TRANSPORTATION ENERGY INSTITUTE

WHITE PAPER

Mid-Level Ethanol Blends: Opportunities and Constraints in the Move Beyond E15

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Contents

Introduction

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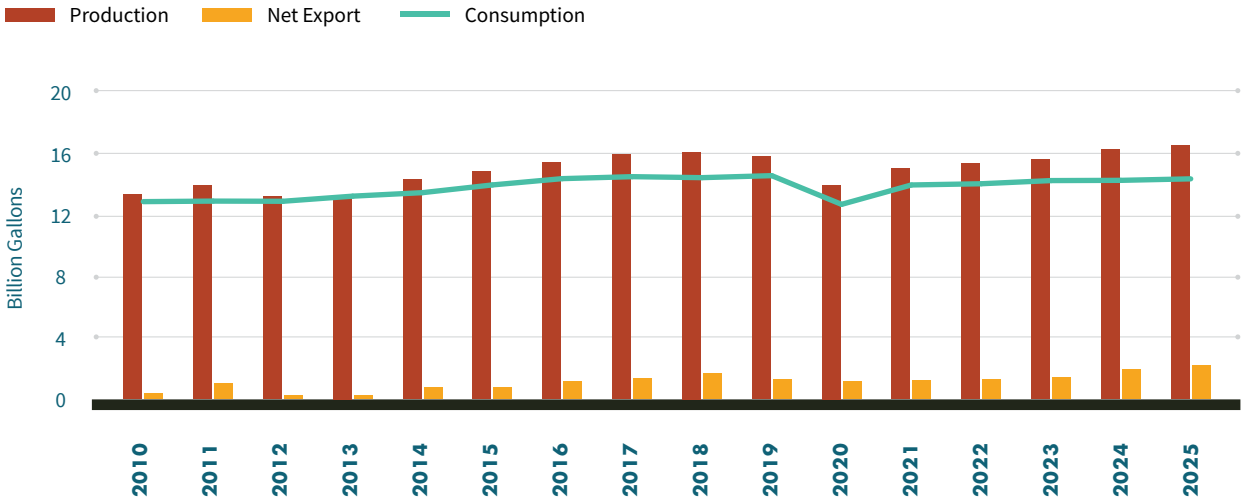
With more than 98% of vehicles in operation in the U.S. powered by an internal combustion engine (ICE)[1], liquid fuels are a critical component of the transportation market. It is therefore important to evaluate the fuels that are used to power these vehicles and determine which formulations make the most sense from environmental and economic perspectives.

1 According to Statista, there were 292.3 million vehicles in operation in the United States at the end of 2024: https://www.statista.com/statistics/859950/vehicles-in-operation-by-quarter-united-states/. According to Argonne National Laboratory, there were 5.7 million battery electric and plug-in hybrid electric vehicles in operation, for a combined market share of 1.95%: https://www.anl.gov/ev-facts/model-sales.

In 2025, the U.S. consumed 136.5 billion gallons of finished motor gasoline,[2] including 14.3 billion gallons of ethanol.[3] Ethanol represented 10.5% of the gasoline pool and was most commonly consumed as E10 (gasoline blended with 9%–10% ethanol), which is considered substantially similar to gasoline, is ubiquitous in the market, and often is not required to be disclosed to the consumer. That year, the U.S. produced 16.5 billion gallons of ethanol and exported 2.2 billion gallons, or 13.3% of production.[4]

FIGURE 1: ETHANOL SUPPLY AND DISPOSITION



Source: U.S. EIA

Ethanol is also offered as E15 (gasoline blended with 10.5%–15% ethanol)[5] and as E85 (gasoline blended with 51%–83% ethanol).[6] At the end of 2025, E15 was available at more than 4,700 retail stations[7] and E85 was available at more than 4,800 stations.[8] For context, there are approximately 150,000 fuel retailing facilities in the U.S. E15 is approved for use in passenger vehicles manufactured as early as 2001, whereas E85 is approved for use only in specially manufactured flexible-fuel vehicles (FFVs),[9] which can run on any type of gasoline blended with 0% ethanol up to 83% ethanol.

2 U.S. EIA. Petroleum & Other Liquids. https://www.eia.gov/dnav/pet/pet_cons_psup_dc_nus_mbbl_a.htm.

3 U.S. EIA. Renewable & Alternative Fuels. https://www.eia.gov/renewable/data.php#alternative.

4 Ibid.

5 AFDC. E15. https://afdc.energy.gov/fuels/ethanol-e15.

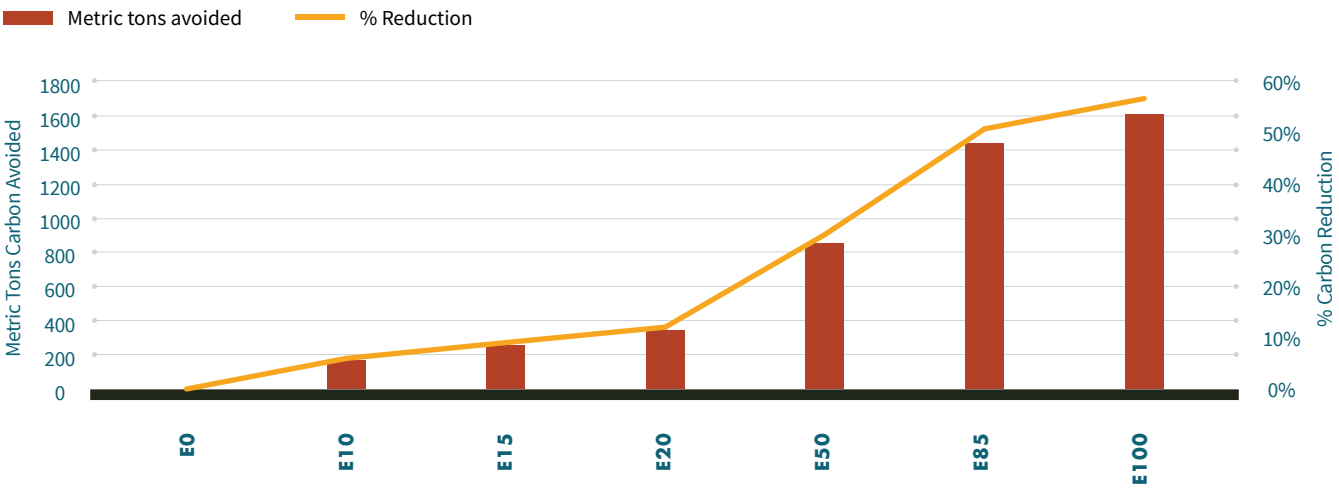
6 AFDC. Flexible Fuel Vehicles. https://afdc.energy.gov/vehicles/flexible-fuel.

7 Growth Energy. Value at the Pump. https://growthenergy.org/value-of-biofuels/value-at-the-pump/.

8 AFDC. Ethanol Fueling Station Locations. https://afdc.energy.gov/fuels/ethanol-locations#/analyze?country=US&tab=fuel&fuel=E85.

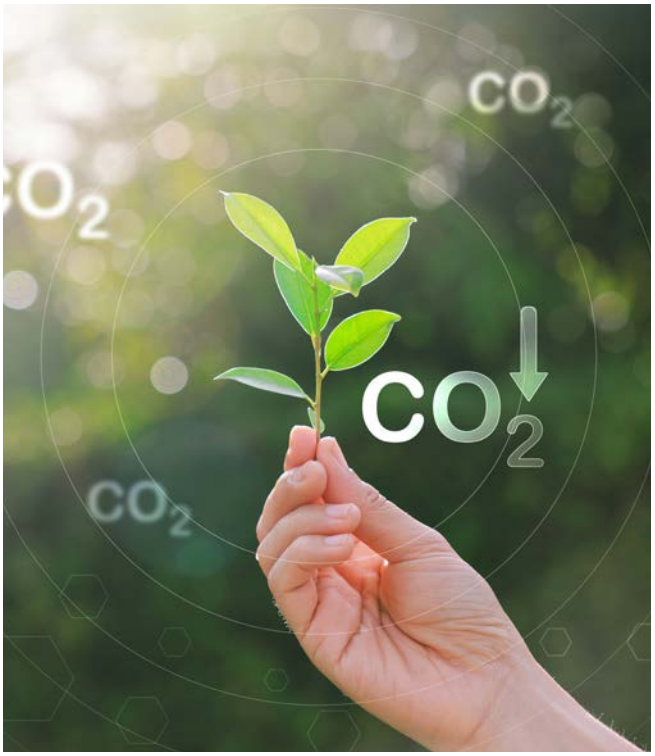
9 U.S. DOE. Flex-Fuel Vehicles. https://www.fueleconomy.gov/feg/flextech.shtml.

FIGURE 2: LIFE CYCLE CARBON EMISSIONS REDUCTIONS WITH ETHANOL



Source: TEI Carbon Avoidance Tracker

Despite recent changes in U.S. federal policies and priorities, the quest to reduce carbon emissions from transportation will continue, and ethanol is considered by many to be a viable option. According to Argonne National Laboratory's greenhouse gases, regulated emissions, and energy use in technologies (GREET) model, [10] E100 has an average carbon intensity[11](CI) of 51.4 (range of 37.6–65.1),[12] which is 45% lower than the regulatory baseline gasoline CI of 93.08.[13] When GREET is applied to ethanol-gasoline blends in a model developed by the Transportation Energy Institute (TEI),[14] the impact on greenhouse gas (GHG) emissions of blending ethanol with gasoline ranges from a 6% reduction in emissions at E10 up to 50.8% with E85. Consequently, ethanol is seen by many as an important element in a strategy to reduce carbon emissions from ICE-equipped vehicles.



10 For these calculations, the TEI Carbon Avoidance Tracker (aka Felix) used the 2023 R&D GREET Fuel Cycle model. Access to GREET models is available at https://greet.anl.gov/greet.models.

11 Carbon intensity refers to the emissions of carbon dioxide equivalents (CO_2e) and is measured in grams of CO_2e emitted per megajoule of energy (gCO_2e/MJ).

12 Scully, M., et al. 2021. Carbon intensity of corn ethanol in the United States: State of the science. *Environmental Research Letters*, vol. 16, no. 4. https://iopscience.iop.org/article/10.1088/1748-9326/abde08.

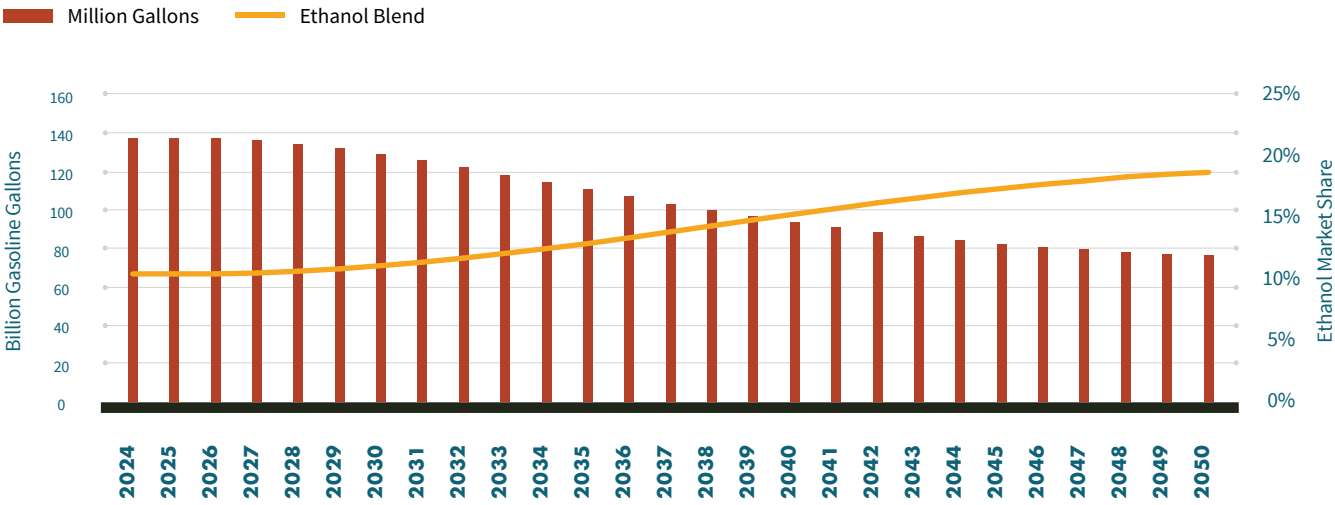
13 The regulatory baseline CI for gasoline is established in the Final Rule establishing RFS2. The value is set at 98 kg CO_2e/mm BTU, which is then converted to 93.08 g/MJ. See Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program. 75 Fed. Reg., 14788, table V.C-1. https://www.govinfo.gov/content/pkg/FR-2010-03-26/pdf/2010-3851.pdf.

14 TEI. Carbon Avoidance Tracking. https://www.transportationenergy.org/carbon-avoidance-tracking.

For a variety of reasons, both environmental and economic, many stakeholders would like to see ethanol blended with gasoline in higher concentrations, often referred to as "mid-level blends," which could include blends between 15% and 51%.

In addition, market conditions may necessitate the marketing of ethanol blends in excess of 10%. With fuel efficiency of new vehicles increasing each model year, the U.S. Energy Information Administration (EIA) projects in its Annual Energy Outlook 2025 Reference case that finished motor gasoline consumption will decline an average of 2.2% per year through 2050, for a cumulative decline of 44.2% by 2050. If the U.S. were to continue blending ethanol at the current volumetric level (i.e., 14.3 billion gallons in 2025), then more mid-level blends must be adopted to offset the overall decline in total finished motor gasoline consumption. In this scenario, the current volume of ethanol would be equal to 18.7% of the entire finished motor gasoline pool in 2050.[15] The 2025 EIA forecast referenced here was developed using the policies that were in existence in 2024; subsequent changes in policy could affect the assumptions and results of EIA's forecast.

FIGURE 3: 15 BILLION GALLONS ETHANOL AS % OF GASOLINE POOL



Source: U.S. EIA Annual Energy Outlook 2025.

