



TRANSPORTATION
ENERGY INSTITUTE

WHITE PAPER

Driving Insight: A Five-Year Synthesis of Combustion Emissions Research

(2020-2024)

DECEMBER 2025





Introduction

Driving Insight: A Five-Year Synthesis of Combustion Emissions Research (2020-2024)

The Transportation Energy Institute (TEI), formerly The Fuels Institute, is dedicated to impartially evaluating options to reduce transportation emissions while preserving access to affordable and reliable transportation energy for all consumers.¹ TEI does not advocate for or engage in efforts to influence policies or industry priorities; rather, TEI seeks to identify and explore alternatives for achieving policy and industry priorities and to present objective assessments of how such alternatives might affect consumers, the environment, and the market in general.

This compilation report identifies the themes that tie together several TEI publications and presents an aggregated summary of the key findings from studies in transportation emissions reduction. The enduring lesson is that there is no silver bullet; effective strategy blends policies, fuels, vehicles, and infrastructure in ways tailored to the market and heterogeneity of the fleet.

In recent years, TEI has published peer-reviewed research papers covering a wide range of topics, including life cycle analyses of electric and combustion vehicles, options for reducing emissions from internal combustion engine vehicles (ICEVs), the carbon intensity (CI) and production capacity of biofuels, business opportunities associated with electric vehicle charging infrastructure, strategies to reduce emissions from medium- and heavy-duty vehicles (MHDVs), the viability of e-fuels, and others. The organization has sought to encourage a broad discussion of transportation energy topics

¹ In this paper, the term “consumer” applies both to drivers of privately owned passenger vehicles as well as to drivers of commercial vehicles.

and inform the market about available options that could simultaneously improve the environment and protect the interests of consumers.

TEI recognizes and has emphasized that multiple strategies are required to achieve emissions reduction objectives from the transportation sector, including the market expansion of electric vehicles (EVs), new vehicle technologies, and diverse transportation energy sources. However, with more than 1.5 billion ICEVs in operation throughout the world, and millions more sold each year, it remains critical to find solutions that can be applied to these vehicles. Consequently, TEI has dedicated significant attention to this challenge.

This paper presents a summary of the key findings from nine specific TEI research papers, published from 2020 to 2024, that examined topics relevant to emissions reduction opportunities for ICEVs and the fuels that power them. During that time, global and domestic policy objectives related to the transportation sector were focused on mitigating carbon emissions, and TEI research explored opportunities for achieving that environmental goal.



While each individual paper addresses a key feature of the transportation sector, they collectively represent a comprehensive assessment of opportunities to reduce emissions from the market which can help guide decision-makers in business and public policy. The work offers critical insights into what strategies have succeeded, what obstacles remain, and how decarbonization pathways have evolved in the face of technological, regulatory, and economic pressures.

INCLUDED IN THIS SUMMARY ARE THE FOLLOWING PUBLISHED TEI PAPERS:

1. [***Impact of Transportation-Related Environmental Initiatives***](#) (October 2020), prepared by [Ricardo Strategic Consulting](#)
2. [***Life Cycle Analysis Comparison: Electric and Internal Combustion Engine Vehicles***](#) (January 2022), prepared by [Ricardo Strategic Consulting](#)
3. [***The Easiest and Hardest Commercial Vehicles to Decarbonize***](#) (April 2022), prepared by [Guidehouse](#)
4. [***The Case for Developing an ESG Plan***](#) (May 2022), prepared by freelance author [Jerry Soverinsky](#)
5. [***Assessment of Biofuels Policy: Effectiveness of Emissions Reductions***](#) (June 2022), prepared by [Stratas Advisors](#)
6. [***Future Capabilities of Combustion Engines and Liquid Fuels***](#) (October 2022), prepared by [Turner, Mason & Company](#)
7. [***Decarbonizing Combustion Vehicles: A Portfolio Approach to GHG Reductions***](#) (July 2023), prepared by [Stillwater Associates](#)
8. [***Balancing the Benefits of Biofuels: The Economics of U.S. Crop-Based Fuel Production***](#) (July 2024), prepared by [Stillwater Associates](#)
9. [***E-fuels: Evaluating the Viability of Commercially Deploying E-fuels in Road Transport***](#) (November 2024), prepared by [ERM](#)

TEI's Research and Mission

The core value of TEI research is to provide objective, fact-based analyses of issues affecting the transportation sector. Delivering unbiased insights is essential to inform but not influence decision-makers. This requires a transparent, inclusive, and robust peer review process that incorporates the perspectives of a diverse group of stakeholders.

TEI research² is led by a board of advisors³ made up of more than 60 people, representing nearly every perspective in the market. Board members include representatives from major oil and refining companies, biofuels producers, engine and vehicle manufacturers, electric vehicle infrastructure companies, fleet operators, fuel wholesalers and retailers, equipment manufacturers, and consumer and public health organizations, as well as national laboratory engineers and individual subject matter experts.

Every research project is identified by the TEI Board of Advisors and guided by contributors of the Institute who are particularly interested in the topic. Every published paper is subject to peer review by the board, whose responsibility is to review the content for accuracy and to ensure the research is unbiased. The final report is then presented to the Board for final approval prior to publication.

TEI's mission is to bring transportation stakeholders together to deliver objective, balanced research and analysis concerning fuels, vehicles, and consumers. TEI is the research-focused organization with the greatest diversity of perspective in the fuels and vehicles markets. TEI provides a venue where stakeholders from all areas of the transportation industry can come together to collaborate, share perspectives, and commission objective research analyzing the challenges and opportunities facing the market. TEI's board members and contributing organizations are dedicated to promoting facts and providing decision-makers with the most credible information possible so the market can deliver the best vehicle and energy options to consumers. This collaborative, non-advocacy approach ensures that TEI's products are both objective and reliable.

