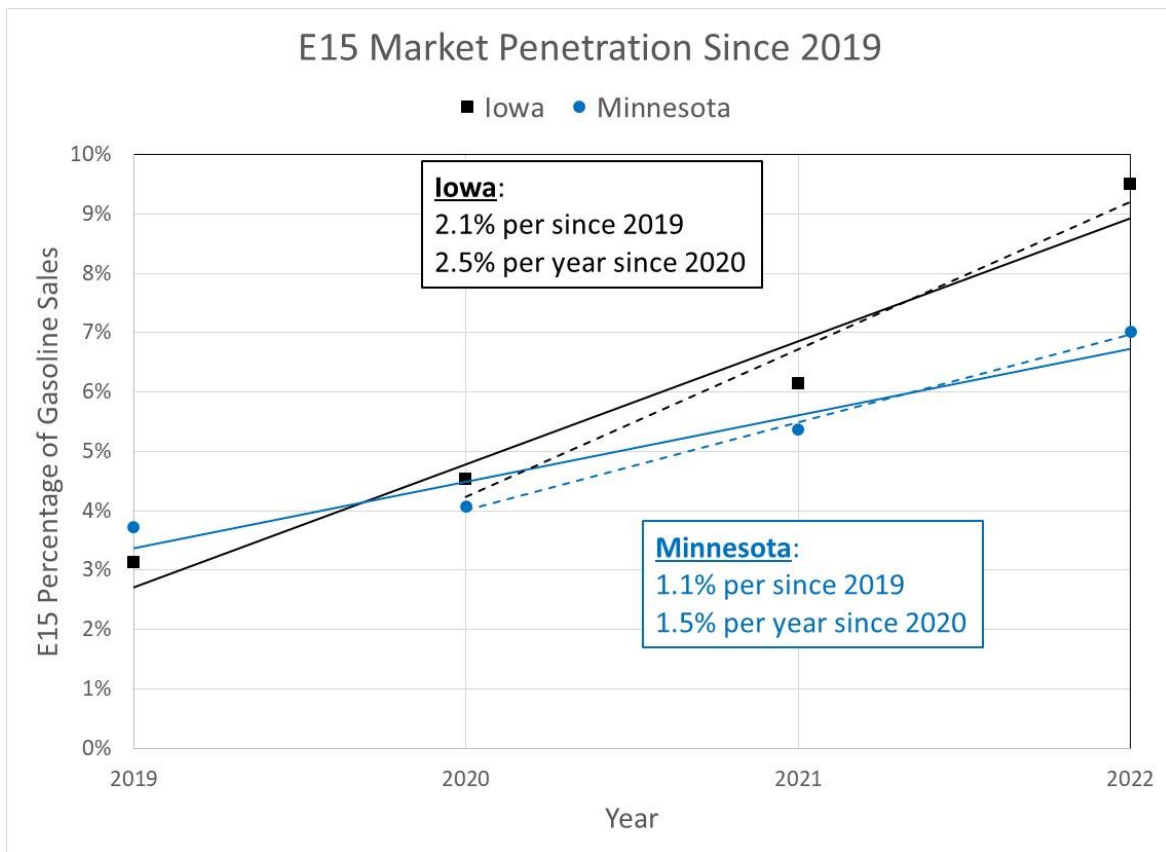


FIGURE 4: E15 MARKET PENETRATION SINCE 2019

²¹ Iowa Department of Revenue "Retailers Fuel Gallons Annual Reports", <https://tax.iowa.gov/retailers-fuel-gallons-annual-report>

Another potential constraint on E15 is compatibility of vehicles. Vehicle compatibility has been extensively studied by Oak Ridge National Laboratory, the National Renewable Energy Laboratory, the U.S. Environmental Protection Agency, the Coordinating Research Council (eight automakers and the American Petroleum Institute), and others.^{22,23,24,25,26,27,28,29,30,31,32} Based on these studies, EPA approved the use of E15 for model year 2001 and newer vehicles.³³

Soon after EPA approved E15 in 2011, automakers started to formally approve use of E15 in their owner's manuals, beginning with General Motors in model year 2012. Some automakers were slow³⁴ to approve use of E15, and a few still do not formally approve it. To the best of our knowledge, no data exists regarding the percentage of people who base refueling decisions on owner's manuals, so multiple scenarios were analyzed as potential constraints on future use of E15. To quantify the scenario of strict adherence to automaker recommendations in owner's manuals, the number of manufacturer-approved E15 vehicles from each automaker was quantified³⁵ for each year starting in 2012, as shown in Figure 5.

²² Bechtold, Thomas, Huff, Szybist, Theiss, West, Goodman, and Timbario, "Technical Issues Associated with the Use of Intermediate Ethanol Blends (>E10) in the U.S. Legacy Fleet: Assessment of Prior Studies", ORNL/TM-2007/37, 2007, <http://info.ornl.gov/sites/publications/files/Pub7767.pdf>

²³ Knoll, West, Clark, Graves, Orban, Przesmitzki, and Theiss, "Effects of Intermediate Ethanol Blends on Legacy Vehicles and Small Non-Road Engines", ORNL/TM-2008/117, 2009, <http://info.ornl.gov/sites/publications/Files/Pub12154.pdf>

²⁴ Knoll, Keith, Brian West, Shean Huff, John Thomas, John Orban, Cynthia Cooper, "Effects of Mid-Level Ethanol Blends on Conventional Vehicle Emissions," SAE Technical Paper 2009-01-2723, 2009, <https://doi.org/10.4271/2009-01-2723>

²⁵ Shoffner, Johnson, Heimrich, and Lochte, "Powertrain Component Inspection from Mid-Level Blends Vehicle Aging Study", ORNL/TM-2011/65, 2010, <http://info.ornl.gov/sites/publications/files/Pub28733.pdf>

²⁶ Sluder, C. and West, B., "NMOG Emissions Characterizations and Estimation for Vehicles Using Ethanol-Blended Fuels", SAE Int. J. Fuels Lubr. 5(2):721-732, 2012, <https://doi.org/10.4271/2012-01-0883>

²⁷ Sluder, West, and Knoll, "Investigating Malfunction Indicator Light Illumination Due to Increased Oxygenate Use in Gasoline", SAE Int. J. Fuels Lubr. 5(3):1360-1371, 2012, <https://doi.org/10.4271/2012-01-2305>

²⁸ West, Sluder, Knoll, Orban, and Feng, "Intermediate Ethanol Blends Catalyst Durability Program", ORNL/TM-2011/234, 2012, <http://info.ornl.gov/sites/publications/Files/Pub31271.pdf>

²⁹ Vertin, Glinksy, and Reek, "Comparative Emissions Testing of Vehicles Aged on E0, E15, and E20 Fuels", NREL/SR-5400-55778, 2012, <http://www.nrel.gov/docs/fy12osti/55778.pdf>

³⁰ EPA, NREL, and CRC, EPA/V2/E-89: "Assessing the Effect of Five Gasoline Properties on Exhaust Emissions from Light-Duty Vehicles Certified to Tier 2 Standards", EPA-420-R-13-004, 2013, <http://www.epa.gov/otaq/models/moves/epact.htm>