15 U.S. EIA. Annual Energy Outlook 2025. https://www.eia.gov/outlooks/aeo/data/browser/#/?id=11-AEO2025&sourcekey=0

Definitions

This paper is designed to establish a common understanding of the current definitions, standards, and regulations related to mid-level blends and to evaluate the opportunities and challenges associated with manufacturing, marketing, and consuming such mid-level blends. It is not intended to resolve all questions about mid-level ethanol blends, but to prompt dialogue and discussion so stakeholders can better understand the issue.

The term "mid-level ethanol blend" has been used to refer to blends such as E20, E25/E30, and E40/E50, each of which have different vehicle, infrastructure, regulatory, and economic implications. But there is no consistent technical definition used across all organizations to address these individual blends or the mid-level category in general. This lack of consistency can impede discussions and understanding about market viability because the actual concentration of the ethanol blend is important in a number of ways, including environmental impact, compatibility with vehicles, and infrastructure and economics.

Below are some examples of how different organizations have attempted to define the term.

- **U.S. Environmental Protection Agency (EPA):** The EPA has approved E15 for use in model year 2001 and newer light-duty conventional vehicles. While technically on the lower end of mid-level, E15 is often discussed in the context of expanding beyond E10. The EPA also recognizes that blender pumps (which mix gasoline and E85) can dispense intermediate blends like E20, E25, and E30, which are considered mid-level and are for use in FFVs.[16]

16 AFDC. Ethanol Blends. https://afdc.energy.gov/fuels/ethanol-blends.

- **ASTM International:** ASTM has two specific standards that contribute to a "definition" of mid-level ethanol blends. ASTM D7794[17] applies to fuels blended with "ethanol concentrations greater than those suitable for conventional-fuel vehicles." In essence, it covers the blending of mid-level ethanol fuel blends for FFVs. ASTM D5798[18] applies to fuels with 51% to 83% ethanol, which are typically referred to as E85, ethanol fuel blends, or flex fuel, rather than mid-level blends. Therefore, the term "mid-level blends" fills the gap between the conventional gasoline standards (like D4814[19] for up to E15) and the E85 standard (D5798).
- **National Council on Weights and Measures (NCWM):** NCWM publishes Handbook 130,[20] which includes the Uniform Regulation for Engine Fuels and Automotive Lubricants and references ASTM standards when addressing specific fuels.

- **UL:** UL's standards for ethanol blended gasoline don't define "mid-level ethanol" as a fuel specification itself, but rather establish the safety and performance requirements for the equipment that handles these blends, including those in the mid-level range (e.g., E15, E20, E25, E30, E40), to ensure they can safely dispense fuels up to E85. UL 87A covers fuel dispensers for pure gasoline (E0) all the way up to E85. This standard specifically includes requirements for dispensing devices handling E25 and blends above 25% and up to 85%. UL 87A specifies that equipment intended for use with the fuel blends E25 and E40 are evaluated using test fluid matching those concentrations. Products certified under UL 87A are required to have specific markings indicating the maximum ethanol concentration for which they are rated (e.g., "E25," "E40," "E85").[21]
- **Canadian General Standards Board (CGSB):** CGSB-3.511-2022 classifies and sets fuel requirements for two types of oxygenated gasoline: Type A, containing 1%–10% ethanol, and Type B, containing 11%–15% ethanol. CGSB-3.512-2023[22] classifies and sets fuel requirements for two types of fuel: Type 1, containing 50%–85% ethanol, and Type 2, containing 20%–25% ethanol.

In summary, the general but unofficial consensus among organizations defining "mid-level ethanol blended fuel" for practical use in FFVs generally points to concentrations between 16% and 50% ethanol by volume. For this reason, the term "mid-level" is insufficient for many purposes, such as determining compatibility with infrastructure and vehicles not designed as FFVs.

17 ASTM. D7794-21: *Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines.* https://store.astm.org/d7794-21.html.

18 ASTM. D5798-21: *Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines.* https://store.astm.org/d5798-21.html.

19 ASTM. D4814-25a: *Standard Specification for Automotive Spark-Ignition Engine Fuel.* https://store.astm.org/d4814-25a.html.

20 McGuire, J. T., et al. 2025. *NIST Handbook 130: Uniform Laws and Regulations in the Areas of Legal Metrology and Fuel Quality, 2026 ed. National Institute of Standards and Technology*. https://doi.org/10.6028/NIST.HB.130-2026.

21 UL. August 10, 2009. UL Announces New Certification Path for Ethanol Fuel Dispensers (press release). https://www.ul.com/news/ul-announces-new-certification-path-ethanol-fuel-dispensers.

22 CGSB. Automotive Ethanol Fuel (E50-E85 and E20-E25): CAN/CGSB-3.512-2023. https://publications.gc.ca/collections/collection_2023/ongc-cgsb/P29-3-512-2023-eng.pdf.

Regulations, Standards, and Specifications

The regulatory landscape for mid-level ethanol blended fuels is complex, involving federal and state regulations as well as industry standards like ASTM, NCWM, and UL. Regulations and standards for mid-level ethanol blends are designed to facilitate their safe and effective use, primarily in FFVs, while mitigating potential risks to conventional vehicles and the environment. The following are some key regulations related to mid-level blends.

U.S. EPA

- **"Substantially Similar" Rule and Waivers:** Historically, the Clean Air Act required fuels to be "substantially similar" to fuels used in vehicle certification (which for a long time meant up to 10% ethanol, or E10). Below are regulatory actions/constraints that are relevant to mid-level ethanol blends.
  - **E15 Waiver:** In 2010 and 2011, the EPA granted partial waivers to allow E15 (10.5%–15% ethanol) to be used in model year 2001 and newer light-duty vehicles (cars, light trucks, and medium-duty passenger vehicles). E15 is still prohibited for use in older vehicles, motorcycles, heavy-duty vehicles, and non-road engines (like those in boats, lawnmowers, etc.) due to potential damage and emissions concerns.
  - **Proposed Rules for Mid-Level Blends (16%–50% ethanol):** In 2016, the EPA Office of Transportation Air Quality proposed the Renewables Enhancement and Growth Support (REGS) Rule[23] to provide regulatory clarity for blends between 16% and 50% ethanol, specifically for use in FFVs through blender pumps. These proposed rules aimed to ensure proper labeling, misfueling mitigation, and fuel quality. While still referenced in discussions about mid-level ethanol blends, this proposal was never finalized and is not in effect.
  - **Reid Vapor Pressure (RVP) Waiver:** A significant regulatory hurdle for ethanol blends, particularly E15, has been the summertime RVP limitations. A higher RVP fuel, during hotter summer months, creates increased evaporative emissions that form smog-generating ozone. When blended with gasoline, ethanol has a nonlinear effect on RVP. Ethanol will increase RVP by a maximum of 1 pound per square inch (psi) in concentrations of about 10%, but this impact diminishes as blends increase up to a 50% concentration, at which point the final fuel has a lower RVP than gasoline without ethanol.[24] To enable the use of ethanol in the market, the Clean Air Act allows gasoline blended with 9%–10% ethanol to exceed RVP controls by 1 psi, but this allowance does not extend beyond 10%. Efforts by EPA to allow E15 to be sold during summer months have been rejected by the courts, which have found that only Congress has the authority to make this change by amending the Clean Air Act. In response, the EPA has used emergency waiver authority to issue temporary approval for sales of E15 during summer months since 2022. In addition, as of April 28, 2025, EPA removed the 1 psi vapor pressure waiver for conventional summer grade gasoline for the states of Illinois, Iowa, Minnesota, Nebraska, Ohio, South Dakota and Wisconsin. This requires refiners to produce a gasoline when blended with ethanol that can meet the RVP requirements without the 1 psi waiver afforded to 10% ethanol blends, thereby creating an opportunity for E15.[25]

23 U.S. EPA. Proposed Renewables Enhancement and Growth Support (REGS) Rule: Rule Summary. https://www.epa.gov/renewable-fuel-standard/proposed-renewables-enhancement-and-growth-support-regs-rule.

24 NREL. March 2012. Discussion Document: Effect of Ethanol Blending on Gasoline RVP (letter to Renewable Fuels Association). https://d35t1syewk4d42.cloudfront.net/file/1410/RVP-Effects-Memo_03_26_12_Final.pdf.

25 U.S. EPA, Request from States for Removal of Gasoline Volatility Waiver. https://www.govinfo.gov/content/pkg/FR-2024-02-29/pdf/2024-04023.pdf

- **Underground Storage Tank (UST) Equipment:** Regulatory requirements that apply to USTs are found in 40 CFR part 280. The section most relevant to mid-level ethanol is Section 32—Compatibility.[26] This section stipulates that UST owners and operators must use a UST system made of or lined with materials that are compatible with the substance stored in the UST system. For UST owners storing fuels containing more than 10% ethanol, they must notify the EPA at least 30 days prior to storing such fuel and demonstrate compatibility of their UST system (including tank, piping, containment sumps, pumping equipment, and spill and overfill equipment) by (1) certification or listing of the equipment or components by a nationally recognized testing laboratory such as UL or (2) manufacturer approval provided in writing, indicating an affirmative statement of compatibility specifying the range of biofuel blends with which the equipment or component is compatible. State regulations may also require advance notification and approval.

Federal law also requires that regulated USTs must maintain financial responsibility requirements through environmental liability coverage. Coverage, whether through private insurance or state fund programs, requires adherence to all state and federal compatibility laws. If compatibility requirements are not met, then the insurance mechanism will no longer be viable, and the UST system will be red-tagged and shut down. Any claims for releases to the environment occurring under a noncompliant system may be denied.

- **Proposed Rulemaking—E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks:**[27] The EPA's proposed rulemaking presented revisions to the 2015 UST regulation. Specifically, the EPA proposed granting certain allowances for owners and operators in demonstrating compatibility, making it easier for them to meet the current requirements. The EPA also proposed a new requirement that in the future, when UST systems are installed or UST equipment and components are replaced, they must be constructed with equipment and components that are compatible with ethanol blends up to 100%. This requirement would be effective within one year of the effective date of the final rule. The EPA accepted comments on the proposed rulemaking through April 19, 2021.

26 40 CFR § 280.32. 2026. Compatibility. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280/subpart-C/section-280.32.

27 U.S. EPA. Proposed Rulemaking—E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks. https://www.epa.gov/ust/proposed-rulemaking-e15-fuel-dispenser-labeling-and-compatibility-underground-storage-tanks

U.S. DEPARTMENT OF LABOR

- **Occupational Safety and Health Administration (OSHA):** OSHA has enacted two separate flammable liquids regulations that concern fuel dispensing facilities: 29 C.F.R. 1910.106[28] and 29 C.F.R. 1926.152.[29] These regulations apply to all liquid motor fuels, including biofuels. Throughout the provisions related to storage and dispensing of fuels, the terms "approved" and "listed" are used in reference to equipment and devices. The regulations define "listed" with a reference to "approved," which reads "approved or listed by a nationally recognized testing laboratory."

NATIONAL FIRE PROTECTION ASSOCIATION (NFPA)

- **NFPA 30A:** *Code for Motor Fuel Dispensing Facilities and Repair Garages*[30] provides comprehensive fire and explosion safeguards for the design, construction, operation, and maintenance of facilities that dispense motor fuels and perform vehicle repairs. While not a regulatory provision, a majority of states have adopted NFPA 30A either directly or indirectly as a key regulatory document for fuel dispensers. The code specifies that all equipment, including individual components, used to dispense motor fuel must be listed by approved testing laboratory as compatible with the fuel it handles.

ASTM INTERNATIONAL

- **ASTM D4814:**[31] *Standard Specification for Automotive Spark-Ignition Engine Fuel* defines the quality characteristics of gasoline and its blends. The standard includes a set of requirements and test methods for gasoline and sets limits for properties like volatility, distillation, octane, sulfur, and oxygenates. The standard accommodates gasoline blended with up to 15% ethanol by volume.
- **ASTM D7794:**[32] *Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines* applies to mid-level ethanol blends (typically 16%–50% ethanol) and is applicable only for FFVs. It establishes blending procedures and includes requirements for selecting components, blending formulas, establishing quality assurance programs, and handling information for these fuels at terminals and retail sites.
- **ASTM D5798:**[33] *Standard Specification for Ethanol Fuel Blends for Flexible-Fuels Automotive Spark-Ignition Engines* applies to fuels with 51%–83% ethanol, which are typically referred to as E85 or flex fuel, rather than mid-level.
- **ASTM D5501:**[34] *Standard Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20% Ethanol by Gas Chromatography* provides a method for testing the actual ethanol content in mid-level and higher blends.
- **ASTM D8076:**[35] *Standard Specification for 95, 98, 100 Research Octane Number Test Fuels for Automotive Spark-Ignition Engines* covers the performance requirements for high-octane test fuel and allows for fuel containing up to 50% ethanol by volume.

28 29 CFR § 1910.106. 2026. Flammable liquids. https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1910/subpart-H/section-1910.106.

29 29 CFR § 1926.152 2026. Flammable liquids. https://www.ecfr.gov/current/title-29/subtitle-B/chapter-XVII/part-1926/subpart-F/section-1926.152.

30 NFPA. 2024. *NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages*. Available at https://www.nfpa.org/product/code-nfpa-30a/p0030acode.