² <https://www.transportationenergy.org/research/reports/>

³ <https://www.transportationenergy.org/about-us/our-board-members/>

LIST OF ACRONYMS AND ABBREVIATIONS

45Q	Carbon sequestration tax credit	LCA	Life Cycle Analysis/Assessment
45V	Clean hydrogen production tax credit	LCFS	Low-Carbon Fuel Standard
45Z	Clean fuel production tax credit	LDV	Light-Duty Vehicle
B5	A blend of 5% biodiesel with 95% petroleum or renewable diesel	LNG	Liquefied Natural Gas
B20	A blend of 20% biodiesel with 80% petroleum or renewable diesel	MHDV	Medium- and Heavy-Duty Vehicle
BD	Biodiesel	NGV	Natural Gas Vehicle
BEV	Battery Electric Vehicle	NOx	Nitrogen Oxides
CCS	Carbon Capture and Sequestration	PHEV	Plug-in Hybrid Electric Vehicle
CI	Carbon Intensity	PM	Particulate Matter
CNG	Compressed Natural Gas	RD100	100% renewable diesel
CO₂	Carbon Dioxide	RD	Renewable Diesel
COP26	26th United Nations Climate Change Conference	RFS	Renewable Fuel Standard (U.S. federal policy)
E10	A blend of 10% ethanol with 90% gasoline	RIN	Renewable Identification Number (credits for biofuel production under RFS)
E15	A blend of 15% ethanol with 85% gasoline	RNG	Renewable Natural Gas
E30	A blend of 30% ethanol with 70% gasoline	ROI	Return On Investment
E85	A blend of 51%–83% ethanol with gasoline	TCO	Total Cost of Ownership
e-fuels	Electro-fuels; synthetic fuels produced from CO ₂ and water using renewable electricity	TEI	Transportation Energy Institute (formerly The Fuels Institute)
ESG	Environmental, Social, and Governance	TRL	Technology Readiness Level
EV	Electric Vehicle	UCO	Used Cooking Oil
FFV	Flexible-Fuel Vehicle	ZEV	Zero (Tailpipe) Emission Vehicle
FT	Fischer-Tropsch		
GHG	Greenhouse Gas		
GREET model	Greenhouse gases, Regulated Emissions, and Energy use in Technologies model (developed by Argonne National Laboratory for LCA)		
HEV	Hybrid Electric Vehicle		
ICE	Internal Combustion Engine		
ICEV	Internal Combustion Engine Vehicle		
ILUC	Indirect Land-Use Change		
IRA	Inflation Reduction Act		



Six Consistent Themes and Observations

The nine reports included in this review span a broad array of decarbonization strategies in transportation, with different scopes and methodologies. Some are sector specific (e.g., MHDVs, ICEVs), others are fuel or technology specific (e.g., biofuels, e-fuels), and others provide foundational frameworks (e.g., environmental, social, and governance; policy impacts). Life cycle analysis and economic feasibility serve as shared evaluative frameworks. Collectively, the reports provide a multifaceted view of how technology, regulation, market dynamics, and environmental goals shape transportation-sector decarbonization.

When reviewing this research, several key themes that connect these reports emerge. These themes form the basis for this compilation and include:

THEME 1 LIFE CYCLE-BASED EVALUATION OF EMISSIONS	7
THEME 2 TECHNOLOGY DIVERSITY, USE CASE SPECIFICITY, AND PORTFOLIO APPROACHES	13
THEME 3 ENVIRONMENTAL, SOCIAL, AND GOVERNANCE AND POLICY ALIGNMENT	16
THEME 4 FUEL- AND ENGINE-BASED DECARBONIZATION OF EXISTING FLEETS	18
THEME 5 INFRASTRUCTURE AND SCALABILITY CONSTRAINTS	23
THEME 6 ECONOMICS AND TOTAL COST OF OWNERSHIP	27



THEME 1.

Life Cycle–Based Evaluation of Emissions

Life cycle analysis (LCA) serves as a core analytic tool across these reports and was amplified in March 2025 when TEI published a short white paper, [Using Life Cycle Assessment to Evaluate the Light Duty Vehicle Transportation Sector](#). That paper noted:

“If the overall objective of emissions reduction efforts is to reduce emissions, including greenhouse gas emissions, then it is important to account for emissions wherever they are generated, apply reduction efforts where they can yield the greatest benefit and credit the transportation sector for all reductions...Further, by evaluating the life cycle emissions of the sector, businesses and policymakers can make informed decisions about product design, material sourcing, production methods and policy provisions to maximize the efficiency of emissions reductions.”⁴

⁴ Using Life Cycle Assessment to Evaluate the Light Duty Vehicle Transportation Sector, 2025, page 1.

When discussing LCA, it is important to understand what is included. TEI’s 2022 [Life Cycle Analysis Comparison](https://www.transportationenergy.org/research/reports/life-cycle-analysis-comparison-electric-and-intern) included the following graphic which details how that report approached the analysis.⁵ The sections surrounded by the green-dashed line represent the analysis of energy production (a.k.a., Well-to-Tank); the orange-dashed line represents the vehicle cycle, which includes vehicle production, end-of-life and operation (which includes energy consumption, or Tank-to-Wheels, and forms the basis for tailpipe considerations); and the blue-dashed line incorporates all facets for a full Cradle-to-Grave (a.k.a., Well-to-Wheel or Life Cycle) analysis.

⁵ <https://www.transportationenergy.org/research/reports/life-cycle-analysis-comparison-electric-and-intern>, 2022, page 9.

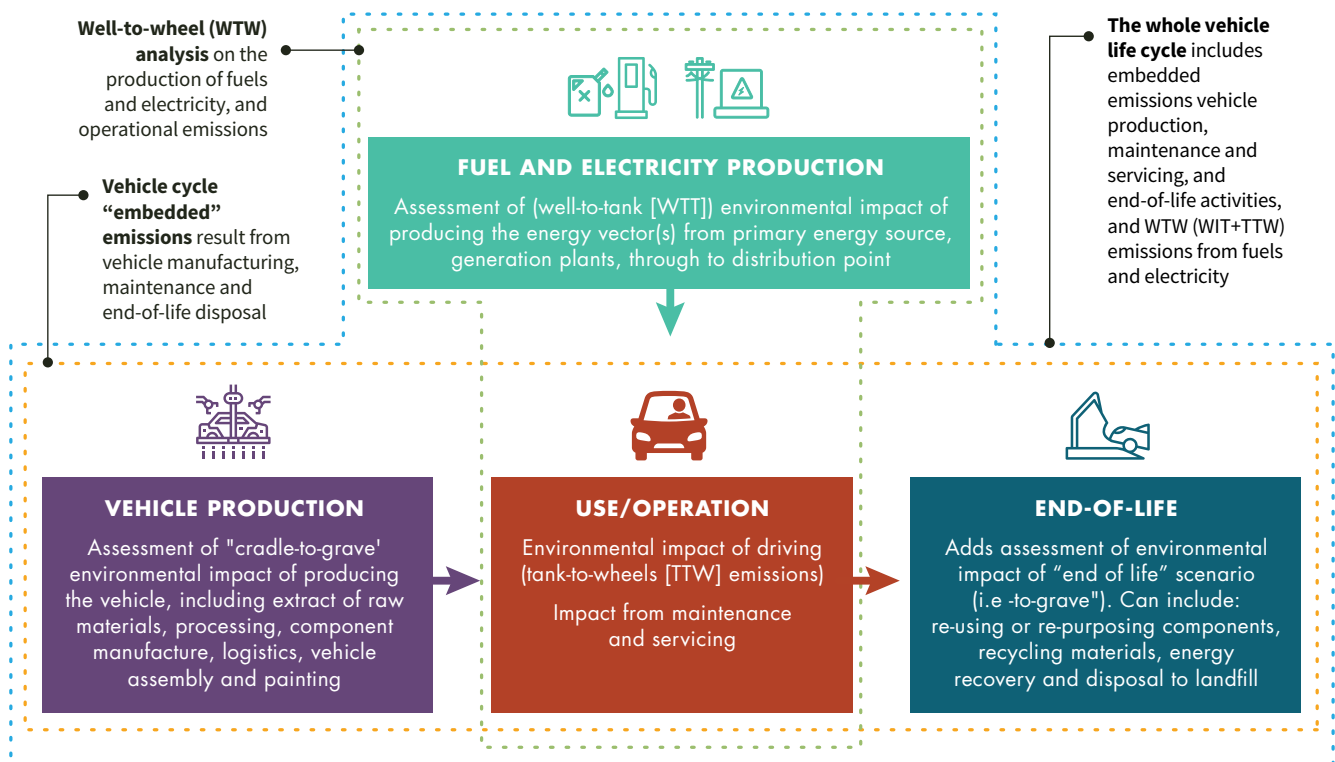
THE USE OF LCA RAISES SOME CHALLENGES.