³¹ West and Sluder, "Mid-Level Ethanol Blends Vehicle Aging Program", Department of Energy Annual Report, DOE/EE-0911, June 2013, https://www.energy.gov/sites/prod/files/2014/03/f8/2012_fuel_lubricant.pdf

³² "Technical Assessment of the Feasibility of Introducing E15 Blended Fuel in U.S. Vehicle Fleet, 1994 to 2000 Model Years", Ricardo Inc. Project FE405 Archive RD.10/231405.1, 2010, <https://www.farmanddairy.com/wp-content/uploads/2010/10/Ricardo-study-on-E15.pdf>

³³ Federal Register, Vol. 76(17), January 26, 2011

³⁴ "RFA Analysis: Automakers Endorse E15 for Almost All New 2024 Vehicles", <https://ethanolrfa.org/media-and-news/category/news-releases/article/2023/12/rfa-analysis-automakers-endorse-e15-for-almost-all-new-2024-vehicles>

³⁵ Sales data by year and manufacturer from Marklines

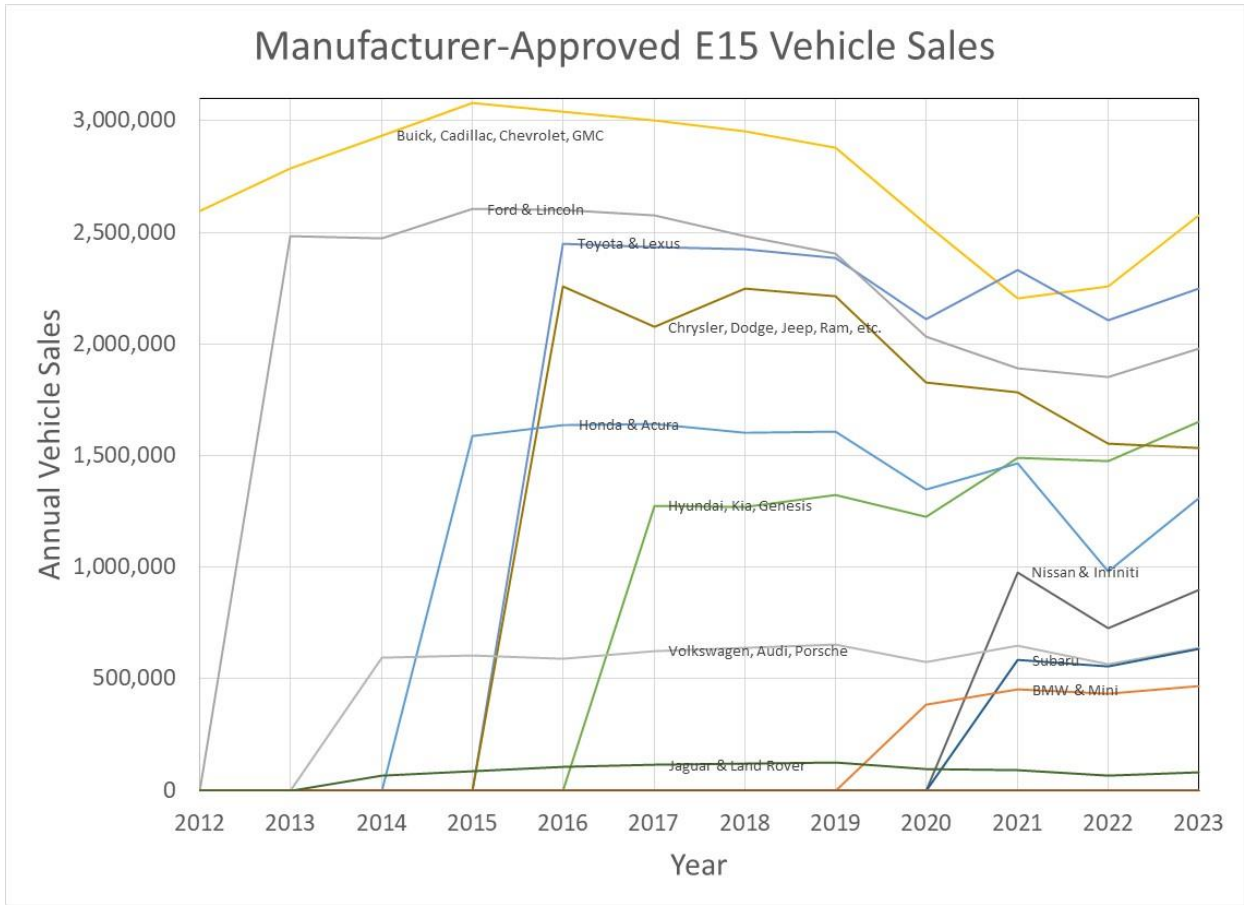


FIGURE 5: MANUFACTURER-APPROVED E15 VEHICLE SALES

To quantify size of the on-road fleet of E15 vehicles, the number of E15 vehicles produced each year (Figure 5) is added to the fleet and the estimated number of E15 vehicles scrapped each year is subtracted from the fleet. Estimated vehicle survival rates were based on vehicle age³⁶. To estimate the future on-road fleet, it was assumed that each manufacturer would continue with the same E15 approval policy and market share as 2023. It is worth noting that battery electric vehicles will not use E15, and future estimates of internal combustion engine (ICE) vehicle sales were based on the recently finalized EPA³⁷ rules. The results are shown in Figure 6 for both manufacturer-approved and EPA-approved E15 capability.