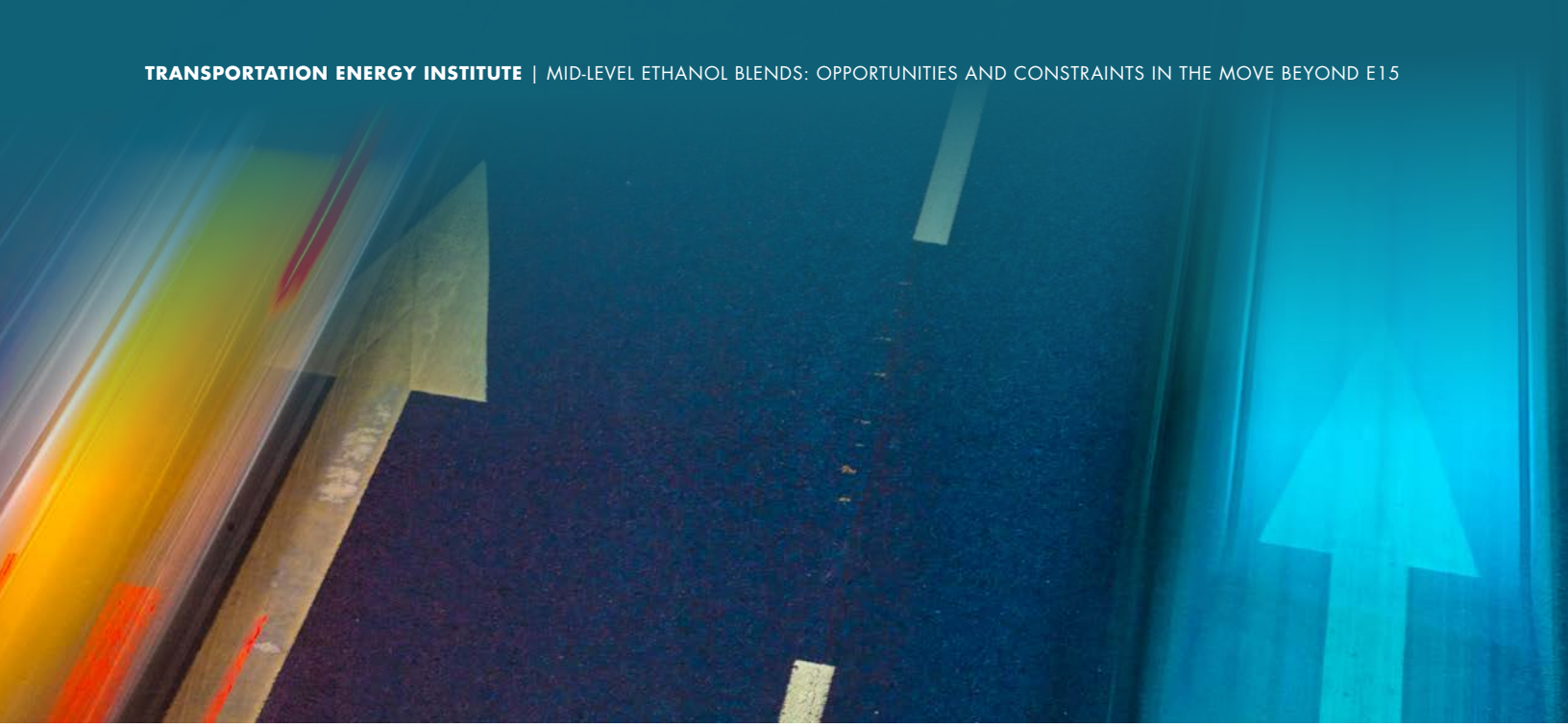
31 ASTM. D4814-22: *Standard Specification for Automotive Spark-Ignition Engine Fuel.* https://store.astm.org/d4814-22.html.

32 ASTM. D7794-21: *Standard Practice for Blending Mid-Level Ethanol Fuel Blends for Flexible-Fuel Vehicles with Automotive Spark-Ignition Engines.* https://store.astm.org/d7794-21.html.

33 ASTM. D5798-21: *Standard Specification for Ethanol Fuel Blends for Flexible-Fuel Automotive Spark-Ignition Engines.* https://store.astm.org/d5798-21.html.

34 ASTM. D5501-20: *Standard Test Method for Determination of Ethanol and Methanol Content in Fuels Containing Greater than 20% Ethanol by Gas Chromatography.* https://store.astm.org/d5501-20.html.

35 ASTM. D8076-24: *Standard Specification for 95, 98, and 100 Research Octane Number Test Fuels for Automotive Spark-Ignition Engines*. https://store.astm.org/d8076-24.html.



Contrasting Perspectives

Stakeholders who advocate for the use of mid-level ethanol blends typically reference the fuel's benefits for the environment, energy security, reduced fuel costs, agriculture economy, and the potential for improved engine efficiency. In response, some raise questions that deserve consideration so all stakeholders can fully understand the opportunities and challenges associated with the fuels.

This section attempts to present some of the primary arguments made in favor of mid-level ethanol along with the questions such arguments have raised. The goal is to provide a comprehensive overview of the issues that may support or detract from the market opportunities associated with mid-level ethanol blends.

ENVIRONMENTAL IMPACT

Because ethanol has a lower CI than gasoline on a life cycle basis, advocates point out that using more ethanol through mid-level blends would amplify this benefit compared to E10. According to a 2021 study published by Argonne National Laboratory, U.S. corn-based ethanol has 44%–52% lower emissions than gasoline.[36]

36 Lee, Uisung, et al. 2021. Retrospective analysis of the U.S. corn ethanol industry for 2005-2019: implications for greenhouse gas emission reductions. *Biofpr*, vol. 15, Issue 5. https://iopscience.iop.org/article/10.1088/1748-9326/ac018f/pdf

Many studies have evaluated the effect of ethanol blended fuel on emissions, with a variety of conclusions. A review of several studies found consensus that ethanol reduces emissions of carbon monoxide and non-methane hydrocarbons but leads to higher emissions of ethanol, acetaldehyde, and formaldehyde. There was less agreement on the impact of ethanol on nitrogen oxides (NOx) emissions, with older studies showing an increase in NOx as ethanol concentrations increased but others finding NOx emissions not to be statistically significant.[37] Ethanol also burns without forming soot precursors and reduces the concentration of aromatics in gasoline that lead to elevated particulate matter (PM) emissions.[38] Another study, however, showed that ethanol's evaporative cooling effect can also increase PM emissions under certain conditions, particularly during cold starts or in some gasoline direct-injection (GDI) engines.[39]

TABLE 1. FUEL CARBON INTENSITY ASSUMPTIONS

FUEL TYPE	CARBON INTENSITY (gCO_2e/MJ)	EER-ADJUSTED CARBON INTENSITY (gCO_2e/MJ)
Gasoline (E0, E10, E15)	93, 91, 89	
Diesel	91	
Natural Gas (CNG / LNG)	75 / 77	
Ethanol (100%)	57	
Ethanol (E85)	64	
Biodiesel (B20)	80	
Biodiesel (100%)	36	
Renewable Diesel (100%)	34	
Electricity (U.S. mix)	130	Light Duty, 33; Heavy Duty, 33
Hydrogen (gas / liquid)	93 / 134	Light Duty, 48 / 69; Heavy Duty, 44 / 64
Propane	79	

Note: Uses a 2021 sales-weight average technology share to GREET fuel economy estimates, to determine LD EV EER of 3.9 and 1.9 FCV. The simple average of GREET 2022 LM&H duty vehicle EERs is 3.9 and 2.1 for EVs and FCEVs, respectively. GREET updates its CI calculations annually, taking into consideration changes in production methodologies, efficiencies, etc. Based upon these updates, the CI of ethanol (excluding ILUC) decreased 23% from 58 to 45 between 2005 - 2019.[40]

Source: 2022 GREET model; *TEI. July 2023.* Decarbonizing Combustion Vehicles: A Portfolio Approach to GHG Reductions. https://www.transportationenergy.org/wp-content/uploads/2023/07/Decarbonizing-Combustion-Vehicles_FINAL.pdf.

37 Iodice, P., et al. 2021. A review on the effects of ethanol/gasoline fuel blends on NOX emissions in spark-ignition engines (review paper). *Biofuel Research Journal*, vol. 32, pp. 1465–1480. https://www.biofueljournal.com/article_140766_cab18af00f687c6d6d21d195ae6a19cc.pdf.

38 Karavalakis, G., et al. June 2022. *Comparison of Exhaust Emissions Between E10 CaRFG and Splash Blended E15* (final report). https://growthenergy.org/wp-content/uploads/2024/04/2022-06-XX-UC-Riverside-study-on-E15.pdf; Stein, R., et al. 2013. An overview of the effects of ethanol-gasoline blends on SI engine performance, fuel efficiency, and emissions. *SAE International Journal of Engines*, vol. 6, no. 1, pp. 470–487. https://doi.org/10.4271/2013-01-1635; Knoll, K., et al. 2009. Effects of Mid-Level Ethanol Blends on Conventional Vehicle Emissions SAE 2009 Powertrains Fuels and Lubricants Meeting, San Antonio, Texas, United States, November 2, 2009. https://doi.org/10.4271/2009-01-2723; Sluder, C. and West, B. 2012. NMOG emissions characterizations and estimation for vehicles using ethanol-blended fuels. *SAE International Journal of Fuels and Lubricants*, vol. 5, no. 2, pp. 721–732. https://doi.org/10.4271/2012-01-0883; Vertin, K., et al. August 2012. *Comparative Emissions Testing of Vehicles Aged on E0, E15, and E20 Fuels.* NREL/SR-5400-55778. NREL. https://docs.nlr.gov/docs/fy12osti/55778.pdf.

39 Kulzer, A.C., Deeg, H.P., Villforth, J., Schwarzenthal, D. et al., "Sustainable Mobility Using Fuels with Pathways to Low Emissions," SAE Technical Paper 2020-01-0345, 2020, doi:10.4271/2020-01-0345. https://www.sae.org/articles/sustainable-mobility-using-fuels-pathways-low-emissions-2020-01-0345

40 Lee, Uisong; Kwon, Hoyoung; Wu, May; Wang, Michael. *Retrospective analysis of the U.S. corn ethanol industry for 2005 – 2019: implications for greenhouse gas emission reductions*. May 2021. Biofpr. Vol 15 Issue 5. https://scijournals.onlinelibrary.wiley.com/doi/10.1002/bbb.2225

ENERGY SECURITY

Advocates argue that increasing the use of ethanol through mid-level blends would further diversify the national fuel supply, reducing dependence on imported petroleum and enhancing energy independence. This was indeed one of the stated objectives of the Energy Independence and Security Act (EISA) of 2007,[41] which expanded the Renewable Fuel Standard (RFS) to a target of 36 billion gallons. Advocates point to data from the EIA to support this argument.

According to the EIA, crude oil and petroleum product imports have declined 35% and 46%, respectively, since the enactment of the Energy Policy Act of 2005, which established the RFS.

Some advocates point to this relationship as evidence that biofuels, and ethanol in particular, helped reduce reliance on petroleum product imports. Others point out that, concurrent with the implementation of the RFS, the U.S. experienced a significant expansion of shale oil production enabled by directional drilling and fracking. The influence of this development is seen by some to overshadow the impact of expanding the use of biofuels.

During this same time (2005–2025), crude oil production increased 162% and ethanol consumption increased 253%. The increase in ethanol consumption displaced 10.5% of petroleum products by 2025, increasing the diversity of the fuel supply pool beyond its 2.9% market share in 2005.

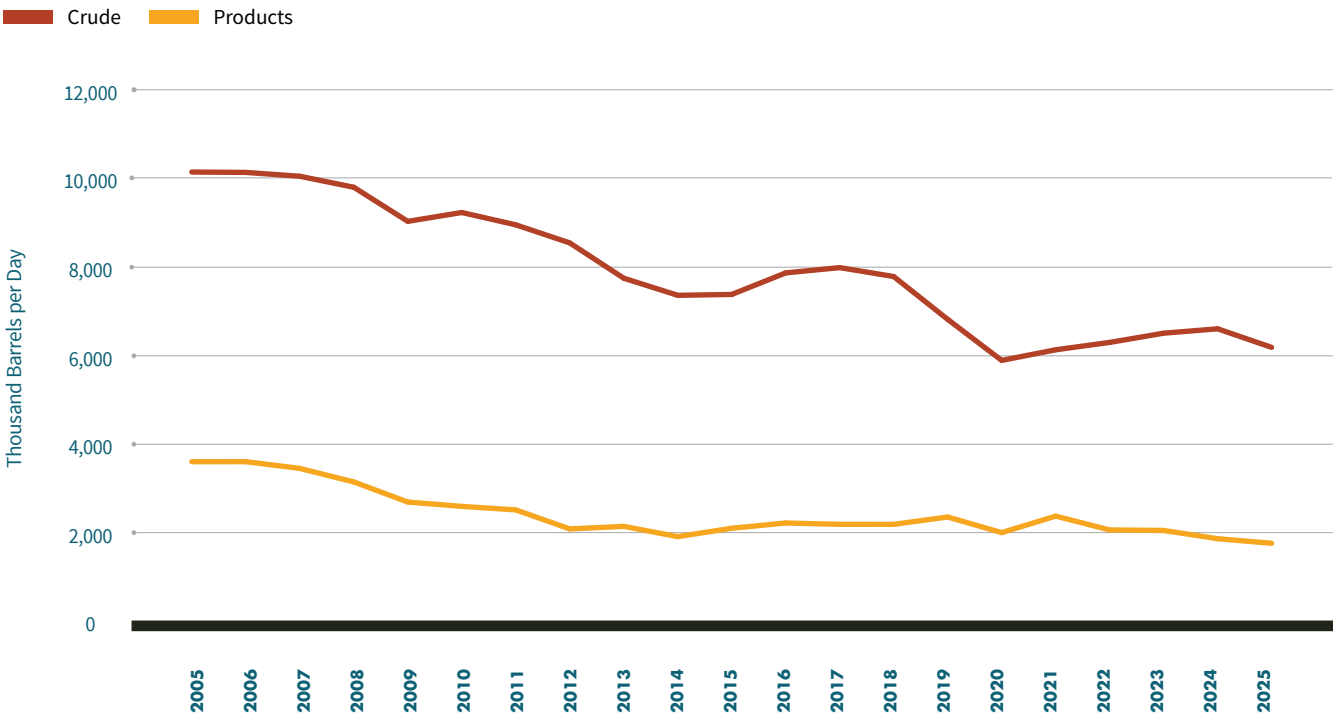
TABLE 2. CHANGE IN PRODUCT SUPPLY: 2005–2025 (THOUSAND BARRELS PER DAY)