Globally, there are several LCA models used in different jurisdictions. Most of TEI’s studies to date have been focused on the U.S. market and apply Argonne National Laboratory’s Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (GREET) model as the LCA methodology.

One exception was the report on e-fuels, which applied a combination of models to evaluate the emissions impact of these products. Because e-fuels are mostly produced outside the U.S., such an approach made sense. However, the paper does compare the results with GREET for consistency with U.S. applications. Implementing a framework to harmonize global LCA models could reduce disputes over methodology and accelerate cross-border investment. This harmonization will also be critical to reporting schemas under a range of proposed directives, many with potential global reach.

TEI LIFE CYCLE ANALYSIS COMPARISON REPORT, 2022

FIGURE 4: LCA AUTOMOTIVE SUBCATEGORIES, INCLUDING WTW AND CRADLE-TO-GRAVE ANALYSES



Note: Energy production cycle (electricity and fuels) is also included.

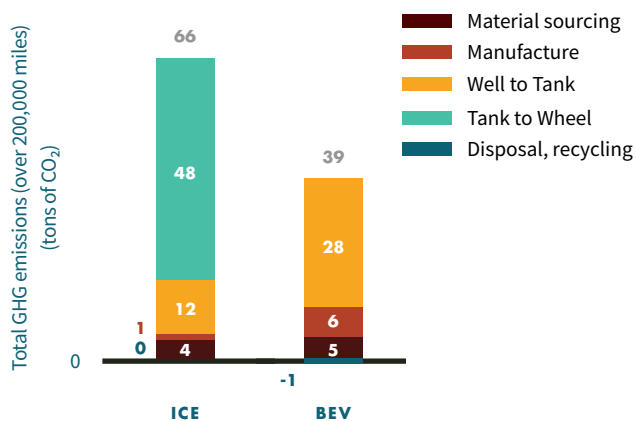
That same report explicitly provides a comparative framework for ICEVs and BEVs on a vehicle-to-vehicle basis. It dissects the emissions implications of BEVs and ICEVs across multiple stages of their life cycle: material extraction, manufacturing, operation, and end-of-life. The report highlights significant variability in outcomes depending on driving conditions, electricity grid CI, and vehicle longevity. Sensitivity analyses show that real-world performance can deviate substantially from modeled projections, underscoring the importance of region-specific assumptions and long-term operational data in evaluating decarbonization strategies.

A key finding of the report was that nearly three-quarters of life cycle greenhouse gas (GHG) emissions from ICEVs and BEVs can be attributed to the CI of the energy the vehicles consume, including liquid fuels and electricity. As the CI of this energy declines so too will the expected life cycle emissions for both powertrains, a fact that is strongly presented by advocates of electrification who expect electricity production to progress to a much lower CI. The study demonstrated that emissions do not originate from the tailpipe alone and that there are opportunities to reduce emissions throughout the life cycle of the vehicle and that of the energy it consumes, noting that an analysis of full life cycle emissions is critical to understanding the true environmental impact of different vehicle technologies. The report explains that the whole vehicle life cycle includes embedded emissions in materials, manufacturing, recycling, and well-to-wheel emissions from fuels and electricity. Conclusions that do not take these stages into account are incomplete at best and can be detrimental to decision- and policymaking.

LCA was also used in reports focused on biofuels, which included analyses of the emissions associated with different fuel pathways and blend ratios. *Assessment of Biofuels Policy* presented a comprehensive LCA of ethanol, biodiesel (BD), renewable diesel (RD), and emerging fuels such

TEI LIFE CYCLE ANALYSIS COMPARISON REPORT, 2022

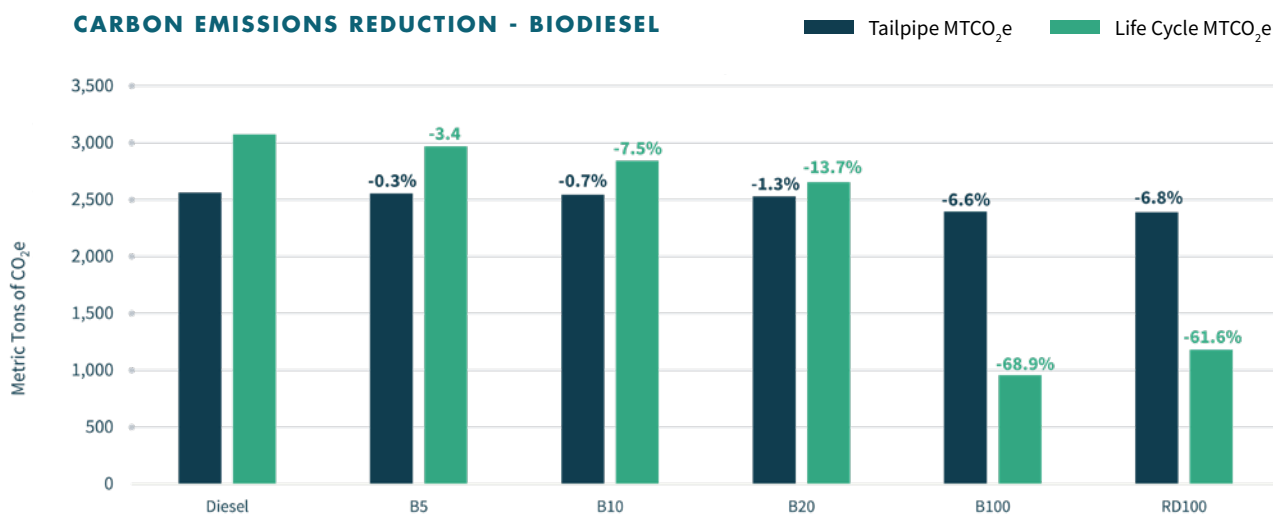
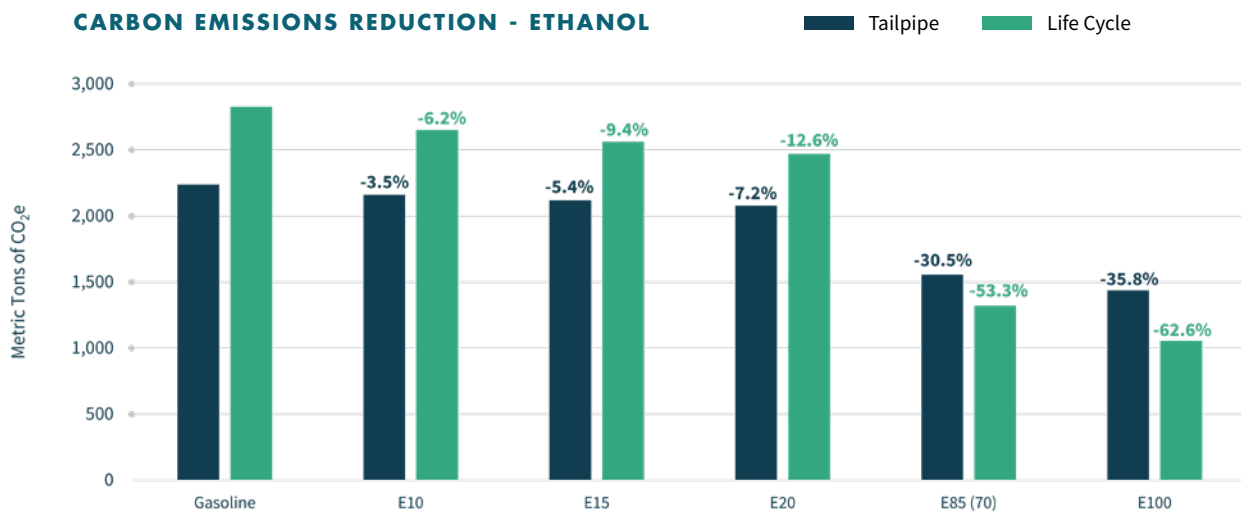
FIGURE 52: LIFE CYCLE GREENHOUSE GAS EMISSIONS