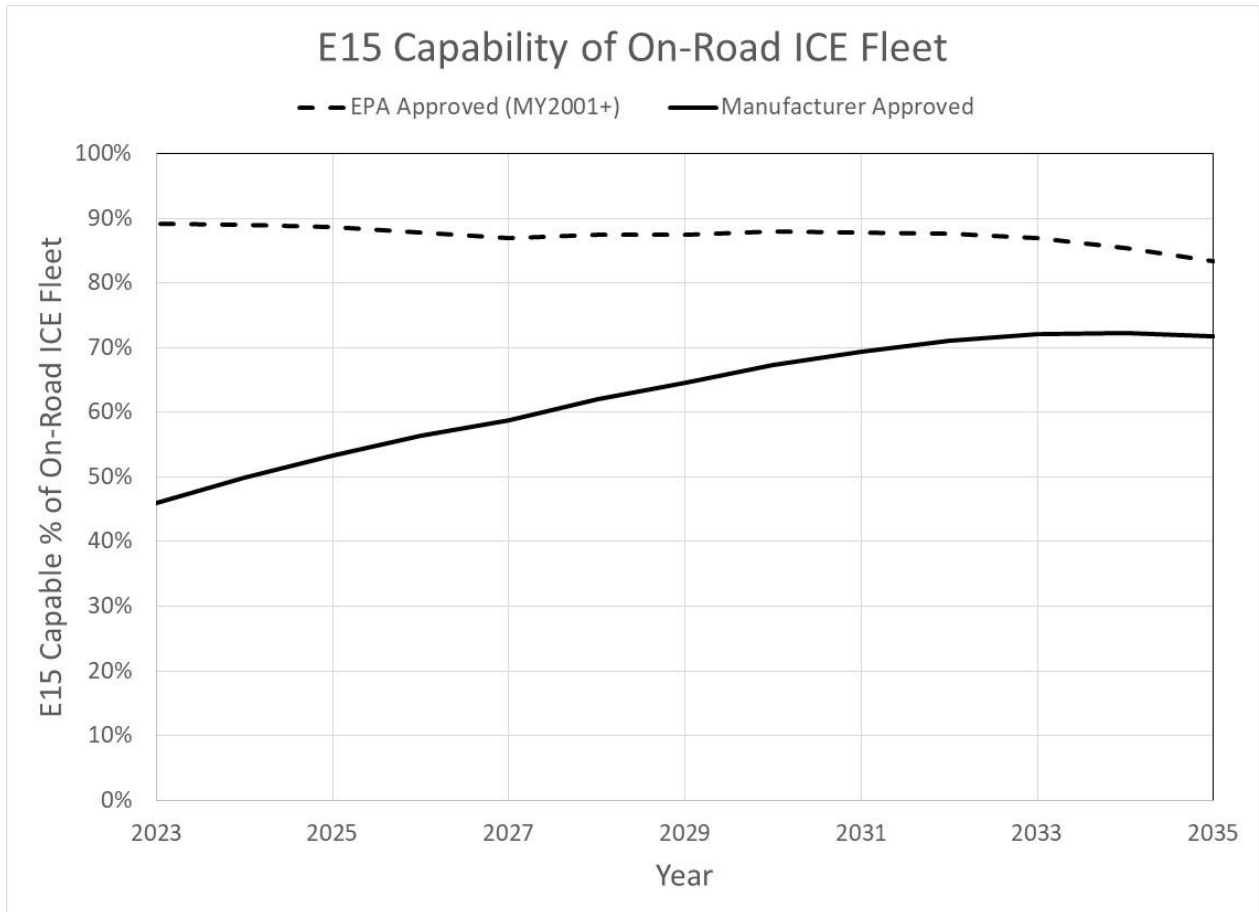


FIGURE 6: E15 CAPABILITY OF ON-ROAD ICE FLEET

³⁶ Using the average of sedan, SUV, and pickup survival rates from 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>

³⁷ Tables 4-27 and 12-66 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 FUTURE SCENARIOS FOR E15

If the Consumer and Fuel Retailer Choice Act of 2023 takes effect, or if other action is taken to equalize vapor pressure regulation for E15 and E10, then fuel retailers will have a much more stable and predictable environment, and future market share growth of E15 could increase faster than recent trends. Faster growth of E15 may also be facilitated by recent increases²⁰ in infrastructure funding from the Inflation Reduction Act. A quantitative example of fast market growth is the transition from E0 to E10 in the early 2000s. As shown in Figure 7, ethanol as a fraction of gasoline increased³⁸ from 2% to nearly 10% in seven years. Some ethanol was also sold as E85, but this isn't quantified in the EIA data. Neglecting the small effect of E85, market share of E10 increased an average of 11 percentage points per year from 2003 to 2010.

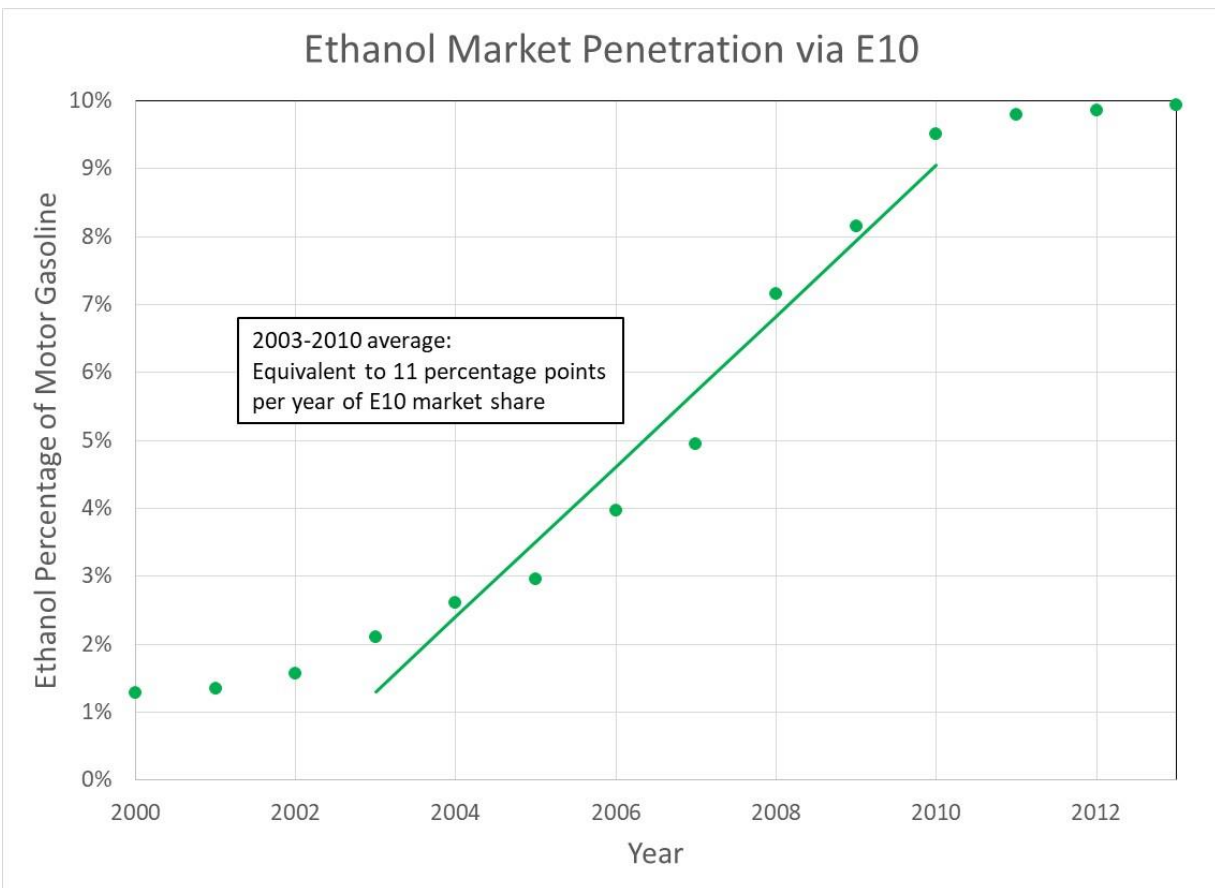


FIGURE 7: ETHANOL MARKET PENETRATION VIA E10

³⁸ U.S. Energy Information Administration, March 2024 Monthly Energy Review, Tables 10.3 and 3.7c, <https://www.eia.gov/totalenergy/data/monthly/>

It is interesting to note that price competitiveness of ethanol was the strongest driver of E10 market growth³⁹ during this time, although the phase-out of MTBE, policy factors (VEETC and RINs), and the octane value of ethanol ("match blends") also contributed, as shown in Figure 8. Similarly, future growth of E15 could be supported with policies which recognize the life cycle greenhouse gas benefits of ethanol. Low-Carbon Fuel Standards or Clean Fuel Standards have already been established in California, Oregon, Washington and New Mexico, and similar standards are under consideration in eight other states⁴⁰.