PRODUCT	2005	2025	% CHANGE
Crude Oil Imports	10,109	6,574	-35%
Petroleum Product Imports	3,333	1,804	-46%
Crude Oil Production	5,184	13,586	162%
Finished Gasoline	9,159	8,906	-3%
Ethanol Consumption	265	936	253%
Ethanol as % of Gasoline Consumption	2.9%	10.5%	

Source: U.S. EIA

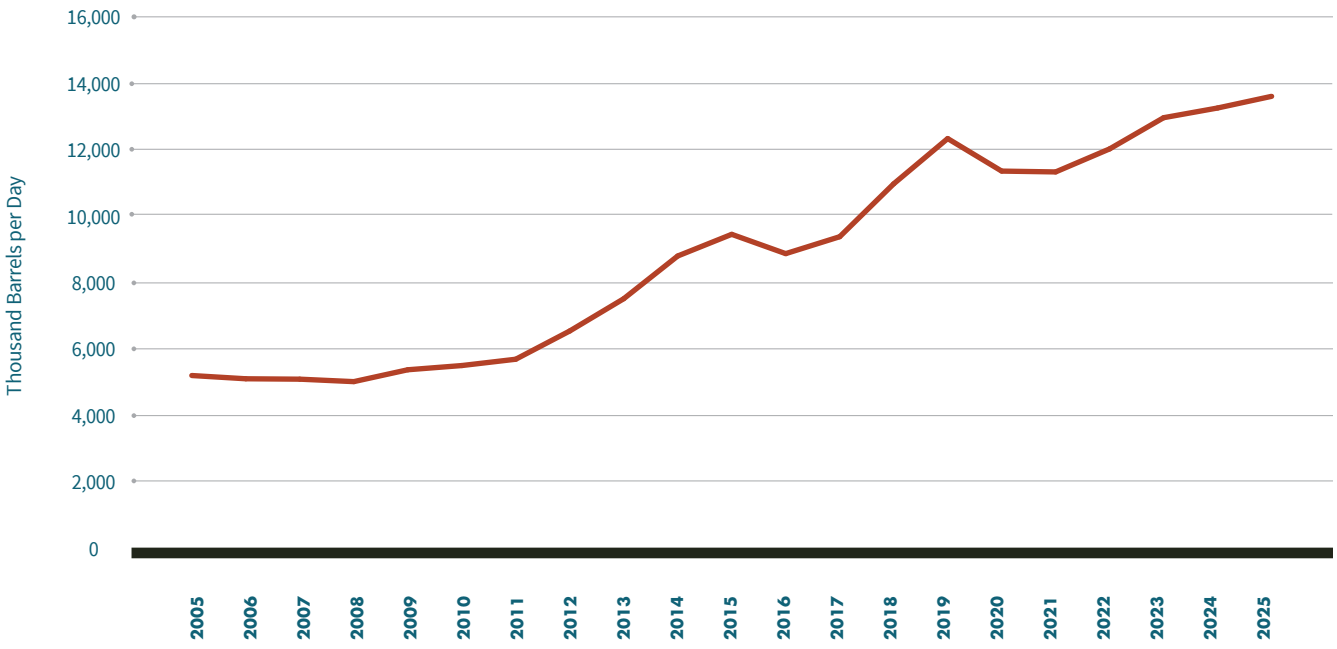
41 H.R.6, Energy Independence and Security Act of 2007, 110th Congress (2007–2008). https://www.congress.gov/bill/110th-congress/house-bill/6/text.

FIGURE 4: PETROLEUM IMPORTS



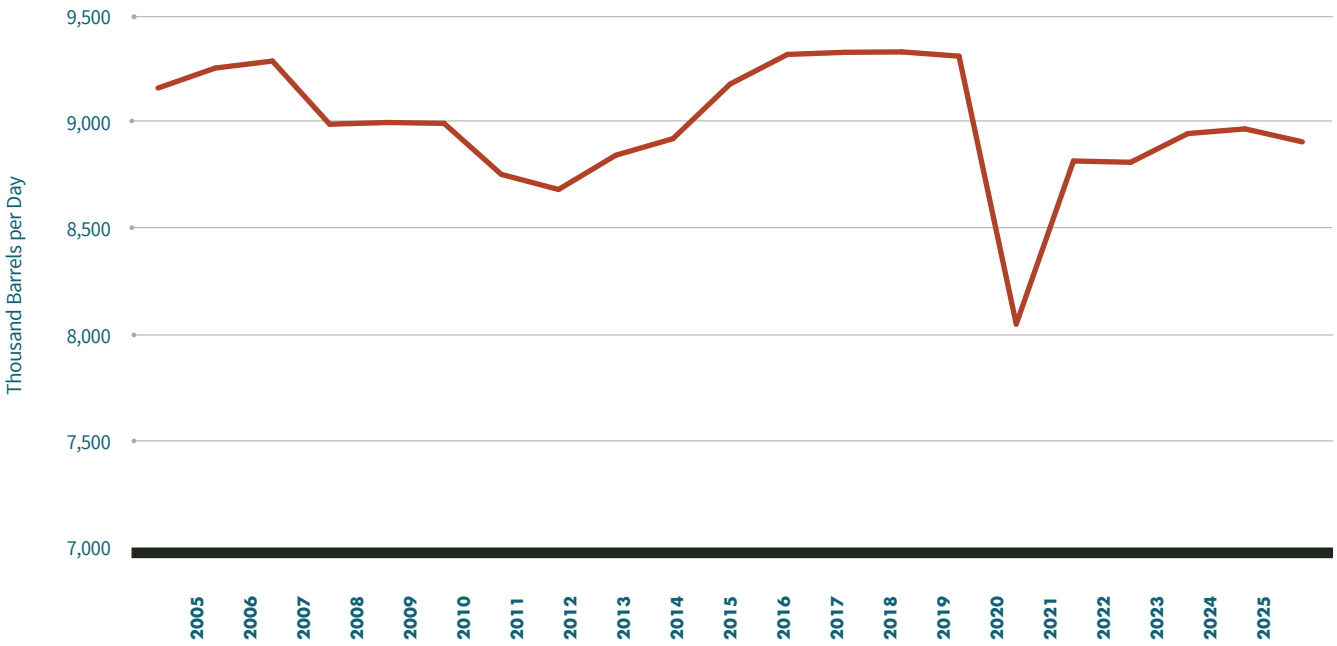
Source: U.S. EIA

FIGURE 5: CRUDE OIL PRODUCTION



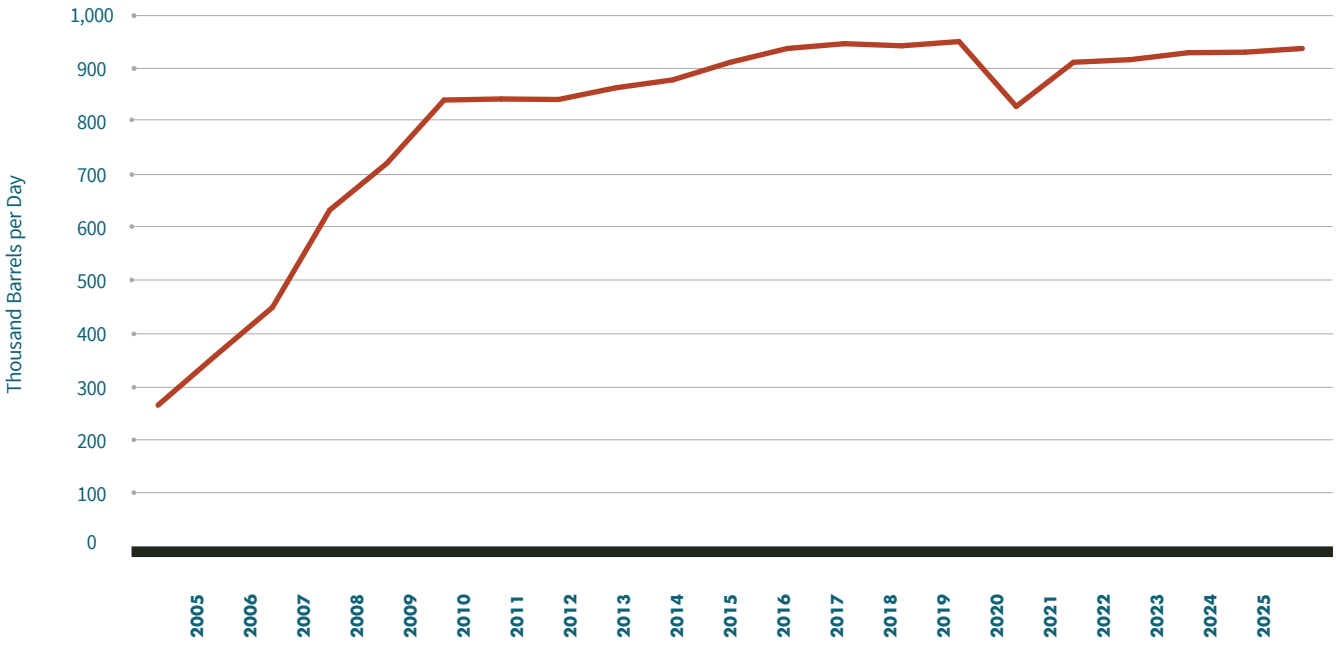
Source: U.S. EIA

FIGURE 6: FINISHED GASOLINE CONSUMPTION



Source: U.S. EIA

FIGURE 7: ETHANOL CONSUMPTION



Source: U.S. EIA

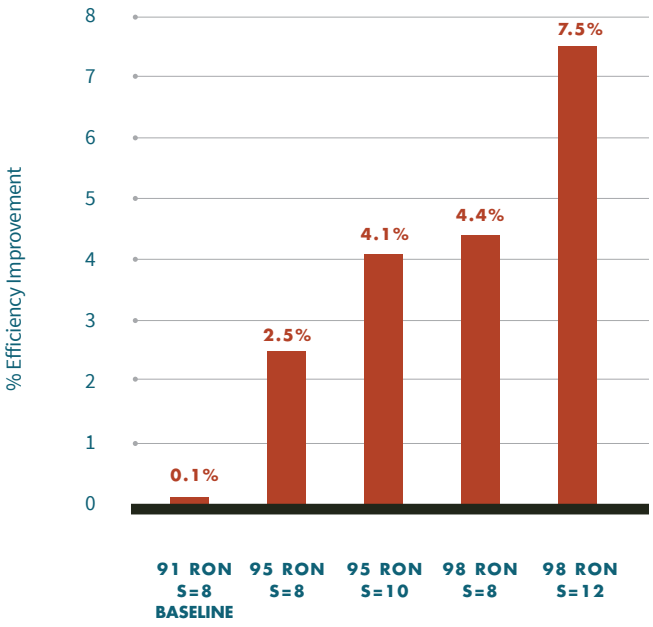
OCTANE, ENGINE PERFORMANCE, AND VEHICLE COMPATIBILITY

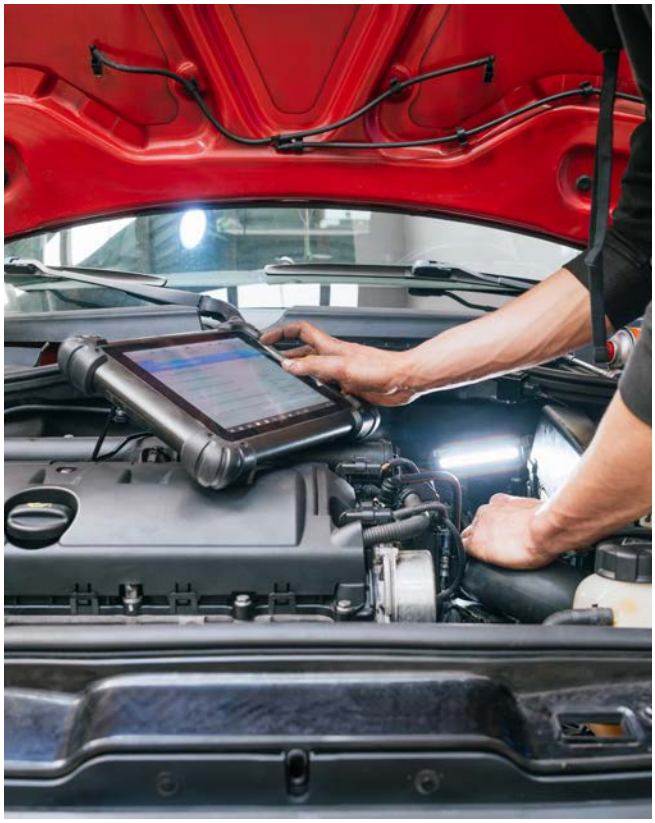
How engines perform on certain fuels affects not only performance and customer satisfaction but also regulatory compliance. Ethanol affects fuel properties, sometimes requiring specific engine design and optimization and other times requiring regulatory or manufacturer approval for its use.

A key attribute of ethanol is that it has a significantly higher fuel octane rating (Research Octane Number [RON] of ~109) than conventional gasoline (typically 91–93 RON). Octane rating is important as automakers seek to achieve greater fuel efficiency and lower emissions from internal combustion engine vehicles (ICEVs) and hybrid electric vehicles (HEVs). To achieve established targets, engineers are turning to smaller engines with higher compression ratios (CR) and turbochargers. The greater the CR, the higher the theoretical efficiency, but the greater the risk of knock and the higher relative octane value required in gasoline. When knock occurs, it reduces fuel economy, robs the engine of power, and may damage the engine.[42]

High-octane optimized engines can deliver improved fuel economy (also measured in terms of lower emissions) or increased power and torque, depending on control strategies, while reducing the risk of engine knock.[43] Such optimized engines can also minimize[44] fuel efficiency penalties associated with the lower energy content in the ethanol blended fuel.

FIGURE 8. EFFICIENCY IMPROVEMENT: BOOSTED SI ENGINES





Source: Co-Optimization of Fuels & Engines Initiative

42 Fuels Institute. March 2019. *Analysis of the Potential for Increasing Octane in the U.S. Fuel Supply,* pp. 1–2. https://www.transportationenergy.org/wp-content/uploads/2022/10/Octane-White-Paper-FINAL.pdf.