as renewable gasoline and e-fuels (referred to as synthetic fuels, or synfuels, in the report). It found that CI reductions varied widely depending on feedstock, process efficiency, and land-use change assumptions and concluded that biofuels remain a critical near-term decarbonization tool for existing fleets, with particular impact in sectors less suited for electrification.

The following graphics show the percent carbon emissions reduction potential of different biofuel blends on both a tailpipe and life cycle emissions basis. The calculations were based upon the national average CI of ethanol, BD and RD and performed by Felix, the Carbon Avoidance Tracker,⁶ a project of TEI, which leverages the Argonne GREET model. For two of the most widely available blends, based upon consumption of 250,000 gallons, E10 reduces carbon emissions by 78.8 MT (3.5%) when restricted to the tailpipe and 176.0 MT (6.2%) on a life cycle basis while B20 reduces emissions by 33.7 MT (1.3%) at the tailpipe and 321.1 MT (13.7%) on a life cycle basis.

CALCULATIONS PERFORMED BY FELIX, THE CARBON AVOIDANCE TRACKER, A PROJECT OF TEI
METRIC TONS OF CARBON EMISSIONS (BASED ON 250,000 GALLONS)



Source: Felix, The Carbon Avoidance Tracker, TEI

6 <https://www.transportationenergy.org/carbon-avoidance-tracking>

Future Capabilities of Combustion Engines and Liquid Fuels demonstrated that for internal combustion engines (ICEs), engine hardware cannot be evaluated in isolation. For example, research has demonstrated that efficiency gains from variable compression ratios in engines are affected by fuel octane and aftertreatment performance.⁷ The report notes that the interplay between technology and fuel types will ultimately shape the most effective pathways for achieving transportation decarbonization goals.

Decarbonizing Combustion Vehicles proposed a portfolio approach to decarbonizing ICEVs. While EVs will increase in market share, the existing ICEV fleet will remain dominant for decades. Incremental

strategies can offer near-term GHG reductions. These include leveraging lower-CI fuels in the existing fleet, like E15 (a blend of 15% ethanol and 85% gasoline), biodiesel (BD), and renewable diesel (RD), and developing systems to increase the efficiency of new ICEVs. The study includes life cycle comparisons of fuel blends and feedstock pathways, revealing substantial gains from even modest shifts in blend rates. Critically, it suggests treating ICEV decarbonization as complementary to, not competing with, electrification, a point echoed in other reports because of the large existing ICEV fleet on the roads today.

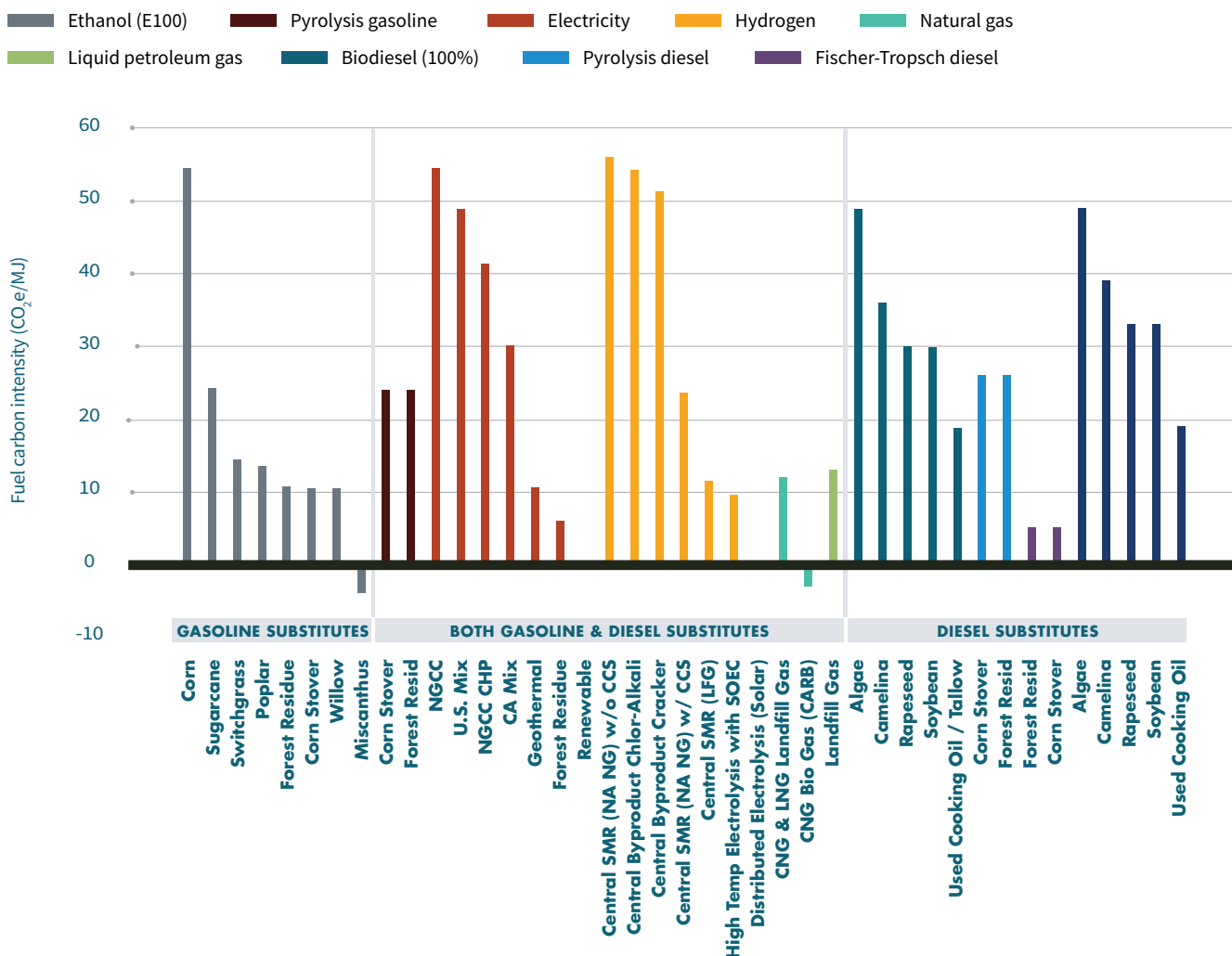
⁷ <https://www.transportationenergy.org/research/reports/analysis-of-the-potential-for-increasing-octane-in>