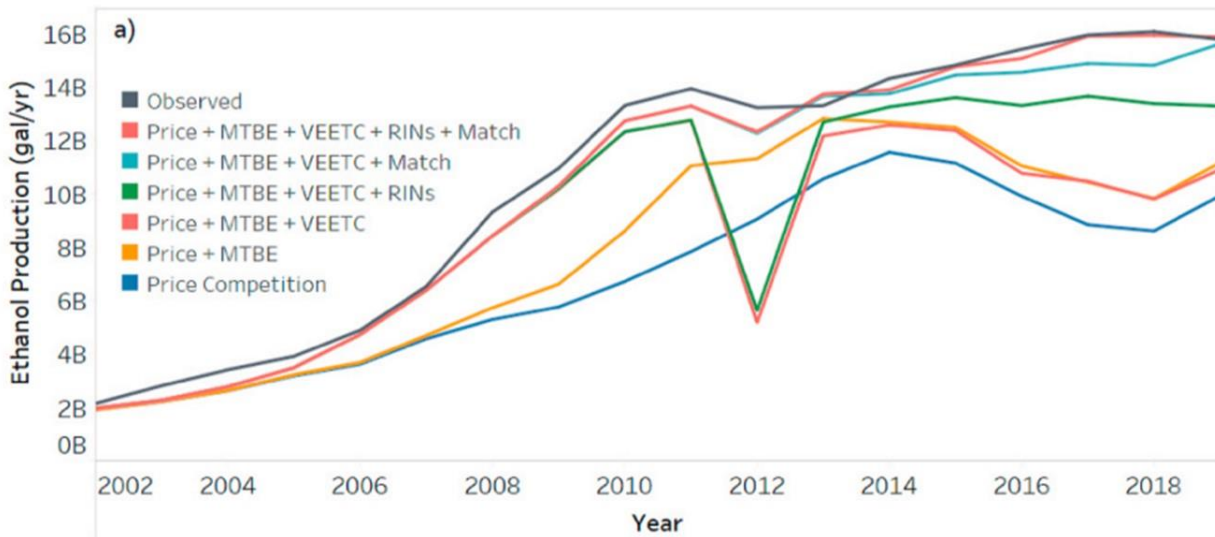


FIGURE 8: POLICY AND PRICE FACTORS DRIVING ETHANOL

³⁹ Newes, Clark, Vimmerstedt, et al. (NREL and EPA), "Ethanol production in the United States: The roles of policy, price, and demand", 2021, <https://doi.org/10.1016/j.enpol.2021.112713>

⁴⁰ "Eight States in Gear with Low-Carbon Fuel Standard Legislation" <https://www.pillsburylaw.com/en/news-and-insights/eight-states-low-carbon-fuel-standard-legislation.html>

The E15 scenarios developed for this study are summarized⁴¹ in Figure 9. In the most optimistic scenario, future nationwide market share of E15 could increase at a up to 11 points of market share per year (based on nationwide E10 data from 2003 to 2010), resulting in 100% E15 by 2033. In the most pessimistic scenarios, it would increase by 1.1 points of market share per year and only in the eight Midwestern states with the current EPA 1-psi waiver (based on Minnesota E15 data since 2019). In the most pessimistic scenario, nationwide market share of E15 would be 1.9% in 2035. In some scenarios, the growth of E15 could be constrained if people base refueling decisions on recommendations from EPA or from vehicle owner's manuals.

It is important to note that scenarios with faster adoption of E15 depend on policy and regulatory factors such as adoption of the Consumer and Fuel Retailer Choice Act of 2023 (or other action to equalize vapor pressure regulation for E15 and E10) and/or adoption of Low-Carbon Fuel Standards (or other action to recognize the life cycle greenhouse gas benefits of ethanol).

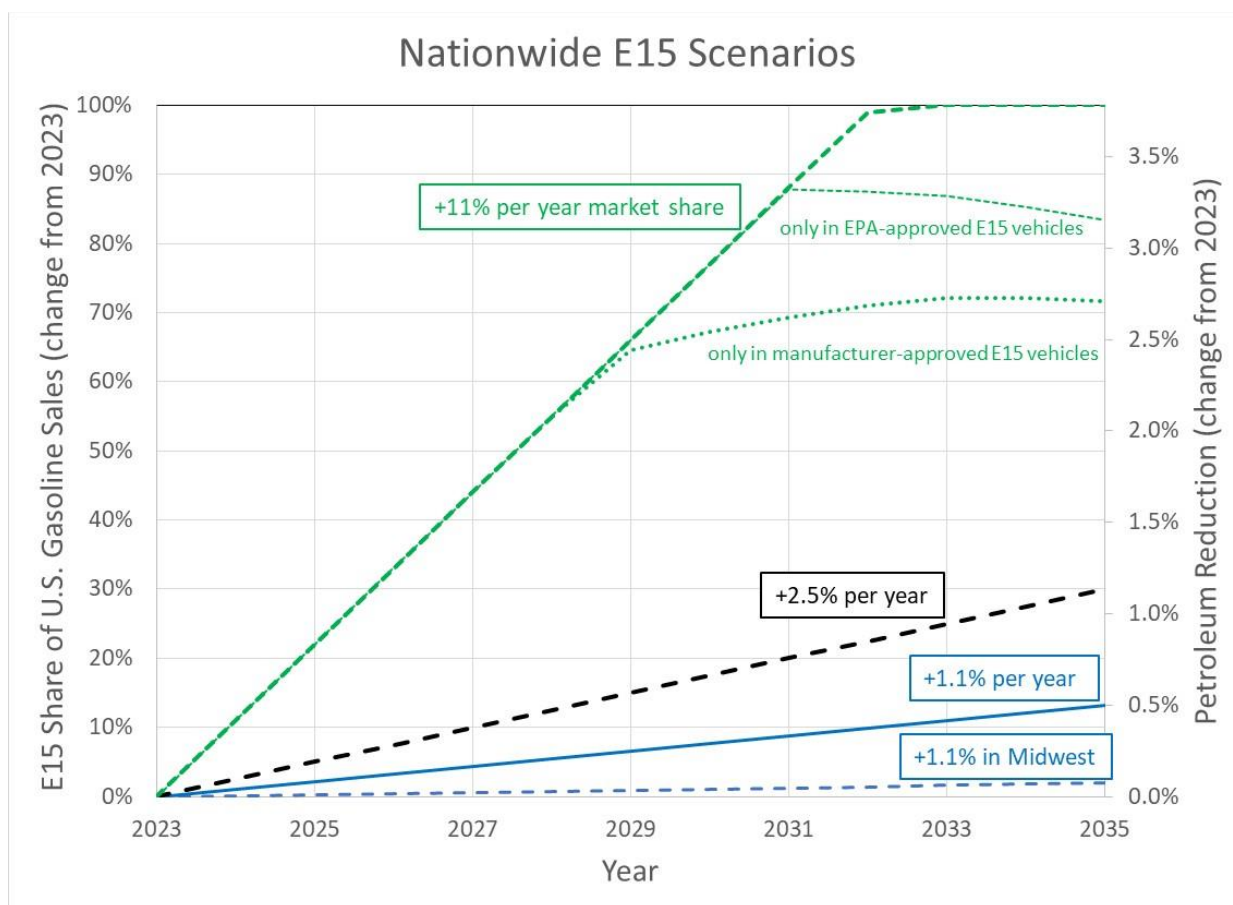


FIGURE 9: NATIONWIDE E15 SCENARIOS

⁴¹ Replacing E15 with E10 reduces petroleum by 5% on a volume basis, but 3.8% on an energy basis.