43 Leone, T. G., et al. 2015. The effect of compression ratio, fuel octane rating, and ethanol content on spark-ignition engine efficiency. *Environmental Science & Technology* vol. 49, no. 18, pp. 10778–10789. https://doi.org/10.1021/acs.est.5b01420; Miles, P. 2018. *Efficiency Merit Function for Spark Ignition Engines*. U.S. DOE Technical Report DOE/GO-102018-5041. https://www.energy.gov/sites/prod/files/2018/02/f48/Co-Optima%20Merit%20Function%20Report%2067584_2.pdf; Szybist, J. P., et al. 2021. What fuel properties enable higher thermal efficiency in spark-ignited engines? *Progress in Energy and Combustion Science* vol. 82. https://doi.org/10.1016/j.pecs.2020.100876.

44 Jung, H., et al., 2013. Fuel economy and CO2 emissions of ethanol-gasoline blends in a turbocharged DI engine. *SAE International Journal of Engines*, vol. 6, no. 1, pp. 422–434. https://doi.org/10.4271/2013-01-1321.

TABLE 3. PRIMARY GASOLINE BLENDSTOCKS

BLENDSTOCK	Typical AKI Range	Typical Volume Share	SOURCING		Refining Process
			Refinery-Produced	Purchased	
HYDROCARBONS					
Butanes	92	2%–4%	•	•	Crude Distillation, Catalytic Cracking
Natural gasoline	60–70	2%–3%		•	
LSR Naptha	60–70	8%–10%	•		Crude Distillation
Alkylate	93–95	10%–12%	•		Alkylation
Isomerate	82–84	5%–4%	•		Isomerization
Reformate	90–100	2%–7%	•	•	Catalytic Reforming
FCC Naptha	84–85	33%–35%	•		Catalytic Cracking (FCC)
Light Hydrocrackate	83–85	< 5%	•		Hydrocracking
Toluene	104	< 1%	•	•	Aromatics Extraction
Pyrolysis Gasoline	84–85	< 1%		•	
Iso-octane	98–100	de minimis		•	
OXYGENATES					
Ethanol	117	10%		•	
ETBE	110	0		•	
MTBE	109	0		•	

Source: Stillwater et al.

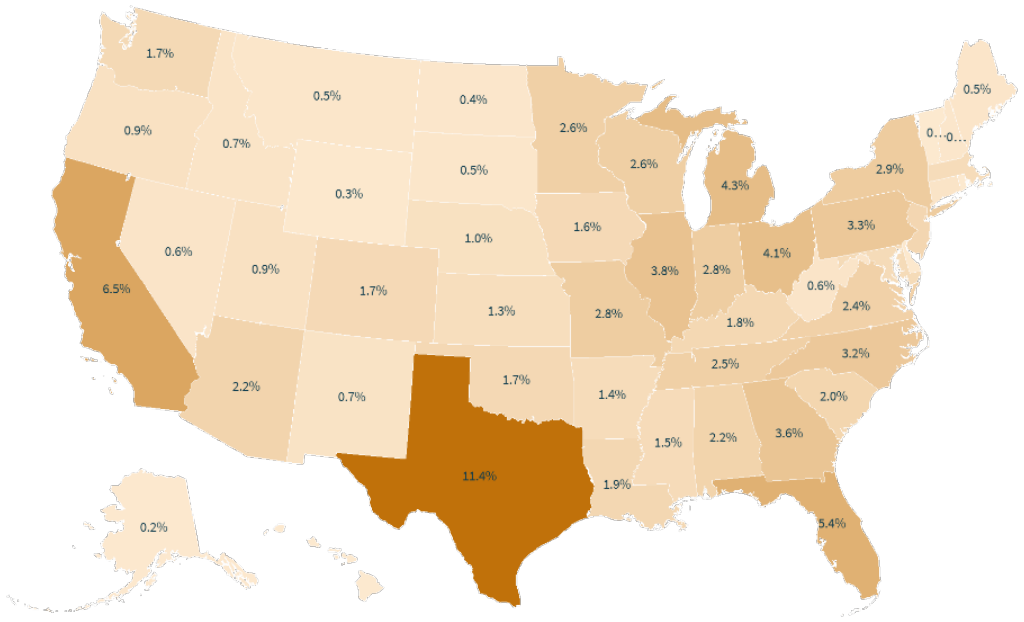
However, because ethanol is not traditional gasoline, at higher concentrations it may present some challenges to vehicles. One of the most widely cited concerns is the potential damage that mid-level ethanol blends could cause in non-FFVs. The on-road vehicle fleet's tolerance to ethanol blends has been extensively studied. A U.S. Department of Energy (DOE) summary of the studies concluded that ethanol blends up to 20% caused no problems with corrosion, wear, aging of emissions aftertreatment systems, or oil consumption, but could lead to higher rates of malfunction indicator light (MIL) illumination.[45] Based on these studies, the EPA approved the use of E15 in model year 2001 and newer vehicles. As of 2025, not all vehicle manufacturers have approved the use of E15 for all models.

A study published in 2021 by the National Renewable Energy Laboratory (now the National Laboratory of the Rockies) indicates that vehicles meeting U.S. Tier 1 (or equivalent) emissions standards or higher could be compatible with E15. The research also indicates that vehicles meeting U.S. Tier 2 or newer standards have the necessary materials and engine control authority for compatibility with E20. Despite these studies, use of higher blends is regulated by EPA and subject to approval by vehicle manufacturers.[46]

45 West, B., and Sluder, S. June 2013. Mid-level ethanol blends vehicle aging program. In FY 2012 *Progress Report for Fuel & Lubricant Technologies,* DOE/EE-0911, pp. IV-19–IV-25. U.S. DOE. https://www.energy.gov/sites/prod/files/2014/03/f8/2012_fuel_lubricant.pdf.

46 Abel, R., et al. 2021. *Global Ethanol-Blended-Fuel Vehicle Compatibility Study*, NREL/TP-5400-81252. NREL. https://docs.nlr.gov/docs/fy22osti/81252.pdf.

FIGURE 9: SHARE OF FFVS IN OPERATION IN 2023



Source: AFDC. TransAtlas. https://afdc.energy.gov/transatlas#/?fuel=E85&year=2023.

Production of FFVs, designed to run on any ethanol blend up to E85, has declined significantly in recent years following the loss of a manufacturer fuel efficiency compliance credit associated with their production. According to the DOE's Alternative Fuel Data Center (AFDC), there were only six FFV models for sale in 2025. Past production vehicles remain in operation, however, and in 2023 there were reported to be 20.2 million FFVs on the road, accounting for 7.1% of the fleet.[47] This leaves approximately 267 million vehicles in operation that are not approved to run on ethanol blended fuels higher than E15.

HOW TO IDENTIFY A FLEXIBLE-FUEL VEHICLE (FFV)

If you're unsure if a vehicle is an FFV, the DOE suggests looking for these indicators:[45]

- **Yellow gas cap:** Many FFVs have a distinctive yellow gas cap.
- **Fuel door label:** A label near the fuel filler opening or on the fuel door may indicate "E85" or "Flex Fuel."
- **Vehicle badge/decal:** Some FFVs have a "Flex Fuel" or "FFV" badge on the rear of the vehicle.
- **Owner's manual:** The owner's manual is the definitive source for compatibility with E85.
- **VIN (vehicle identification number):** The eighth character of the VIN can sometimes indicate FFV capability, though this varies by manufacturer.
- **AFDC website:** The DOE's AFDC website has a search tool you can use to look up specific models and model years. Visit https://afdc.energy.gov/.

47 AFDC. Flexible Fuel Vehicles. https://afdc.energy.gov/vehicles/flexible-fuel.

48 U.S. DOE. Flex-Fuel Vehicles. https://www.fueleconomy.gov/feg/flextech.shtml.

MISFUELING

Some stakeholders argue that introduction of mid-level ethanol blends should be accompanied by safeguards to prevent their use in non-approved vehicles. In addition, some contend that for manufacturers to fully realize the fuel efficiency compliance benefits associated with engines optimized to operate on higher-octane mid-level ethanol blends, those vehicles may need to operate exclusively on the certified fuel and be restricted from using fuels outside the certification parameters.

As the availability of the new fuel expands, consumers might be presented with a lower-priced, higher-octane fuel option, which could result in intentionally fueling non-approved vehicles with the new fuel. While some advocates claim mid-level blends present no risk to legacy vehicles, often presenting examples of their use in the market (e.g., use of E30 in a vehicle that requires premium fuel), such use might violate regulations. Therefore, some argue that misfueling mitigation measures would have to protect legacy vehicles as well, while others maintain that such concerns are overstated.

Misfueling concerns raised in the past have been addressed in variety of ways. For example, the market does not physically prevent non-FFVs from fueling with E85, nor does it physically prevent pre-2001 model year passenger vehicles from fueling with E15.

TABLE 4. SUMMARY OF MISFUELING REGULATIONS

REQUIREMENT	DESCRIPTION
Misfueling Prohibition	E15 cannot be used in non-waived vehicles/equipment.
Fuel Pump Labeling	Dispensers must have EPA-approved E15 labels specifying acceptance details.
Product Transfer Document (PTD) Documentation	Transfers must document ethanol content and RVP.
Compliance Surveys	Quarterly checks via plan or consortium.

Source: U.S. EPA. Regulation to Mitigate the Misfueling of Vehicles and Engines with Gasoline Containing Greater Than Ten Volume Percent Ethanol and Modifications to the Reformulated and Conventional Gasoline Programs. 76 Fed. Reg., 44406–44450. https://www.federalregister.gov/documents/2011/07/25/2011-16459/regulation-to-mitigate-the-misfuelling-of-vehicles-and-engines-with-gasoline-containing-greater-than.

Similarly, the market does not physically prevent premium-required vehicles from fueling with regular fuel, nor does it prevent widespread use of sub-regular fuel with an Anti-Knock Index (AKI) rating of 85, which is not approved for modern on-road vehicles.

Efforts to prevent misfueling with these fuels are executed through labels on the fuel dispenser. Some argue that labeling would be sufficient to prevent misfueling with mid-level ethanol blend fuels as well, while others have called for some form of physical prevention, especially since optimized engine regulatory compliance might be contingent upon exclusive use of the new fuel.

FUEL PRICE

The influence of ethanol on the cost of gasoline and prices paid by consumers at the pump is not as straightforward as some may imagine. A variety of factors influence the real value to the consumer (contrasting with the value they perceive and act upon) and the overall cost of production. This section addresses several key issues—commodity markets, regulations, and energy density—and provides a high-level overview of these factors. A more exhaustive analysis of the economics associated with ethanol blending and the RFS can be found in Chapter 10 of the EPA's regulatory impact analysis published concurrently with the final RFS for 2026 and 2027.[49]

COMMODITY MARKETS

While the retail price is critical to the consumer, the overall economics of gasoline production and blending is complex and is influenced by regulation. Gasoline is sold on the wholesale market as an unfinished blendstock and referenced as either Conventional or Reformulated Blendstock for Oxygenate Blending (CBOB or RBOB).

MISFUELING MITIGATION EXPERIENCE

The only physical barrier implemented to prevent misfueling occurred with the transition to unleaded gasoline in the early 1980s. In that transition, all new vehicles were required to operate on unleaded fuel to avoid damaging their catalytic converter. To achieve this, new vehicles were designed with a fuel tank opening that was too small to accommodate the fuel pump nozzles that dispensed leaded fuel. Unleaded fuel nozzles were designed to fit into the new, unleaded-only vehicles. The physical limitation was largely successful, although there were instances of consumers finding ways to bypass the restriction in order to purchase the less expensive leaded gasoline.

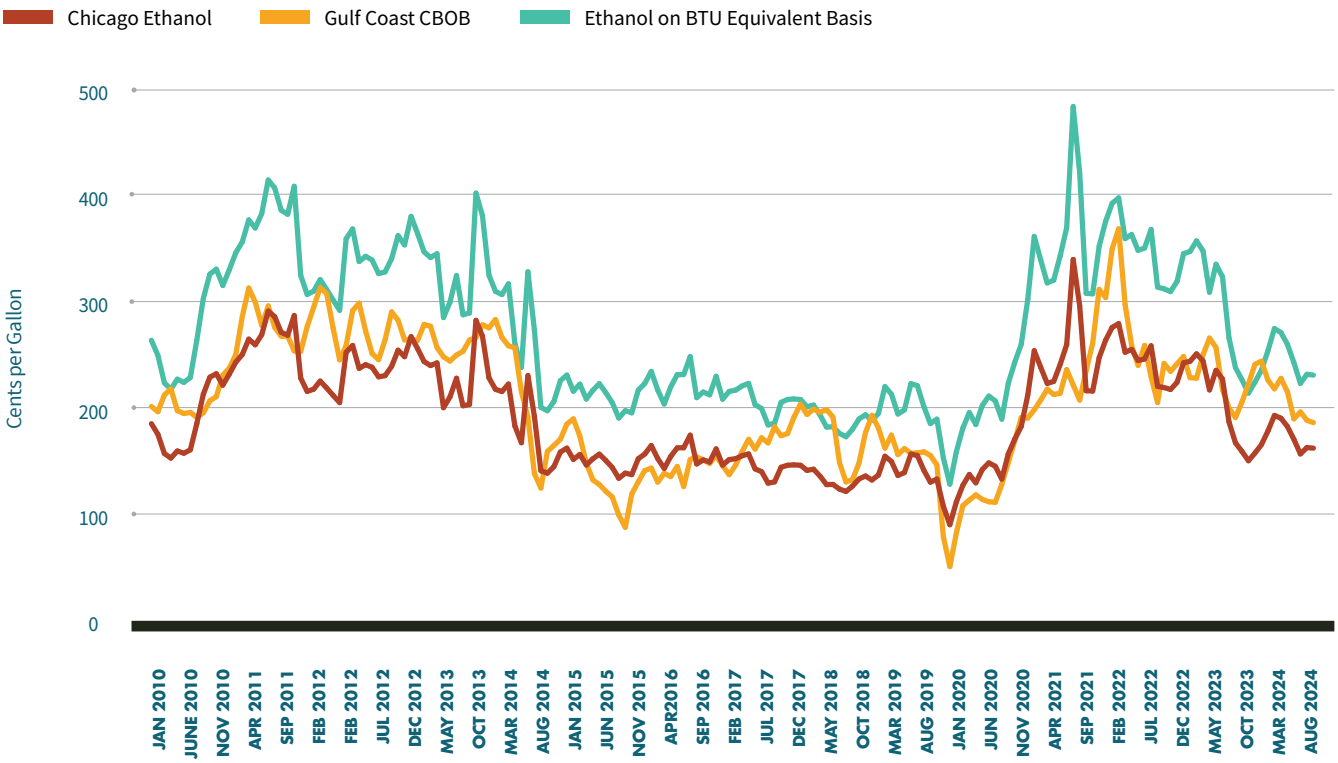
Another fuel transition involved reducing the sulfur content in on-road diesel fuel. Regulation required 80% of diesel supply to satisfy the ultra-low-sulfur diesel (ULSD) specifications beginning in 2004. Vehicles manufactured in model year 2006 and onward were required to be equipped with diesel particulate filters (DPF) and selective catalytic reduction (SCR) technologies that were susceptible to sulfur poisoning. Consequently, these vehicles were required to operate on ULSD. There was no physical barrier to prevent misfueling. Rather, the regulations relied on oversupply of ULSD in the market in advance of vehicle introduction and labels. Vehicle owners also knew that use of higher-sulfur diesel fuel could damage their emissions control technologies and lead to expensive repair costs. Owners of vehicles manufactured prior to 2006 could use either legacy diesel fuel (i.e., low-sulfur diesel) or the new ULSD.