Throughout the studies, LCAs found that different combinations of fuel options with existing vehicle technologies can deliver equivalent or superior emissions reductions than could be achieved from converting the fleet to EVs that are charged with electricity equal to the CI of the U.S. grid average at the time the reports were written. For example, *Decarbonizing Combustion Vehicles* found there are at least 24 fuel sources for ICEVs that could provide “equal or greater GHG reductions to the reduction seen in present U.S. BEVs charged using the average U.S. mix electricity (excluding coal).”⁸ (See graphic below.) It concluded that ICEVs plus biofuels are considered a “winning immediate and long-term combo,” potentially providing “at least 80% of total on-road transport GHG reductions through 2035 and 68% of GHG reductions through 2050.”⁹

In essence, the research encourages the use of a data-driven, life cycle–based assessment that acknowledges the varied impacts of different transportation energy sources and technologies, aiming for a pragmatic and multi-faceted approach to decarbonization rather than relying on a single, potentially insufficient, solution.

TEI DECARBONIZING COMBUSTION VEHICLES REPORT, 2023
FIGURE 22. LOW-CARBON FUEL OPTIONS AVAILABLE FOR TRANSPORTATION FUELS



Source: GREET 2021 & 2022. Assumes EV EER of 2.4 and FCEV 1.7.

8 Decarbonizing Combustion Vehicles, 2023, pages 10, 43.

9 Ibid.



THEME 2.

Technology Diversity, Use Case Specificity, and Portfolio Approaches

Another consistent theme across these reports is the recognition that effective emissions reductions can be achieved by matching technologies with specific vehicle use cases. They emphasize that there is no single solution that can be applied to all scenarios, and that decarbonization solutions should be tailored to specific vehicle types and operational demands. Therefore, a portfolio approach is necessary because of the varied technical requirements, operational conditions, and economic considerations across different vehicle types and transport modes.

The MHDV market exemplifies the importance of a portfolio approach. The report [Easiest and Hardest Commercial Vehicles to Decarbonize](#) emphasized that no single technology can address all transportation segments. That report identified 17 different vehicle applications (e.g., long-haul cargo, school busing, refuse trucking), representing 91% of MHDVs in operation, and evaluated their potential paths to decarbonization, identifying opportunities and challenges associated with each.¹⁰ This report, combined with [Decarbonizing Combustion Vehicles](#) and the [Future Capabilities of Combustion Engines and Liquid Fuels](#), underscores the complexity of this vehicle segment, with its diversity of applications, duty cycles, and technical requirements.

TEI THE EASIEST AND HARDEST COMMERCIAL VEHICLES TO DECARBONIZE REPORT, 2022
TABLE 2: MHDV APPLICATIONS RANKED BY GHG SHARE

APPLICATION	VEHICLE TYPES	KEY CONSIDERATIONS	ANNUAL TRAVEL (THOUSAND MILES)	MARKET SHARE	SHARE OF GHG
Long-haul cargo	Tractors	Challenge: public infrastructure network	75-100	14%	40%
Regional cargo	Class 6-8 trucks and tractors	Driver: stakeholder's sensitivity	30-50	12%	19%
Last-mile cargo	Class 3-6 trucks and vans	Driver: stakeholder's sensitivity	12-20	31%	17%
School busing	Class 6 buses	Driver: duty cycle	10-15	5%	2%
Heavy construction	Class 6-8 trucks with superstructures (cement, dump, drilling, etc.)	Challenge: auxiliary loads	12-20	2%	2%
Refuse trucking	Class 6-8 trucks with refuse superstructure	Driver: duty cycle	20-30	1%	2%
Oil and gas	Class 6-8 tanker trucks and tractors	Challenge: public infrastructure network	25-35	1%	2%
Public transit	Class 7-8 buses	Driver: stakeholder's sensitivity	40-50	1%	2%
Light construction	Class 3-5 trucks	Challenge: public infrastructure network	5-10	8%	1%
Government	Class 3-8 trucks	Challenge: on-call services	5-10	6%	1%
Utilities	Class 3-6 trucks with boom superstructures	Challenge: on-call services	5-10	5%	1%
Agriculture	Class 3-8 trucks and tractors	Challenge: public infrastructure network	12-20	2%	1%
Tow trucking	Class 3-8 trucks	Challenge: on-call services	12-20	2%	1%
Private coach	Class 8 buses	Challenge: duty cycle	75-100	<1%	<1%
Moving	Class 3-8 trucks	Challenge: public infrastructure network	12-20	1%	<1%
Logging	Class 8 tractors	Challenge: public infrastructure network	25-35	<1%	<1%
Emergency	Class 3-8 trucks and vans	Challenge: on-call services	5-10	<1%	<1%

Source: Guidehouse Insights

10 <https://www.transportationenergy.org/research/reports/decarbonizing-medium-and-heavy-duty-vehicles>, 2022, page 12.

[Decarbonizing Combustion Vehicles](#) also emphasized the need for a portfolio approach, stating that “decarbonizing the on-road transportation sector does not have a one-size-fits-all solution”¹¹ and found that blended approaches can outperform purist strategies in both cost and carbon. Even the report analyzing e-fuels, which are often characterized as a rival to electrification, finds synergy rather than conflict among the options, noting that “battery electric vehicles (BEVs)...will play a significant role in emissions reduction, but the speed at which they could replace existing internal combustion engine vehicles (ICEVs) is uncertain.... As a result, it is expected that ICEVs will continue to be on the road into the 2040s. E-fuels could be deployed to achieve

higher emissions reductions from existing vehicles, particularly if the supply of sustainable biofuels is slow to ramp up.”¹²

The reports discuss a wide array of decarbonization technologies and potential future opportunities, noting achieved progress and promising developments for both ICE improvements and combustion fuels innovation. Overall, the reports emphasize that successful decarbonization requires a nuanced approach that considers the specific needs and limitations of each vehicle type and operational context, and they promote the exploration of a diverse portfolio of technological and fuel-based solutions.

¹¹ [Decarbonizing Combustion Vehicles](#), 2023, page 178.

¹² [E-fuels](#), 2024, page 7.





THEME 3.

Environmental, Social, and Governance and Policy Alignment

[The Case for Developing an ESG Plan](#) and the [Impact of Transportation-Related Environmental Initiatives](#) lay out how policy, business relationships, and investor expectations shape emissions strategies.