5 LIFE CYCLE GREENHOUSE GAS BENEFITS

The life cycle greenhouse gas benefits of ethanol have been studied extensively. A critical review⁴² 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 gCO₂e/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.

The most 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 studied² changes in the carbon intensity of corn ethanol, and found a 23% improvement from 2005 to 2019 (the black bars in Figure 10). The biggest contributor to the improvement was reduced natural gas consumption in ethanol production (the blue bars in Figure 10). 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".

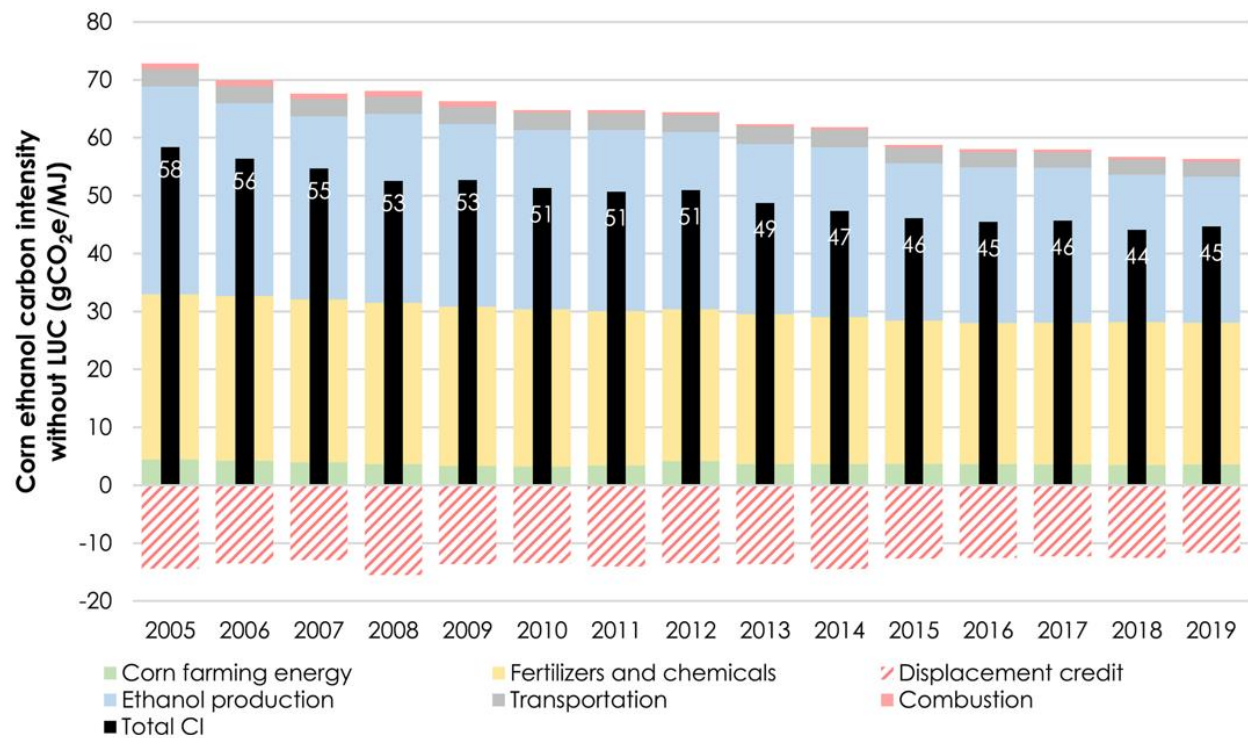


FIGURE 10: CARBON INTENSITY OF CORN ETHANOL, 2005 TO 2019

⁴² 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 ethanol (the yellow bars in Figure 10). 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 yield⁴³ has been improving for many decades, as shown in Figure 11.

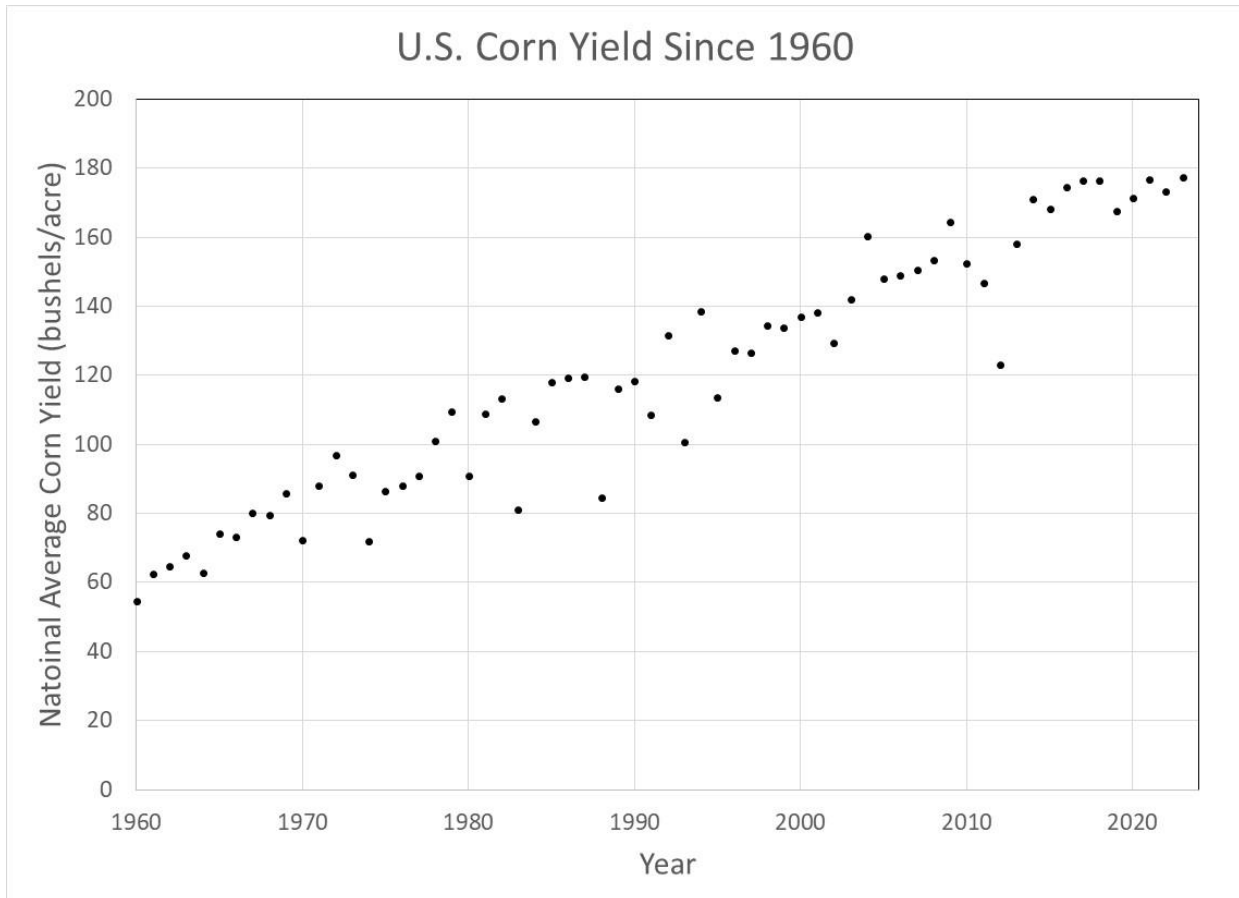


FIGURE 11: CORN YIELD SINCE 1960

⁴³ U.S. Department of Agriculture, National Agricultural Statistics Service, <https://quickstats.nass.usda.gov/results/29260F67-A60C-3C6A-B323-8E5049510EBB>