49 U.S. EPA. *Renewable Fuel Standard (RFS) Program: Standards for 2026 and 2027, Partial Waiver of 2025 Cellulosic Biofuel Volume Requirement, and Other Changes—Regulatory Impact Analysis*. https://www.epa.gov/system/files/documents/2026-03/420r26011.pdf.

It is then blended with up to 10% volume ethanol to create a finished motor gasoline to meet its final specifications. This blending has an impact on the final price paid on the open market.

A review of the daily average prices for ethanol traded on the Chicago Mercantile Exchange and for Gulf Coast CBOB traded on the New York Mercantile Exchange from January 2010 to December 2024 shows that the price of ethanol averaged $1.908 compared with $2.053 for CBOB, an average nominal price delta of 14.5 cents per gallon. Ethanol posted a lower nominal volumetric price in 120 of 180 months, and in 60 of those months the average discount exceeded 30 cents per gallon. These commodity prices are based on volumes and do not take into account differences in energy density, which ultimately affects the value of the final product for the end user and is addressed below.

FIGURE 10: ETHANOL AND CBOB PRICES



Source: OPIS, BTU equivalent price calculated by TEI.

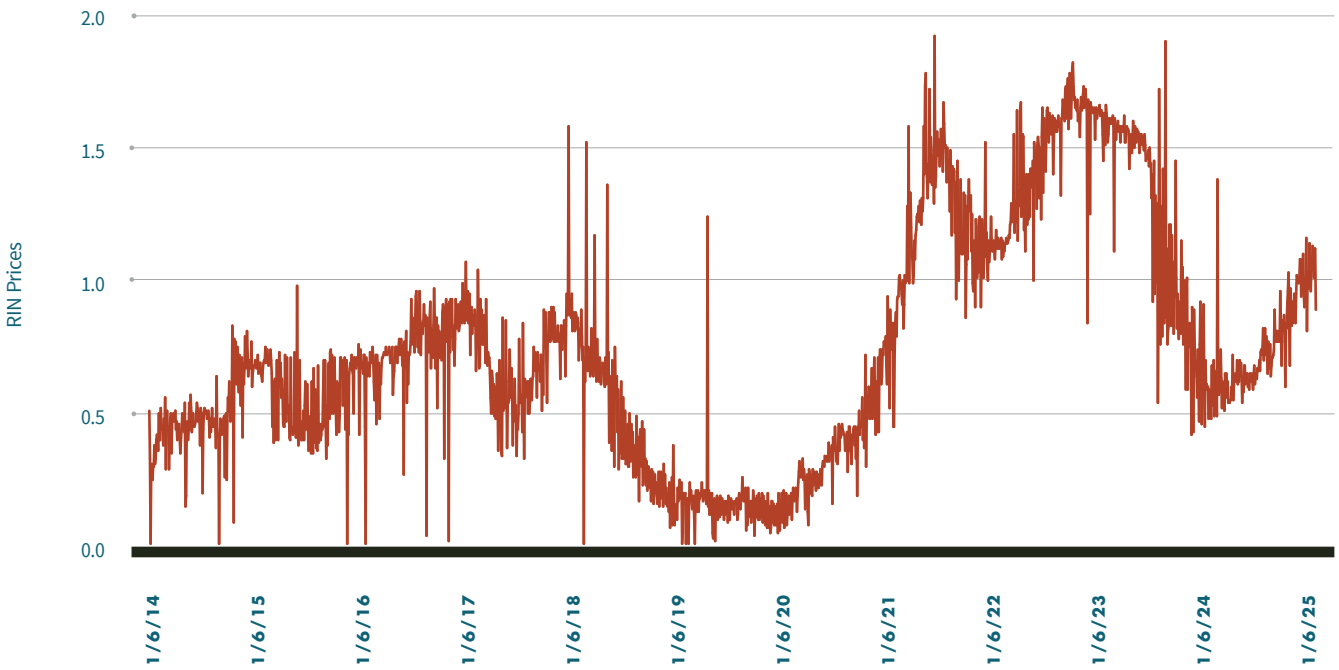
REGULATORY INFLUENCES

Another significant factor influencing the economics of ethanol blending is the RFS. Biofuels generate renewable identification number (RIN) credits at the point of production in different categories (D codes), depending on the type of fuel (e.g., ethanol, biomass-based diesel), feedstock, and the carbon reduction potential of that fuel relative to petroleum. Corn-derived ethanol generates RINs in the D6 category. A RIN becomes marketable when the biofuel has been blended for use or used as transportation fuel, heating oil, or jet fuel. Petroleum refiners and importers incur renewable fuel volume obligations (RVOs) on every gallon of gasoline and diesel fuel they introduce into the U.S. for each of the four nested RFS standards (cellulosic, biomass-based diesel, advanced biofuel, and total renewable fuel). To comply with these RVOs, refiners and

importers procure RINs, with D codes corresponding to the different RFS standards, either by blending them themselves or buying them from others. Although the cost of all RINs for all four RVOs impacts the cost of gasoline and diesel production, for the discussion below on ethanol blended fuels, only the impact of D6 RIN prices is addressed.

Since 2014, the value of D6 RINs has experienced significant volatility and has ranged from $0.01 to $1.92, with an average value of $0.74. Some argue that this value is reflected in the retail price of the finished gasoline, lowering costs to consumers. In this argument, if the value of the RIN is $0.74, then theoretically E10 should be discounted an additional 7.4 cents per gallon. Others argue that this claim is not true because the value of the RIN increases the cost of the petroleum portion and decreases the cost of the ethanol portion, both of which affect the final price of the blended fuel. The RINs lower the price of fuel blends with high renewable content (e.g., E85) and raise the price of fuel blends with low renewable content (e.g., E0 and E10). In the Regulatory Impact Analysis published by EPA when releasing the RFS standards for 2026-2027, the Agency estimated the cost of compliance and the value of the RIN at different ethanol blend levels. It showed that the RIN equaled the cost of compliance when blended as E15 and exceeded the cost when blended above 15%.[50]

FIGURE 11: WEEKLY AVERAGE D6 RIN PRICES



Source: U.S. EPA. RIN Trades and Price Information. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information.

50 U.S. EPA, Renewable Fuel Standard (RFS)Program: Standards for 2026 and 2027, Partial Waiver of 2025 Cellulosic Biofuel Volume Requirement, and Other Changes, Regulatory Impact Analysis. https://www.epa.gov/system/files/documents/2026-03/420r26011.pdf, Page 410, Table 10.5.2-1

The price of RINs themselves fluctuates depending on the demand for RINs (influenced by RVOs, announced for each year by the EPA), feedstock pricing, and other market forces. Higher RIN prices tend to increase fuel prices to compensate for the obligated party's compliance costs.

Historically, the largest category to fulfill the RVO is the renewable fuel category, which is the only category of the four that D6 RINs can fulfill. By contrast, biomass-based diesel RINs (D4s) can also be used in the advanced biofuel and total renewable fuel RVO categories, and obligated parties might blend more biodiesel and/or purchase more D4 RINs if demand for D6 RINs along with compliance costs are driving up its value.

VALUE TO CONSUMERS—OCTANE AND ENERGY DENSITY

Ethanol can often be produced at a lower cost than gasoline components, which can translate to lower prices for mid-level ethanol blends at the pump and deliver to the customer a higher-octane fuel at a lower nominal price. This offers point of purchase savings to consumers, especially if state incentives are in place.[51] Ethanol advocates point to this cost savings as a benefit of ethanol blends. Advocates also point out increased value to the consumer because ethanol boosts the octane of the finished gasoline, which can improve the performance and fuel efficiency of vehicles designed to take advantage of the properties of octane, even if not specifically optimized for the fuels.

The value to the consumer of octane is difficult to quantify, however, because so few drivers understand the role of octane in their vehicles. Data from the market does not provide much clarity. According to the NACS *State of the Industry Report of 2024 Data*, in 2024 the average retail price increased $0.40 per gallon between each grade (87 AKI, 89 AKI, and 91 AKI).[52] However, while surveys indicate that consumers often interpret higher octane as an indication of a superior product,[53] sales figures show that many are not willing to pay the price premium. According to NACS, sales volumes for mid-grade and premium grades were less than 10% that of regular gasoline in 2024.

51 AFDC. All Laws and Incentives Sorted by Type. https://afdc.energy.gov/laws/matrix?sort_by=incentiveand/.

52 Available at https://www.convenience.org/power-your-business/store/nacs-state-of-the-industry-report-of-2024-data.

53 Fuels Institute. March 2019. *Analysis of the Potential for Increasing Octane in the U.S. Fuel Supply*. https://www.transportationenergy.org/wp-content/uploads/2022/10/Octane-White-Paper-FINAL.pdf.

Consumers do value lower prices at the pump, however, with 72% saying that price is the most important factor in determining where they purchase gasoline.[54] Consequently, a lower price point at the pump delivers a perceived value and could influence consumer decisions, but the true economic value to the consumer can only be fully understood when taking into consideration the energy content of the fuel.

Ethanol has a lower energy density (BTU per gallon) than gasoline. According to the lower heating values reported by the DOE, ethanol contains 76,330 BTU per gallon and gasoline contains 112,114 BTU.[55] Consequently, vehicles typically get fewer miles per gallon on mid-level blends compared to E10 or pure gasoline. Although studies have demonstrated that this energy deficit can be at least partially overcome when using engines optimized to run on higher-octane mid-level blends (see Figure 8, page 18), existing vehicles are not optimized to take advantage of the increased octane. Consequently, to deliver an economic value to the customer, the retail price of ethanol blended fuels must be low enough to offset the energy deficit.

TABLE 5. ENERGY DENSITY OF ETHANOL BLENDED GASOLINE

PRODUCT	E0	E10*	E15	E20	E25	E30
BTU/Gallon	112,114	108,536	106,746	104,957	103,168	101,379
BTU of Blended Fuel as % of Unblended Gasoline	100.00%	96.81%	95.21%	93.62%	92.02%	90.42%
Theoretical Price Equity	$3.00	$2.90	$2.86	$2.81	$2.76	$2.71

**NOTE: The vast majority of gasoline sold in the United States is E10.*

SUMMARY

Ultimately, the economics of blending ethanol vary based on the commodity prices on the open markets, the energy equivalency between ethanol and gasoline, and the compliance costs of obligated parties under the RFS, indicated by the value of the RIN. While it can easily be demonstrated by market observation that consumers typically pay less at retail for ethanol blended fuel (i.e., E0 is more expensive than E10 and E10 is more expensive than E15), the ultimate value to the consumer depends on the relationship between the posted prices and the energy difference of the fuels. For the blender and retailer, the economic value of ethanol blends is a combination of the difference between the commodity price, the compliance price (e.g., RIN value), and the retail price. Ultimately, the economic impact of ethanol on the value of blended fuel is not a straightforward calculation.

54 TEI. 2025. Consumer Survey: 2025 Driver Behaviors and Perspectives. https://www.transportationenergy.org/research/reports/consumer-survey-2025-driver-behaviors-and-perspectives/.