While environmental, social, and governance (ESG) policies and funds have come under additional scrutiny since the publication of “The Case for Developing an ESG Plan,” the foundational elements of the study, and especially the emissions component of the ESG concept, remain relevant to corporate strategic planning. Whether the motivation is regulatory compliance, business-to-business relationships, access to affordable capital, or adherence to company values, the pursuit of achieving, tracking, and reporting lower emissions

while generating a positive return on investment (ROI) continues to drive businesses throughout the world and there is a significant connection between these efforts and public policy.

THE REPORTS COLLECTIVELY ILLUSTRATE A COMPLEX AND EVOLVING RELATIONSHIP BETWEEN BUSINESS MOTIVATIONS TO REDUCE EMISSIONS, THE RESILIENCE OF ESG EXPECTATIONS, AND THE INFLUENCE OF GOVERNMENT POLICY.

Businesses are increasingly motivated to reduce emissions because of a combination of factors, including compliance with state, federal, and global requirements. Another primary motivation is to reduce costs and enhance economic opportunities. By adopting sustainable practices, particularly those related to energy, water, and raw materials, businesses can generate significant cost savings. In addition, embracing ESG values can drive companies to channel capital toward sustainable initiatives and avoid investments with potential environmental costs. Other benefits of such an approach are that it can improve a company’s reputation, increase its reach in existing markets, and facilitate expansion into new ones. This can also lead to better access to capital and enhanced appeal in contract bids from public and private entities that prioritize environmentally friendly sourcing.

When these studies were written, major financial institutions controlling vast assets were increasingly incorporating climate change and ESG criteria into their investment decisions. While this momentum has slowed recently, other business-related motivations remain. Companies face intense public scrutiny, particularly via social media. Aspirational statements without action backing them up can lead to accusations of “greenwashing” and cause reputational damage, sometimes severe. Companies are increasingly requiring their suppliers to demonstrate sustainability practices, influencing private companies down the supply chain. However,

the informal and evolving nature of ESG metrics creates challenges in consistent measurement and reporting. Different rating systems (e.g., from agencies such as FTSE, MSCI, and Sustainalytics) can yield varied assessments for the same company, highlighting the lack of standardized criteria. This has pushed some in industry to advocate for a unified regulatory framework.

Government policies play a critical role in shaping the emissions reduction landscape and interacting with business motivations. Policies like the federal Renewable Fuel Standard (RFS) and state-level low-carbon fuel standards (LCFSs) such as those in California, Oregon, and Washington mandate the blending of renewable fuels and set CI reduction targets for transportation fuels. The Cleaner Trucks Initiative aims to reduce nitrous oxide (NOx) emissions from heavy-duty trucks. The Inflation Reduction Act (IRA) introduced tax credits like 45Z (clean fuel production), 45V (clean hydrogen production), and 45Q (carbon sequestration) to incentivize low-carbon fuel production and carbon capture. These credits aim to reduce net production costs and attract investment in the U.S. Clear emissions reduction targets and strategies for achieving them in specific transport sectors aim to improve market certainty and guide investment decisions. However, regulatory timing, changes in policy direction, credit pricing, and state-federal interactions can create uncertainty and hamper investments and innovation.

In essence, government policies create the framework and incentives that align business interests with broader environmental goals, while increased ESG expectations from investors and the public add pressure and motivation for companies to actively pursue emissions reductions. This dynamic interplay will continue to drive significant shifts in energy production, vehicle technology, and market strategies across the transportation sector and around the world.



THEME 4.

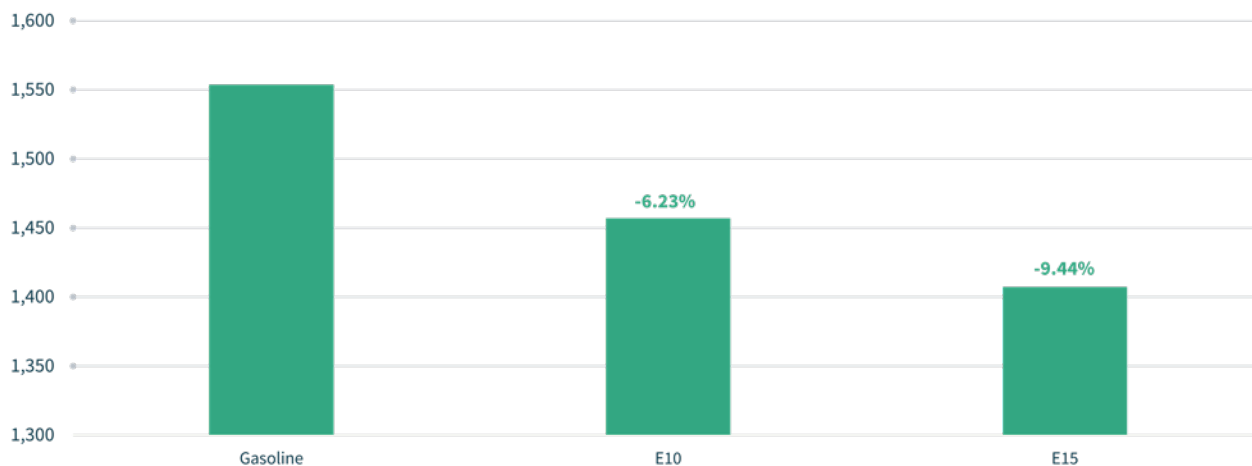
Fuel- and Engine-Based Decarbonization of Existing Fleets

With nearly 300 million ICEVs projected to remain on U.S. roads in 2035, ignoring the legacy fleet will significantly impede efforts to reduce transportation-related emissions. [*Decarbonizing Combustion Vehicles*](#) explains that “many near-term options for reducing the carbon intensity of ICEV fuels will have near-term reductions since those fuels will be used in the current fleet.”¹³ Overall, the reports suggest a multifaceted approach to reducing emissions from the existing fleet of vehicles, focusing heavily on advancements in both fuel composition and engine technology.

¹³ [Decarbonizing Combustion Vehicles](#), 2023, page 12.

FUEL PATHS TO DECARBONIZATION: The primary strategy for fuel-related emissions reductions revolves around increasing the use of low-CI fuels and optimizing their blends within existing vehicle infrastructure. Ethanol is the most consumed renewable fuel in the U.S., with corn-based ethanol typically having a 45% lower CI than gasoline. E10 (10% ethanol) is widely used, and transitioning to E15 (15% ethanol) for light-duty vehicles (LDVs) could significantly reduce carbon dioxide (CO₂) emissions. In fact, if the entire 2024 U.S. gasoline market of 137.4 billion gallons¹⁴ was converted to E15, life cycle carbon emissions would be reduced by an additional 50 million MT.¹⁵

**CALCULATIONS PERFORMED BY FELIX, THE CARBON AVOIDANCE TRACKER, A PROJECT OF TEI
LIFE CYCLE CARBON EMISSIONS (BASED ON U.S. POOL OF 137.4 BILLION GALLONS)**