To quantify the potential future greenhouse gas benefits of E15, 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^{44,45} for estimating the future carbon intensity of electricity production. According to documentation from the California Air Resources Board, ethanol used for credit under the Low-Carbon Fuel Standard improved in carbon intensity⁴⁶ by 25% between 2011 and 2019. As described above, it is reasonable to expect that the two trends contributing to recent improvements in ethanol carbon intensity will continue in future years. For this study, the future carbon intensity of ethanol is assumed to continue the 2005-2019 trend⁴⁷ from Figure 10, as shown in Figure 12.

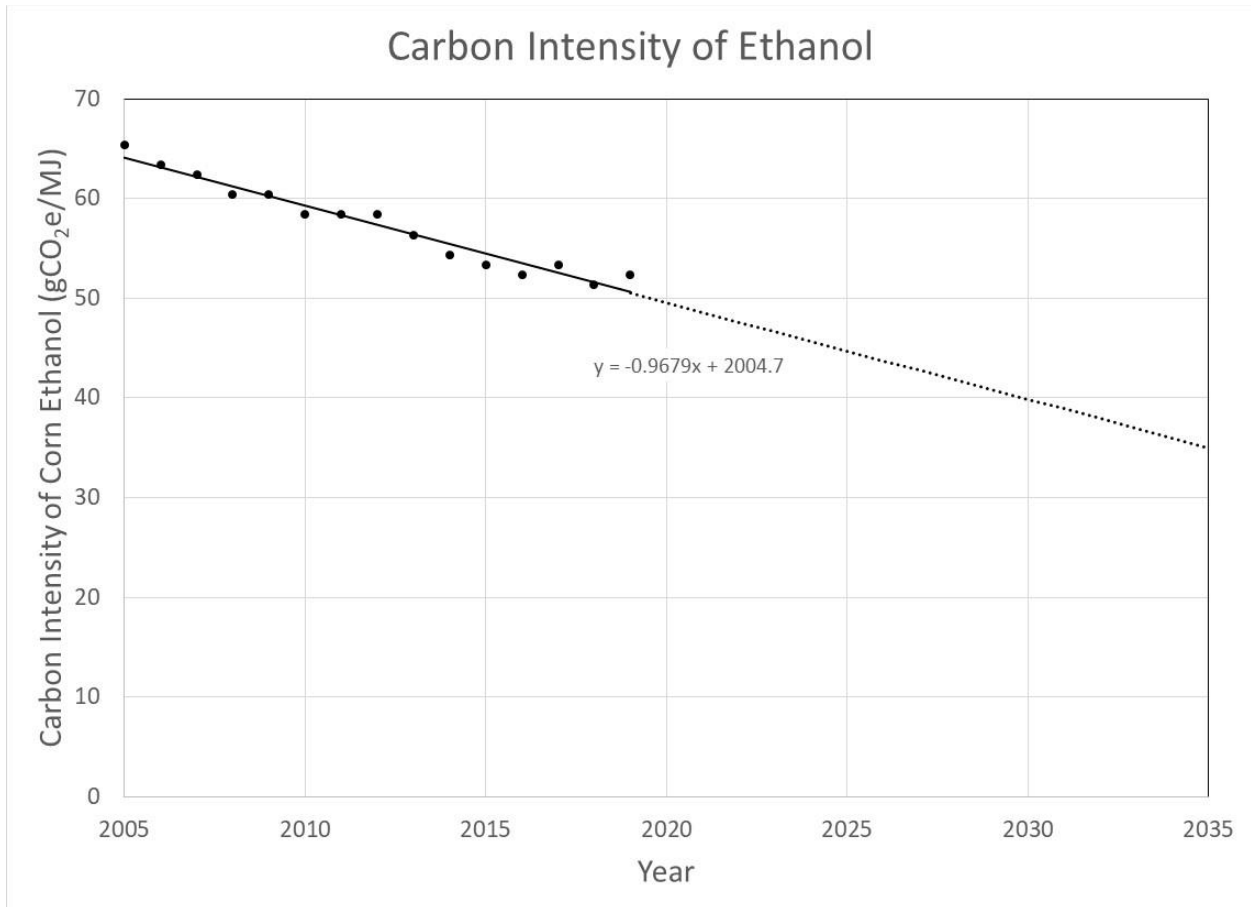


FIGURE 12: CARBON INTENSITY OF ETHANOL

⁴⁴ 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>

⁴⁵ U.S. Energy Information Administration, Annual Energy Outlook, <https://www.eia.gov/outlooks/aeo/>

⁴⁶ 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, 2020, https://www.usda.gov/sites/default/files/documents/CA_LCFS_Incentivizing_Ethanol_Industry_GHG_Mitigation.pdf

⁴⁷ Plus 7.4 gCO₂e/MJ for land use change, as noted in the paper²

Based on the carbon intensity of ethanol from Figure 12 and a few key values⁴⁸ from GREET, the carbon intensity of E10 and E15 can be calculated for future years. As shown in Figure 13, both E10 and E15 improve over time as the carbon intensity of ethanol improves. Due to the higher ethanol content of E15, the CO₂ benefit of E15 vs. E10 improves from 1.8% in 2022 to 2.3% in 2035.