55 AFDC. Fuel Properties Comparison. https://afdc.energy.gov/fuels/properties?fuels=GS,ETH.

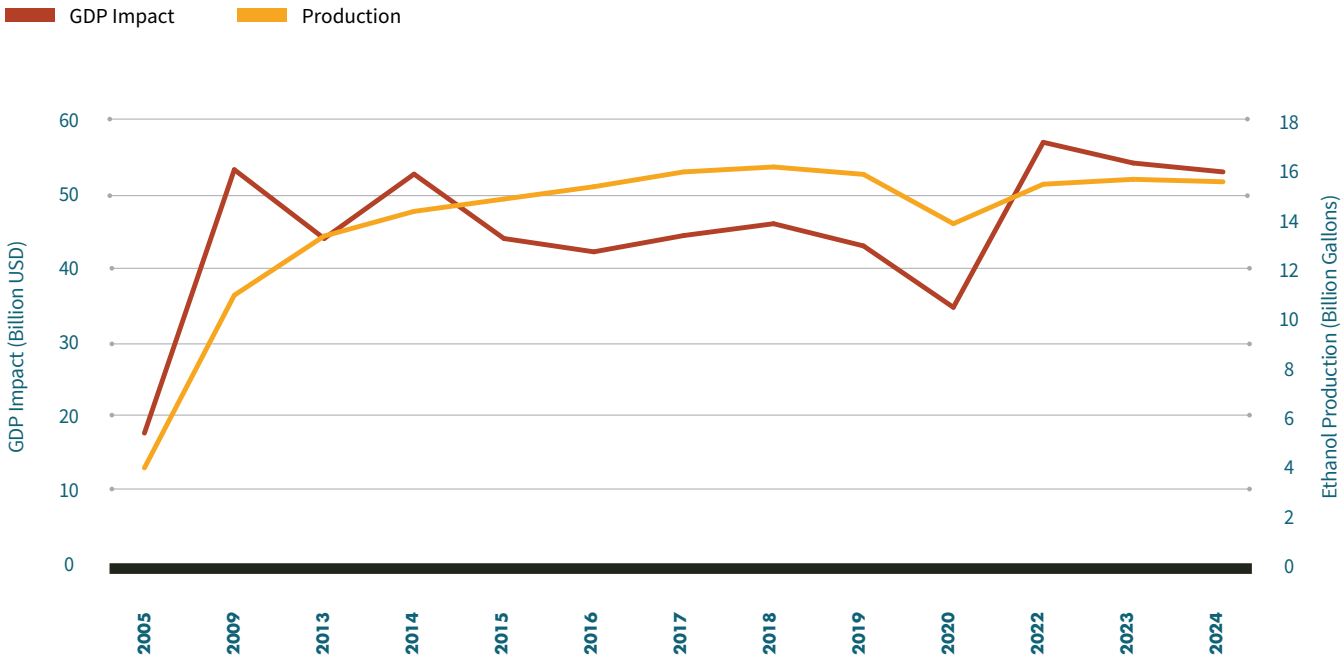
AGRICULTURE ECONOMY

Ethanol advocates point out that the production of ethanol creates jobs and economic activity in agricultural regions, providing a market for crops and supporting rural communities. They argue that the overall economic impact of ethanol production is relevant to the discussion about the opportunities represented by the fuel, especially when concerns are expressed about using agricultural commodities for fuel production when they might otherwise be used to produce food. Others question whether the impact of ethanol production on agriculture economics is relevant to a discussion about the effect ethanol has on the economics of the transportation market. This paper presents data relevant to the economics of agriculture, food production, and transportation to enable readers to review related data and determine for themselves what is relevant to the discussion.

The U.S. Grains and Bioproducts Council reports that the production of ethanol contributed $53 billion to U.S. GDP in 2024 and generated $28 billion in employment-related income. A more granular breakdown of the 2024 employment figures reveals a total of 313,899 jobs, with 55,810 direct, 172,521 indirect, and 85,568 induced jobs. They argue that the sheer volume of indirect and induced jobs, which represent roughly 4.6 positions for every direct job, demonstrates the reach of the industry throughout the economy.[56] In addition, the expansion of ethanol production has contributed to the economic value of agriculture operations, including an increase in agricultural land values and net on-farm income.

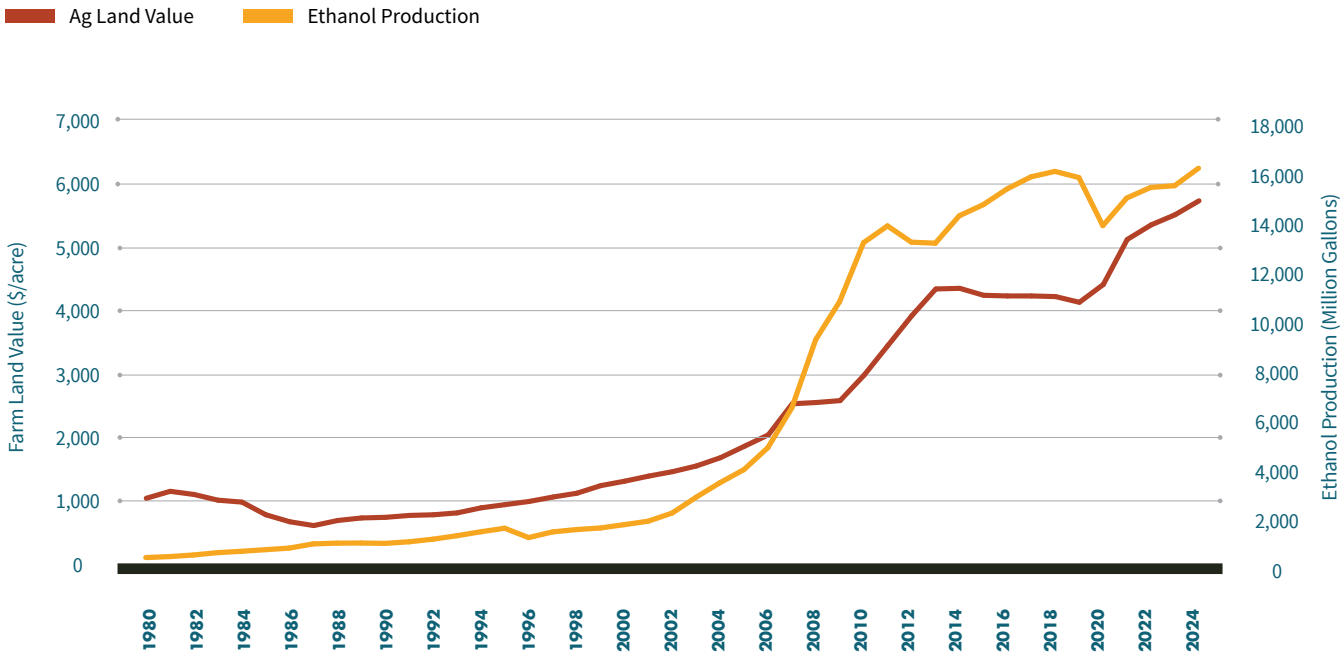
56 Renewable Fuels Association. 2025. *Economic Impact of the U.S. Ethanol Industry*, 2024. https://ethanolrfa.org/file/2917/2024%20Economic%20Contribn%20of%20Ethanol%20Industry_RFA_2025-02-17.pdf.

FIGURE 12: U.S. ETHANOL PRODUCTION AND GDP CONTRIBUTION (2005-2024)



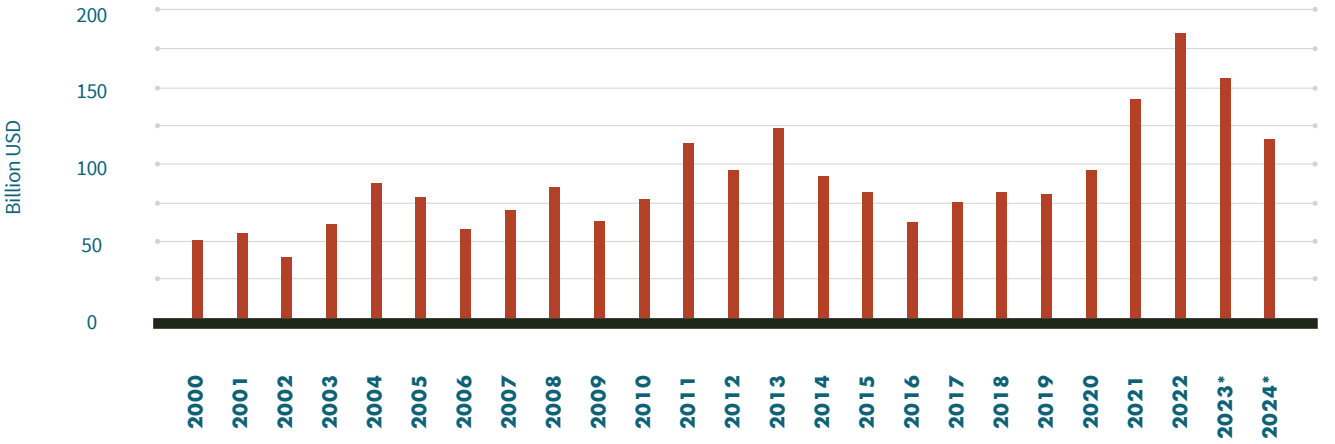
Source: Graphic produced by TEI using information collected from the DOE, Renewable Fuels Association, Biomass Magazine, Advanced BioFuels USA, and LECG, LLC.

FIGURE 13: ETHANOL PRODUCTION VS FARM LAND VALUE (TOP 10 ETHANOL PRODUCING STATES)



Source: U.S. Department of Agriculture, National Agricultural Statistics Service. (2025). Land values 2024 summary. Economics and Asset Values Series. https://quickstats.nass.usda.gov/; U.S. Energy Information Administration. (2024). State Energy Data System (SEDS): Fuel ethanol production. https://www.eia.gov/state/seds/

FIGURE 14: U.S. NET FARM INCOME



Source: USDA, Economic Research Service, sourced from Statista.

The effect of ethanol on the agricultural economy extends beyond on-farm income and affects the use of land for producing feedstocks to support both fuel and food markets, as well as the overall allocation of land resources to the production of fuel. TEI has reviewed these issues extensively in multiple research papers. The following are key findings relevant to these topics.

- **Food vs. Fuel Debate:** A long-standing argument against corn-based ethanol is that it diverts significant resources from the food and animal feed markets to fuel production, potentially driving up food prices and impacting global food security. However, a 2024 TEI report, *Balancing the Benefits of Biofuels*, explored the relationship between biofuels and food production and found that biofuels had not affected food availability or prices in the United States.[57] The report found that biofuels are not a primary driver of high commodity prices. While biofuel production has increased agricultural commodity prices by an estimated 10%–30% and corn prices by an average of 14% in the long term, its impact on final U.S. consumer prices is estimated to be around 1%. The EPA also found in its 2026 regulatory impact analysis that food expenditures in 2027 would be only 0.23% higher than if the RFS did not exist.[58] Historical data shows no obvious correlation between livestock producer prices and ethanol production. Technological advancements in agriculture have improved productivity, leading to declining land in agricultural use despite increased demand for food and fuel.
- **Land Use and Agricultural Impact:** *Balancing the Benefits of Biofuels* found that, while biofuel feedstock acreage sharply increased between 2010 and 2011, it has remained relatively steady since then, averaging 44.3 million acres per year. Per-acre yields of primary biofuel feedstocks have consistently grown, leading to a faster increase in feedstock supply than in the acreage dedicated to these crops. This growth is attributed to improved seeds and agronomic practices. Net acreage for biofuel production peaked at 28 million acres in 2012 and has stabilized between

57 TEI. July 2024. *Balancing the Benefits of Biofuels: The Economics of U.S. Crop-Based Fuel Production.* https://www.transportationenergy.org/wp-content/uploads/2024/07/Balancing-the-Benefits-of-Biofuels-FINAL.pdf.

58 U.S. EPA. Renewable Fuel Standard (RFS) Program: Standards for 2026 and 2027, Partial Waiver of 2025 Cellulosic Biofuel Volume Requirement, and Other Changes—Regulatory Impact Analysis, p. 335, table 9.4-2. https://www.epa.gov/system/files/documents/2026-03/420r26011.pdf.

22 and 25 million acres since. In addition, ethanol production produces distillers dried grains with solubles (DDGS), which is a valuable feed product for livestock. The report found that without this byproduct from ethanol production, farmers would need to put an additional 15 million acres into production in order to generate enough feed for the livestock population in the U.S.[59]

RETAIL AVAILABILITY

While advocates point out the opportunities associated with mid-level ethanol and others point out concerns or limitations, the challenges associated with retail availability are quite clear. In this respect, issues related to market viability as well as regulatory impediments must be overcome before mid-level blends have a chance of gaining market share.

First, introducing a new fuel presents a chicken-and-egg dilemma. As noted, vehicle manufacturers may be unwilling to invest in a design change unless this would assist their efforts to comply with emissions regulations, which might require the new vehicles to operate only on the new fuel. Consequently, manufacturers would require widespread availability of the new fuel before selling vehicles required to operate on that fuel.

Retailers, however, might be hesitant to make the necessary infrastructure investments (e.g., replacing existing equipment with higher-compatibility-rated equipment, adding or converting a storage tank to accommodate a new fuel, etc.) to accommodate the fuel if there was insufficient consumer demand to justify the investment. Resolving this dynamic would be challenging in the absence of a government requirement or investment incentives.[60]

In addition, as discussed in the Regulations, Standards, and Specifications section, fuel storage and dispensing systems must be listed as compatible with the fuels they store and dispense by a nationally recognized testing laboratory. Some existing fuel infrastructure (storage tanks, pipelines, pumps, hoses, hanging hardware, ancillary equipment, thread sealant compounds, etc.) may not be compatible with higher ethanol concentrations and would need to be replaced. While equipment designed and listed as compatible with higher blends is available, upgrading to this infrastructure can be expensive for retailers.

- **Underground Storage Tanks and Equipment**
  To determine compatibility, 40 CFR 280.32 stipulates:[61]
  (1) Demonstrate compatibility of the UST system (including the tank, piping, containment sumps, pumping equipment, release detection equipment, spill equipment, and overfill equipment). Owners and operators may demonstrate compatibility of the UST system by using one of the following options:
    (i) Certification or listing of UST system equipment or components by a nationally recognized, independent testing laboratory for use with the regulated substance stored; or
    (ii) Equipment or component manufacturer approval. The manufacturer's approval must be in writing, indicate an affirmative statement of compatibility, specify the range of biofuel blends the equipment or component is compatible with, and be from the equipment or component manufacturer; or,
  (2) Use another option determined by the implementing agency to be no less protective of human health and the environment than the options listed in paragraph (b)(1) of this section.

59 Ibid.

60 The AFDC has a database of laws and incentives relevant to ethanol retailing operations. This link (currently set for ethanol-related programs) enables users to filter the data to fit their interests and can narrow results by jurisdiction, type of incentive, which user the programs are designed for, and the status of the program: https://afdc.energy.gov/laws/search#/?technology=ETH&incentive=GNT.

61 40 CFR § 280.32. 2026. Compatibility. https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280/subpart-C/section-280.32.