Source: Felix, The Carbon Avoidance Tracker, TEI

The major hurdles for widespread E15 adoption are regulatory (e.g., Reid vapor pressure limits during summer) and provisions requiring confirmation of compatibility.¹⁶ Higher ethanol blends like E85 (51%–83% ethanol) offer substantial GHG reductions, but their use is limited to flexible-fuel vehicles (FFVs) and their market penetration is constrained by declining FFV production¹⁷ and limited retail availability.¹⁸

BD can be blended up to 20% (B20) in existing diesel engines without modifications. Its CI varies based on feedstock, with waste feedstocks (e.g., used cooking oil [UCO], animal fats) having lower CIs than crop-based oils. RD meets the ASTM technical standard for petroleum diesel, making it a “drop-in” fuel that can be used at up to 100% (R100) in existing diesel infrastructure and engines. RD production is growing rapidly, especially driven by LCFS programs in states like California, and is expected to increasingly displace BD

14 [https://www.eia.gov/todayinenergy/detail.php?id=66005#:~:text=On%20an%20annual%20basis%2C%20between,vehicle%20miles%20traveled%20\(VMT\)](https://www.eia.gov/todayinenergy/detail.php?id=66005#:~:text=On%20an%20annual%20basis%2C%20between,vehicle%20miles%20traveled%20(VMT))

15 Carbon emissions reduction calculated using Felix, the Carbon Avoidance Tracker <https://www.transportationenergy.org/carbon-avoidance-tracking>

16 <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280/subpart-C/section-280.32>

17 Vehicle manufacturers no longer receive a fuel economy compliance incentive for producing FFVs, resulting in a significant reduction in vehicle availability. According to the 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. <https://afdc.energy.gov/vehicles/flexible-fuel>

18 <https://afdc.energy.gov/stations#/analyze?tab=fuel&country=US&fuel=E85>



due to its compatibility advantages.¹⁹ That said, demand for BD is growing within the marine,²⁰ rail²¹ and long-haul trucking sectors with some vehicles transitioning to operate on B100 and fueling stations adding B100 to their product offer.

Produced from biomass decomposition (e.g., landfills, manure), renewable natural gas (RNG) offers extremely low or even negative CI thanks to avoided methane emissions. It is used in natural gas vehicles (NGVs) as compressed natural gas (CNG) or liquefied natural gas (LNG). Growth is tied to fueling infrastructure and the NGV fleet size, which may benefit from the 2025 commercial launch of the Cummins X15N CNG engine which delivers improved performance over legacy units. Market opportunities for RNG, both compressed

and liquified, are supported by growing demand in the marine industry as shippers seek to comply with International Maritime Organization (IMO) requirements.

E-fuels are synthetic fuels produced from CO₂ and water using renewable electricity, yielding near-zero emissions when sustainably produced. They are designed as drop-in replacements for gasoline and diesel and are compatible with existing ICEVs and infrastructure without requiring major modifications. While still in the early commercial stages and currently encumbered by high costs of production, they are considered a promising long-term solution, especially for hard-to-electrify sectors like aviation and shipping.

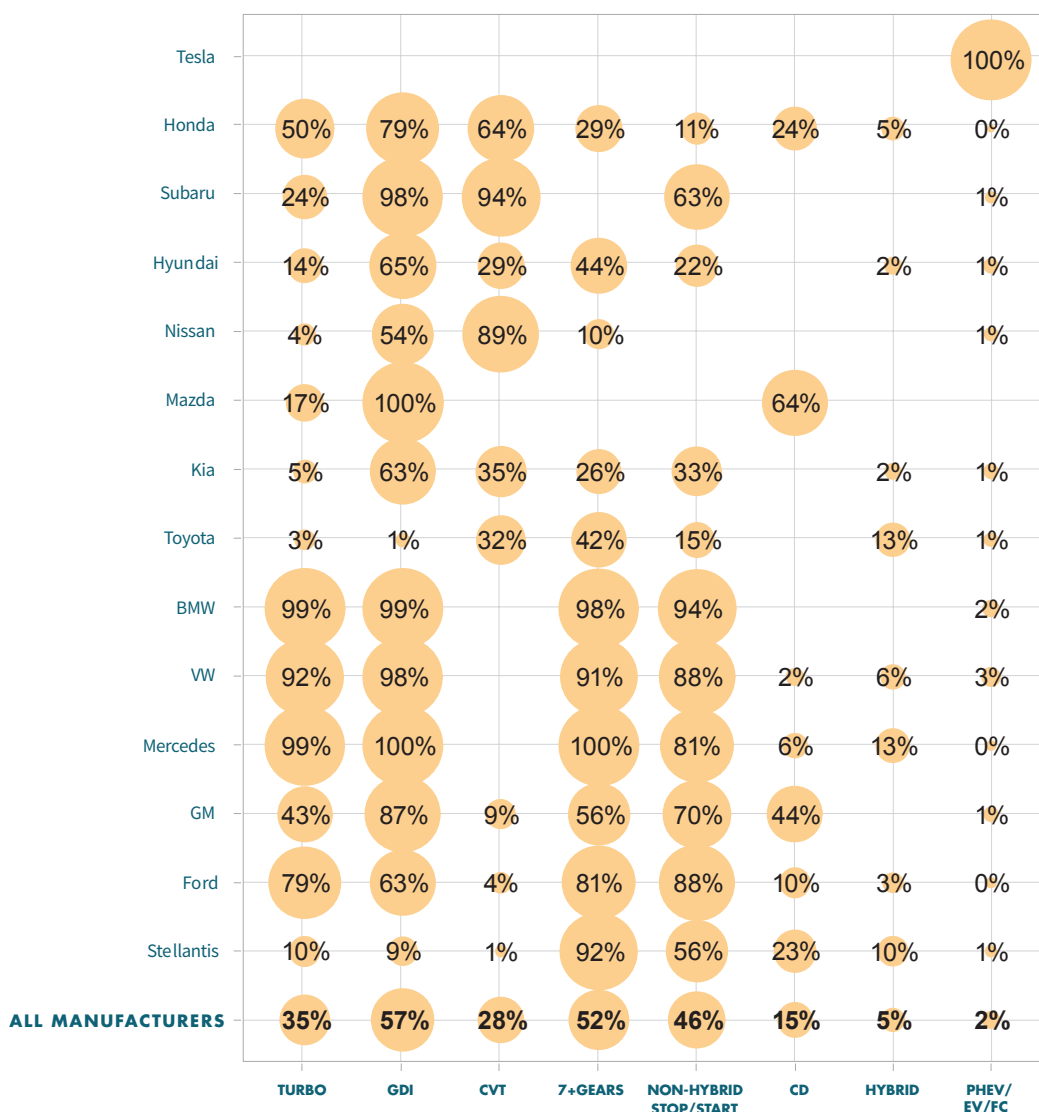
¹⁹ Production of biomass-based diesel fuels has slowed since publication of these reports due to expiration of the biodiesel blenders tax credit and uncertainty regarding future tax policy implications for the fuels.