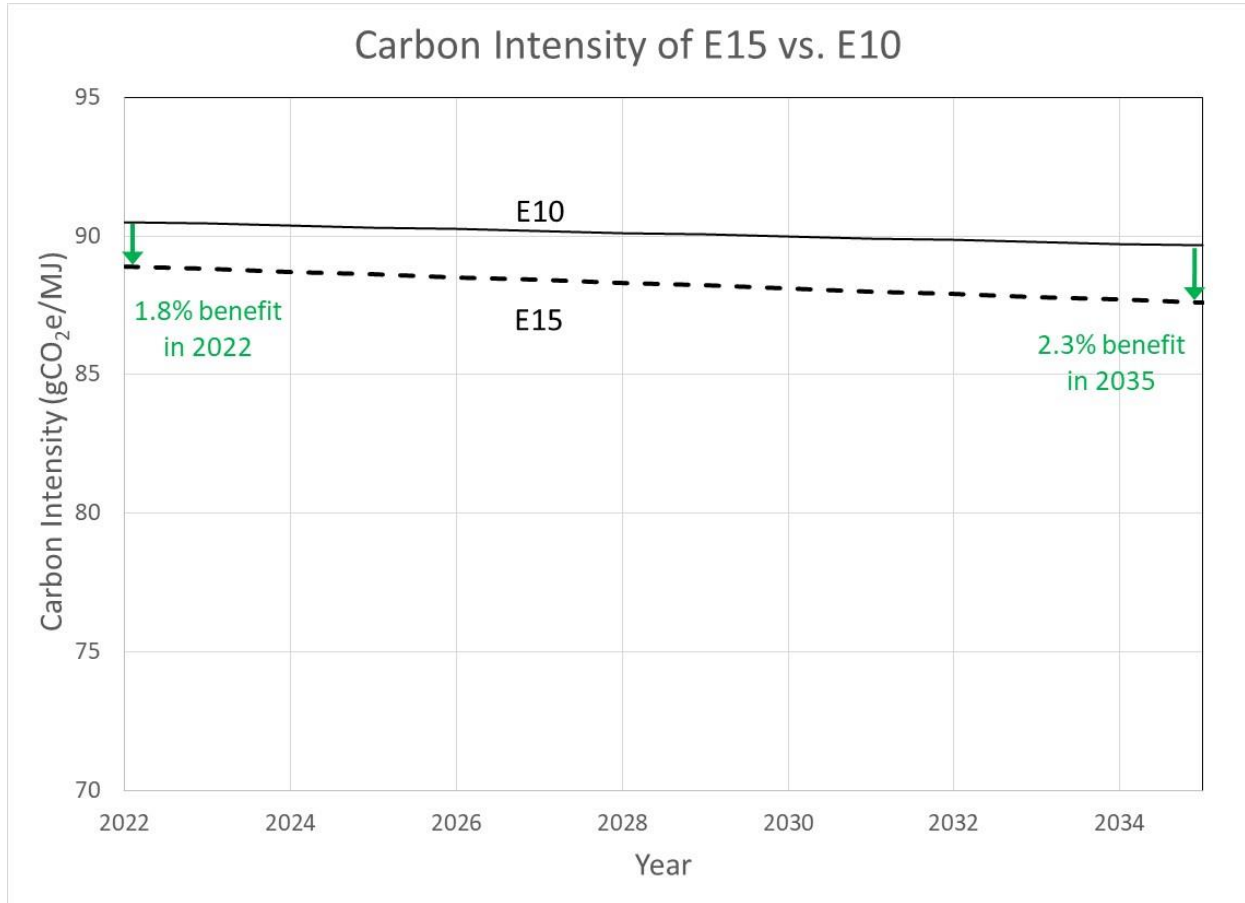


FIGURE 13: CARBON INTENSITY OF E15 VS. E10

⁴⁸ From GREET.NET 2023, simulation year 2022: ethanol LHV = 21,274 MJ/m³, gasoline blendstock LHV = 32,356 MJ/m³, E10 LHV = 31,270 MJ/m³, E10 CI = 90.1 gCO₂e/MJ

Using the carbon intensity benefit of E15 from Figure 13 and projected gasoline consumption from the U.S. Energy Information Administration⁴⁹, the total greenhouse gas benefit of E15 can be calculated for each of the scenarios in Figure 9. The results are shown in Figure 14. Modest market share increases of E15 result in millions of tons of greenhouse gas benefits. Fast growth of E15 would allow a benefit of up to 29 million tons annually.

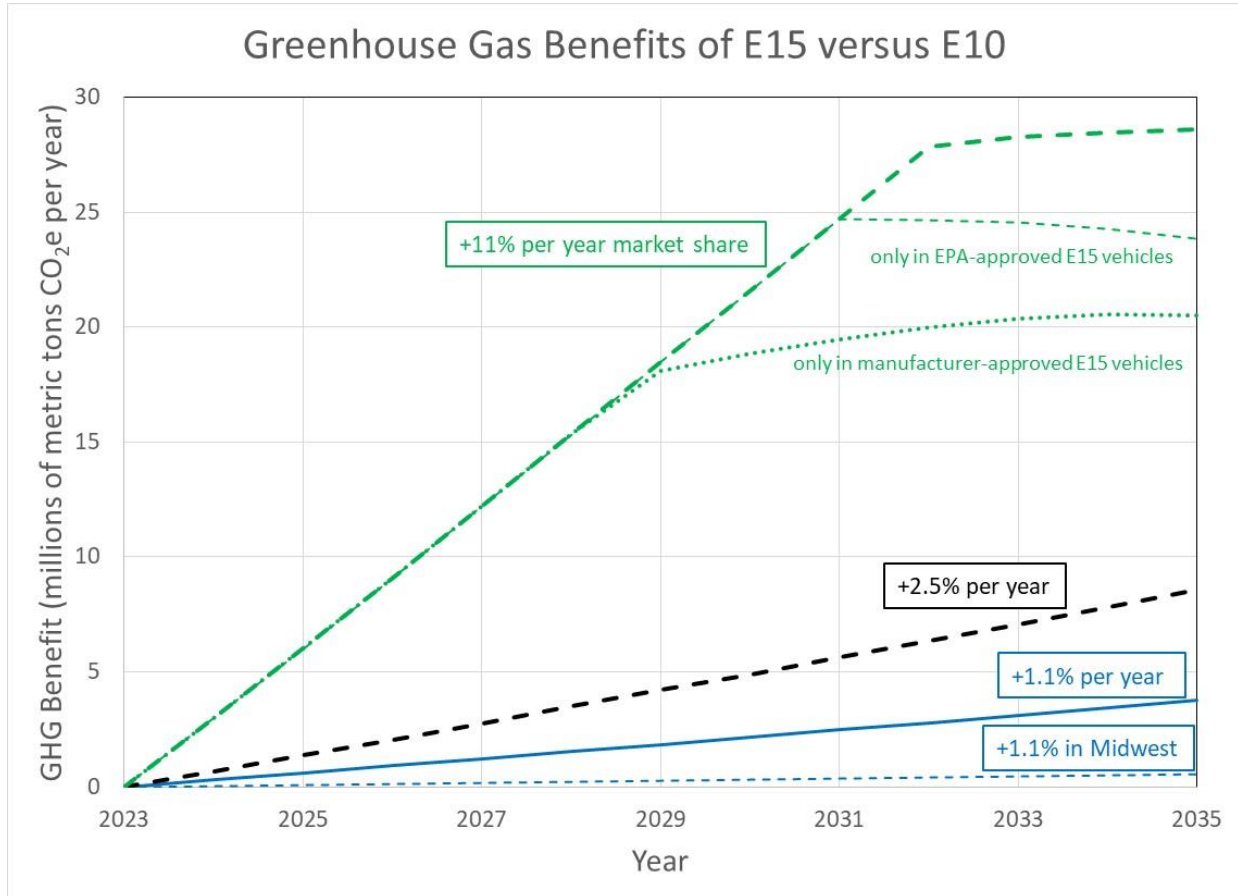


FIGURE 14: GREENHOUSE GAS BENEFITS OF E15 VERSUS E10

⁴⁹ EIA Annual Energy Outlook 2023, Reference Case <https://www.eia.gov/outlooks/aeo/data/browser/>

6 RETAIL COST SAVINGS OF E15

The retail cost of E15 versus E10 was analyzed using data from E15prices.com, which is "crowdsourced" price information contributed by individuals nationwide. The analysis only used data where E15 and E10 prices were reported for the same station on the same date. The data was adjusted for the difference in volumetric energy content⁵⁰.