- **Dispensers**

  The industry relies on UL to satisfy the listing requirements from a nationally recognized testing laboratory, and its standards for fuel dispensers are found in UL 87A. UL 87A has testing and certification standards to determine dispenser compatibility with E10, E25, E40, and E85. A manufacturer must submit a device to UL for testing and listing. If listed, that listing applies to the specific model that was evaluated and is available only for devices sold after listing has been issued. A model that was previously sold and listed as compatible with a lower ethanol concentration can be relisted for a higher ethanol blend, but any units that were sold prior to that new listing date are restricted to ethanol blends covered under the original listing; their compatibility listing cannot be adjusted once sold.

Equipment experts often cite key dates and types of equipment as points of compatibility transition. For example, certain fiberglass tanks manufactured by certain companies after 1991 should be compatible with neat ethanol, as should most steel tanks. While such references are helpful in narrowing the understanding of compatibility, they are neither inclusive of all details nor official. To help equipment owners determine the compatibility of their equipment, the Petroleum Equipment Institute (PEI) maintains an inventory of manufacturer letters of compatibility on their website.[62] In addition, UL maintains a searchable database to help owners access certification and listing information.[63] Retailers must also ensure they are compliant with provisions in their insurance policies.

62 PEI. UST Component Compatibility Library. https://pei.org/resources/ust-component-compatibility-library/.

63 Available at https://www.ul.com/software/product-sourcing-and-certifications-database.

Conclusion

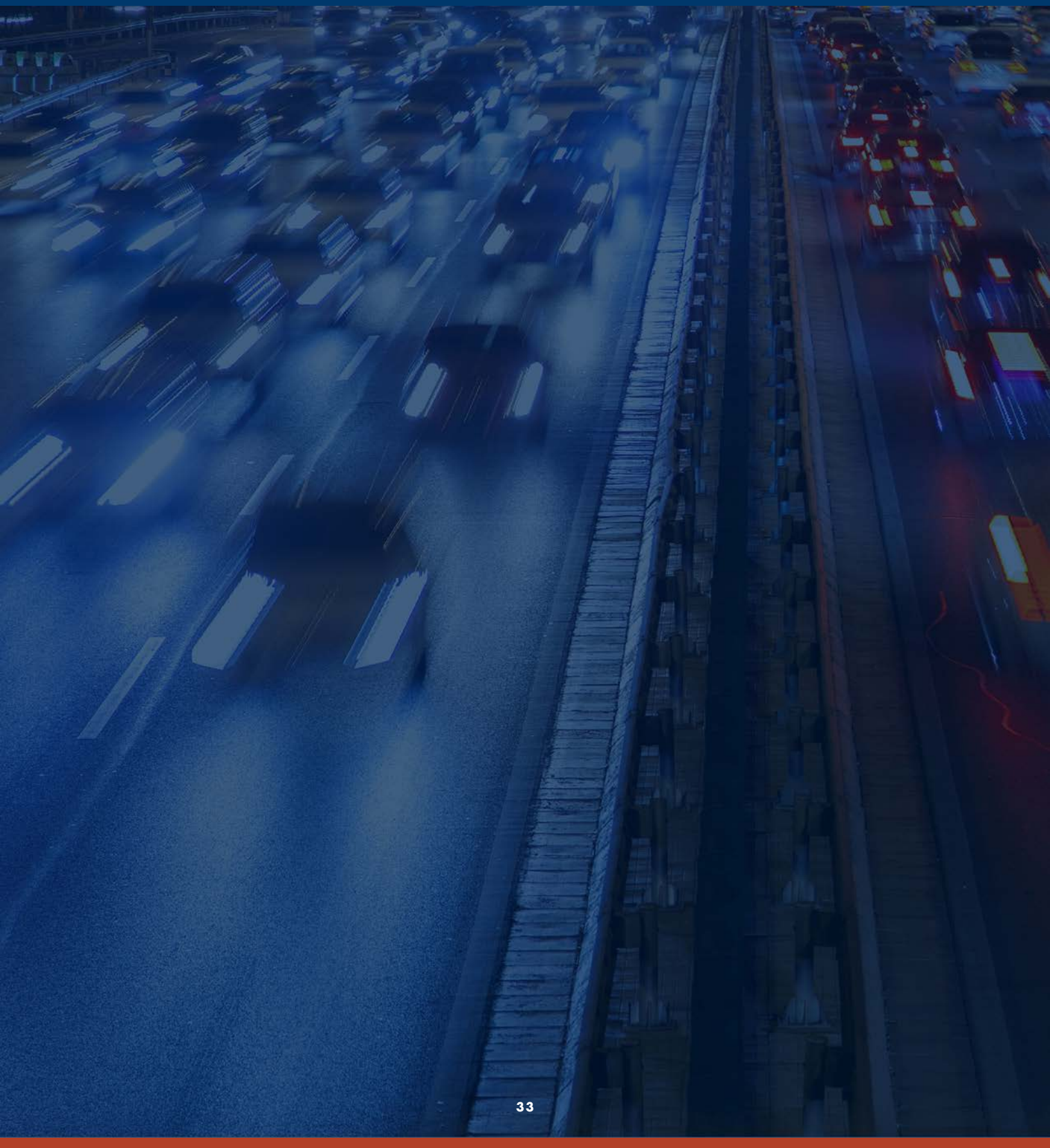
Considerable research and data demonstrate the performance and environmental benefits associated with the production and use of fuels blended with greater than 15% ethanol. Likewise, significant evidence points to the economic value of ethanol production in the United States. Hence, there is value in exploring how to successfully bring these fuels to market.

That said, significant challenges must be overcome before a successful transition can be achieved. While many of these are technological or regulatory in nature, others reflect long-held assumptions or strongly divergent priorities within the transportation sector. The latter of these may be more difficult to resolve.

To open the market opportunities for mid-level ethanol blended fuels, at a minimum the following would be required:

- A standard definition for mid-level ethanol blended fuels agreed upon by all authorities having jurisdiction.
- Regulatory clarity concerning the marketability of the fuel, including applicable emissions controls (e.g., RVP), seasonal fuel specifications, equipment compatibility, fuel registration requirements, labeling requirements, etc.
- Widespread availability and installation of fuel storage, monitoring, handling, and dispensing equipment listed as compatible with the fuels and updated regulatory guidance for equipment owners and manufacturers.
- An agreement among stakeholders and regulators regarding whether and how to prevent the fueling of vehicles with a fuel for which they have not been approved.
- Regulations to define the vehicles that would be authorized to, prohibited from, or given the option to use the fuel, as well as any requirements or compliance allowances affecting vehicle manufacturers.
- Industry coordination or enactment of government regulations to ensure that any vehicles required to operate and those prohibited from operating on the new fuel have access to their authorized fuels.

APPENDIX



Appendix

IOWA'S TRANSITION TO E15: AN EXAMPLE OF EQUIPMENT REQUIREMENTS TO SELL MORE ETHANOL

Iowa has established itself as a front-runner in requiring an expansion of gasoline blended with more than 10% ethanol. In 2022, Iowa passed the E15 Access Standard, which requires most retail gasoline fueling stations to advertise and sell E15 through at least one dispenser by January 1, 2026. For those stores built after January 1, 2023, or for those that replace or convert certain infrastructure, they are required to offer E15 from at least 50% of fueling positions. To enforce the requirements, the law provides for civil penalties of up to $1,000 per day for retailers found in noncompliance with the standard. In addition, the state may suspend, revoke, or refuse to renew retail fuel licenses for noncompliance.

The standard recognizes that the transition may impose financial or logistical burdens on some retailers and has some flexibility. For example, stations that sell, on average, less than 300,000 gallons of gasoline per year are exempt from the standard. In addition, retailers may be eligible for waivers based on incompatible fuel storage tanks (based on age and material) or if the cost to make the fuel infrastructure compatible with E15 exceeds a specified dollar amount, although this cost analysis is limited to those retailers converting just one dispenser. Retailers have objected to this limitation, noting that it lowers the allowable cost to such a level that few retailers will qualify for the waiver and that it is insufficient because it makes no business sense for a facility to dedicate a storage tank to accommodate a new fuel for only one dispenser.

In addition, retailers that have encountered obstacles may apply for a "Safe Harbor" designation. Safe Harbor applications were due October 31, 2025, and if granted, retailers will receive an extension for compliance until September 30, 2026. To qualify, a retailer must provide proof of ordering equipment or having submitted a state grant application for E15 infrastructure.

To help retailers transition to comply with the new standard, the state's Renewable Fuels Infrastructure Program (RFIP) provides cost-share grants to help retailers install, replace, or convert fuel dispensing and storage infrastructure to support E15. Record grant funding has been approved to assist stations in their transition.

In addition, the state legislature has, at times, streamlined some of the compatibility requirements (e.g., adjusting the required compatibility for new dispensers during the transition period) to ease the compliance burden. Retailers note that while the state declared any dispenser listed as compatible with E10 to be recognized by the state as compatible with E15, this does not absolve them of compatibility requirements in federal regulation or insurance policy requirements nor does it protect them from liability for using non-listed devices.

As of September 2025, a significant number of Iowa fuel retailers were either already offering E15, are in the process of upgrading, or have been granted waivers. As of a recent estimate, more than one-third of Iowa fuel stations offered E15, and the number is growing, with officials stating that retailers are on track to meet the deadline.

GLOBAL EXAMPLES

BRAZIL

Brazil has one of the world's most established and successful programs for the use of ethanol blended gasoline, primarily derived from sugarcane. Since 1976, Brazil has required the blending of anhydrous ethanol with gasoline. The program, originally known as Proálcool (National Alcohol Program), was initially intended to reduce the country's dependence on imported oil and to utilize excess sugarcane capacity in response to the 1973 oil crisis. As of August 31, 2025, the program mandates a fuel blend of 30% ethanol and 70% gasoline (E30). The previous mandate was for E27.

A major development that supported the expansion of ethanol use in Brazil came with the introduction of FFVs in 2003, which can run on pure hydrous ethanol (E100, which is about 95% ethanol and 5% water), the gasoline blend E30, or any mixture of the two. These vehicles now dominate new car sales and the overall light-duty fleet.

The use of sugarcane-based ethanol provides a renewable fuel source, enhances energy security, creates jobs, and offers environmental benefits by reducing greenhouse gas emissions compared to fossil fuels. For FFV owners, the choice between filling up with the gasoline blend or hydrous ethanol is often determined by the price difference between the two fuels.

PARAGUAY

Paraguay operates one of the most aggressive and established ethanol programs in the world outside of Brazil, characterized by high mandatory blending rates and a strong focus on domestic agricultural production. The defining feature of Paraguay's program is its high minimum mandatory blending rate for gasoline, which is set at 18% and up to 25% (often referenced as E24 or E25 in practice). This is one of the highest mandatory blending rates globally.

The program's goals, established under laws like the Biofuels Promotion Law (2005) and Law 5444/15, are to reduce dependence on imported fossil fuels, diversify the energy supply, improve environmental quality, and develop the local agricultural sector, particularly by providing a reliable market for small sugarcane and corn producers.

The government supports the availability of FFVs, including imposing no import duties on new and used FFVs and mandating the government's own vehicle fleet to progressively switch to E85-capable vehicles. However, given the mandatory blend rate, even non-flexible-fuel gasoline vehicles in Paraguay are operating on a significantly higher ethanol content than in most other countries.

INDIA

India's government policies and market dynamics concerning ethanol are characterized by an ambitious, accelerated blending mandate supported by aggressive fiscal incentives, which has resulted in rapid production growth but has also created significant market and consumer challenges.

India's ethanol policy is centered on the Ethanol Blended Petrol (EBP) Programme and the National Policy on Biofuels (NPB), driven by the goals of reducing crude oil imports, saving foreign exchange, and boosting farmer incomes. A government target for 20% ethanol blending (E20) was advanced from 2030 to 2025 (specifically ethanol supply year 2025–26). India achieved an average blending rate of over 10% in 2022 and has continued to ramp up supply toward E20. The long-term goal is to achieve 27% blending (E27) by 2030, and the policy increasingly supports second-generation ethanol (from agricultural waste like rice straw) through viability gap funding to address food versus fuel concerns.

The rapid policy acceleration has transformed the market, leading to strong production growth. Incentives have allowed ethanol production capacity to more than double in recent years, exceeding the initial requirement projections for E20. Meanwhile, E20 is rapidly becoming the most common fuel across many regions, often replacing the older E10 entirely, leaving many consumers with no alternative fuel choice at the pump. This presents a challenge because the majority of the existing fleet of vehicles is not certified for E20 use.

About the Transportation Energy Institute

The Transportation Energy Institute (TEI) is a 501(c)(4) non-profit, non-advocacy think tank dedicated to the transportation energy sector. In a constantly evolving market, TEI delivers objective, data-driven research and analysis that inform business and policy decisions.

Grounded in rigorous methodology, peer review, and real-world market insights, TEI fosters cross-industry collaboration to produce trusted, forward-looking analysis. Committed to neutrality and analytical rigor, TEI does not advocate for specific outcomes, but instead equips decision-makers with clear, fact-based insights to navigate the future of transportation energy.

For more information:

TRANSPORTATION ENERGY INSTITUTE STAFF

John Eichberger
Executive Director
jeichberger@transportationenergy.org

Liz Menz
Director, Research & Engagement
lmenz@transportationenergy.org

Meagan Ray
Administrative and Project Manager
mray@transportationenergy.org

Marjorie Frankel
Director, Marketing and Communications
mfrankel@transportationenergy.org

Genevieve Comtois
Senior Strategic Advisor
gcomtois@transportationenergy.org

Amy Kalafa
Multimedia Designer
amy@a-ray.tv

For a list of current Transportation Energy Institute Board members and financial supporters, please visit transportationenergy.org.

TRANSPORTATION
ENERGY INSTITUTE

(703) 518-7970
TRANSPORTATIONENERGY.ORG
@TEI_INSTITUTE

1600 DUKE STREET
SUITE 700
ALEXANDRIA, VA 22314