The individual data points show significant scatter, but the monthly averages show a cost savings for every month from January 2022 to April 2024. As shown in Figure 15, the median cost savings of E15 was 3.2% over this time period.

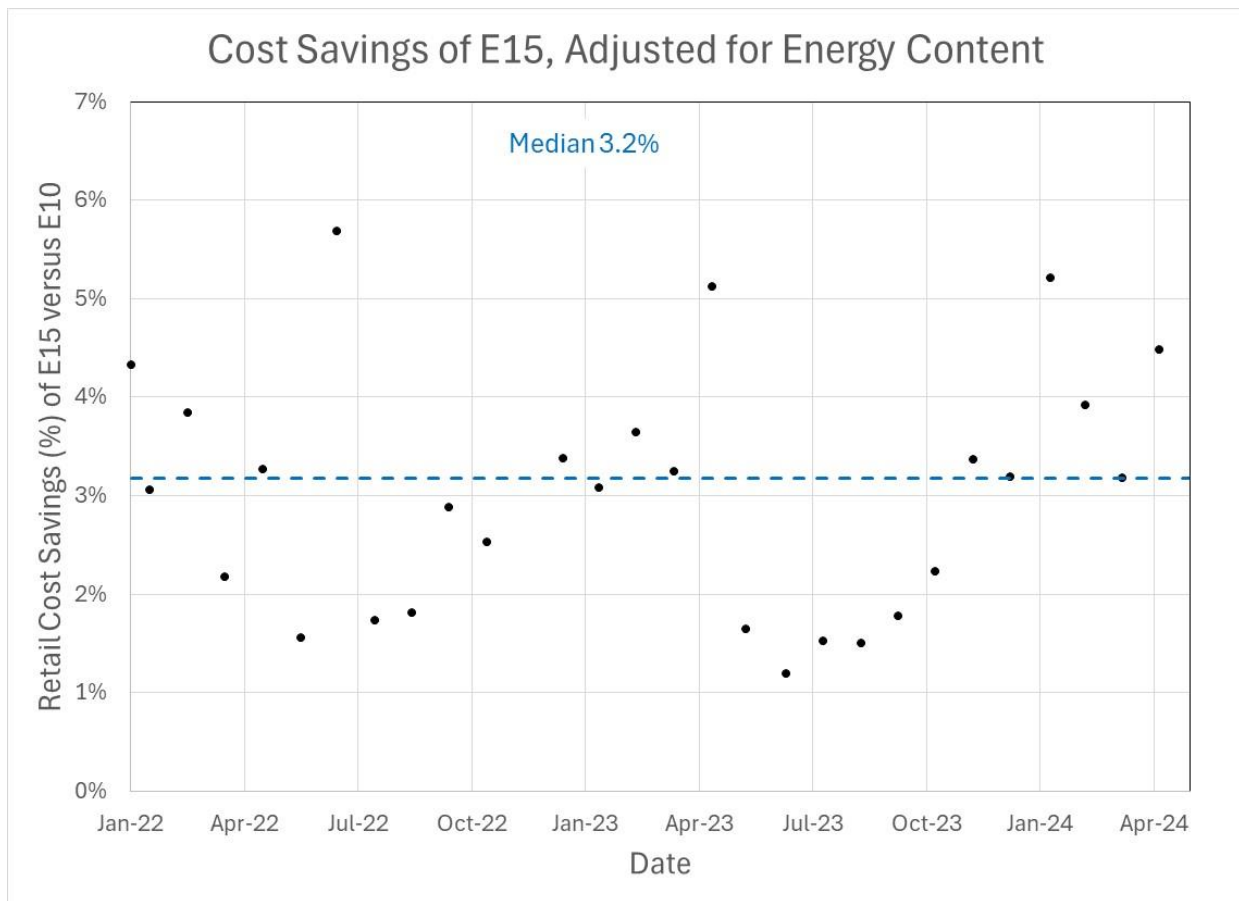


FIGURE 15: COST SAVINGS OF E15 VERSUS E10

⁵⁰ Volumetric energy content of E15 is 1.8% lower than E10 based on values in GREET.NET 2023, simulation year 2022: ethanol LHV = 21,274 MJ/m³, gasoline blendstock LHV = 32,356 MJ/m³. Note that UC-Riverside measured only 1.2% lower fuel economy for E15 in back-to-back testing of twenty vehicles: Karavalakis, Durbin, and Tang, "Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15", 2022, https://ww2.arb.ca.gov/sites/default/files/2022-07/E15_Final_Report_7-14-22_0.pdf

7 DISCUSSION AND CONCLUSIONS

Widespread use of E15 (gasoline with 15% ethanol) would significantly reduce greenhouse gas emissions from transportation. This study identified realistic scenarios for widespread adoption of E15 and quantified the greenhouse gas benefits using life cycle analysis.

A major obstacle to increasing E15 market share is the "1-psi waiver" for E10. The EPA recently approved a rule which will apply the same vapor pressure requirements to E10 and E15 in eight Midwestern states which account for 14.5% of U.S. gasoline sales. The Consumer and Fuel Retailer Choice Act of 2023 would apply the same vapor pressure requirements to E10 and E15 throughout the U.S., and thus create a stable environment for faster nationwide growth of E15.

Expansion of E15 sales may be constrained by compatibility of the fuel distribution system. The growth of E15 sales in Iowa and Minnesota provide quantitative examples of how quickly these constraints can be overcome, even with the recent uncertainty of petitions, temporary waivers, and lawsuits related to E15. Future growth of E15 is likely to be faster than recent trends due to the elimination of this uncertainty in the Midwestern states - and perhaps nationwide.

Adoption of E15 could be much faster than recent trends, depending on policy and regulatory factors. Greater adoption of Low-Carbon Fuel Standards, or other action to recognize the life cycle greenhouse gas benefits of ethanol, could encourage very fast growth. An example of fast market growth is the transition from E0 to E10 in the early 2000s, and this was used to quantify a more optimistic scenario for E15.

The scenarios in this study estimate E15 market share ranging from 1.9% to 100% in 2035. The scenarios show petroleum gasoline consumption reductions of 0.1% to 3.8%, and life cycle greenhouse gas benefits of 0.6 to 29 million metric tons CO₂e per year.

To put these numbers in perspective, the EPA estimates⁵¹ that its new standards will achieve benefits of 140 million metric tons CO₂e per year in 2035. These aggressive standards will require light-duty vehicles in MY2032 to produce about 54% lower average CO₂ emissions than in MY2026. But the standards are based on tailpipe emissions, not life cycle emissions. Because electric vehicles have zero tailpipe emissions, they are expected to play a dominant role; EPA estimates new vehicle sales to be about 56% battery electric vehicles by 2032. Fast growth of E15 could achieve a large fraction of this benefit, because E15 would improve life cycle CO₂ emissions for the huge fleet of existing vehicles, not just new vehicles.

In addition to the greenhouse gas benefits, E15 generally offers a retail price advantage, which averaged 3.2% since January 2022.

⁵¹ Table 204 of EPA final rule "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>