²⁰ <https://www.marketresearchfuture.com/reports/marine-biofuel-market-25237>

²¹ <https://www.skyquestt.com/report/railway-based-biofuels-market>

ENGINE PATHS TO DECARBONIZATION: Improvements in ICE technology have been crucial for reducing emissions from the existing fleet and will continue to be so for new-to-market ICEVs, even as renewable fuels gain traction. Decades of evolution in light-duty engine development have led to improvements like variable valve timing, direct injection, turbocharging, engine downsizing, cylinder deactivation, and stop/start systems. These technologies aim to optimize fuel consumption and thermal efficiency and have achieved approximately 31% reduction in CO₂ emissions since 2005.²² Heavy-duty diesel engines, which are more efficient than gasoline engines, are being further improved with technologies such as turbochargers, thermal barrier coatings, low-friction components, and advanced emission control systems. These developments can yield significant fuel savings and emissions reductions.²³

TEI DECARBONIZING COMBUSTION VEHICLES REPORT, 2023
FIGURE 39. MANUFACTURER USE OF EMERGING TECHNOLOGIES FOR MODEL YEAR 2020²³



Source: The 2021 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975 (EPA-420-R-21-003, November 2021)

22 <https://www.epa.gov/automotive-trends>

23 <https://www.transportationenergy.org/research/reports/decarbonizing-combustion-vehicles-a-portfolio-approach-to-ghg-reductions/>, 2023, page 78.

Vehicles like HEVs and plug-in HEVs (PHEVs) integrate electric motors and batteries with ICEs, allowing the ICE to operate closer to peak efficiency and use regenerative braking to recapture energy. Hybrids offer substantial fuel economy advantages of approximately 30% compared to conventional ICEVs²⁴ and are compatible with existing and future low-carbon fuels. Alternative fuel ICE engines, such as those that can run on CNG/RNG and B100, are also available in the heavy-duty vehicle market and can result in lower emissions.

Modern ICEVs incorporate advanced emission control technologies (e.g., catalytic converters, selective catalytic reduction for NOx) that significantly reduce criteria pollutants like NOx and particulate matter (PM). In addition, [Decarbonizing Combustion Vehicles](#) found that modern diesel vehicles, in certain on-road conditions, can have

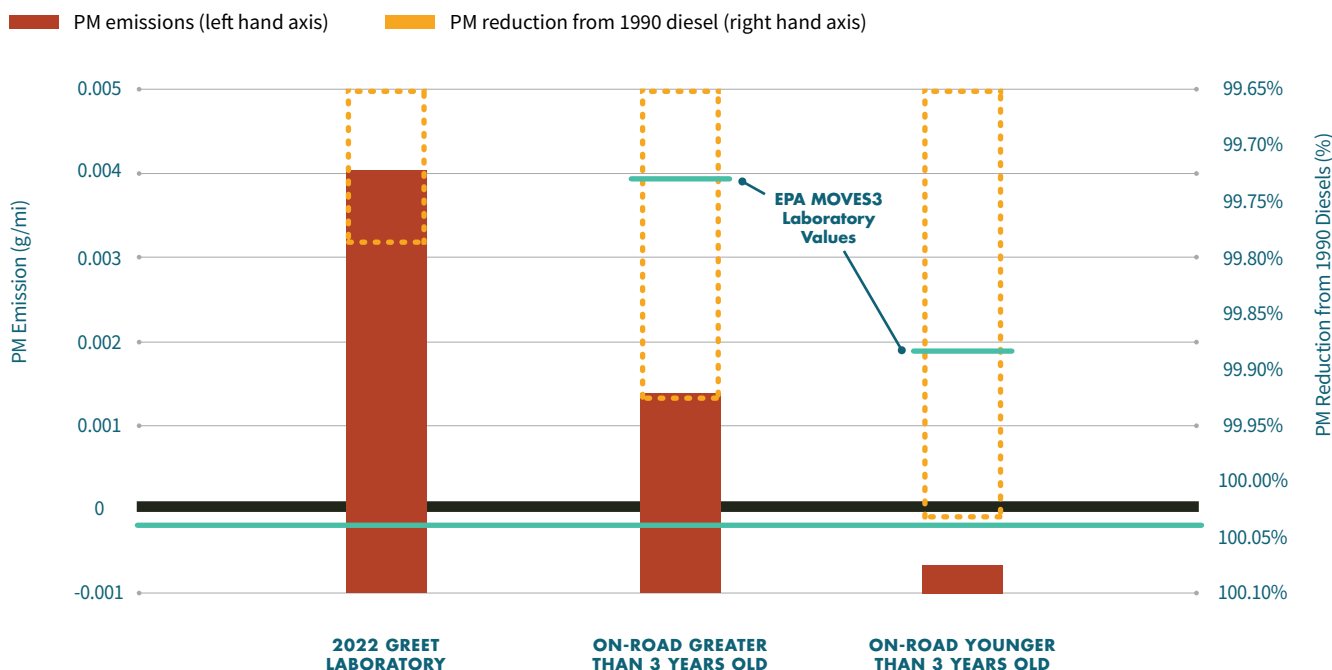
net-negative PM emissions by consuming existing air pollution (see figure below).²⁵

In addition, engines can be optimized to work more efficiently with specific fuel properties. For example, higher-octane ethanol blends (e.g., E30) enable higher compression ratios and more aggressive turbocharging, leading to further fuel efficiency gains,²⁶ lower emissions and potentially lower costs to consumers.

Taken together, the reports suggest a dual-pronged approach: maximizing the use of low-carbon fuels in existing ICEVs and continuously improving ICE technology itself. This portfolio strategy aims to achieve substantial near-term GHG reductions while the number of BEVs in operation gradually increases over several decades.

TEI DECARBONIZING COMBUSTION VEHICLES REPORT, 2023

FIGURE 28. HEAVY-DUTY DIESEL VEHICLE TAILPIPE PARTICULATE MATTER EMISSIONS



Source: Stillwater Associates analysis of 2022 GREET and EPA MOVES3 Emission Rates

24 <https://publications.anl.gov/anlpubs/2022/07/176270.pdf>

25 <https://www.transportationenergy.org/research/reports/decarbonizing-combustion-vehicles-a-portfolio-approach-to-ghg-reductions/>, 2023, page 66.

26 <https://pubs.acs.org/doi/10.1021/acs.est.5b01420> and <https://www.transportationenergy.org/research/reports/analysis-of-the-potential-for-increasing-octane-in>



THEME 5.

Infrastructure and Scalability Constraints

Infrastructure challenges, ranging from electric grid limitations and fueling compatibility to land availability and feedstock volumes to supply chain difficulties, appear across nearly all reports. These bottlenecks affect market viability and are often decisive in scaling capabilities. The reports detail these various constraints affecting the decarbonization of the existing vehicle fleet.

INFRASTRUCTURE CONSTRAINTS: The transition to a decarbonized fleet faces significant infrastructure hurdles. Higher blends of biofuels, like E15, E85, and B20+, can reduce the CI of the fuel consumed in the fleet but may require additional regulatory approvals, upgraded retail station equipment, and/or dedicated dispensing systems, which incur costs and slow adoption. In addition, while NGVs use a widely available natural gas grid, the number of dedicated refueling stations is limited, primarily serving depot-based commercial fleets rather than private consumers. Retail availability of alternative fuels is directly related to demand and could be expected to grow to satisfy demonstrated

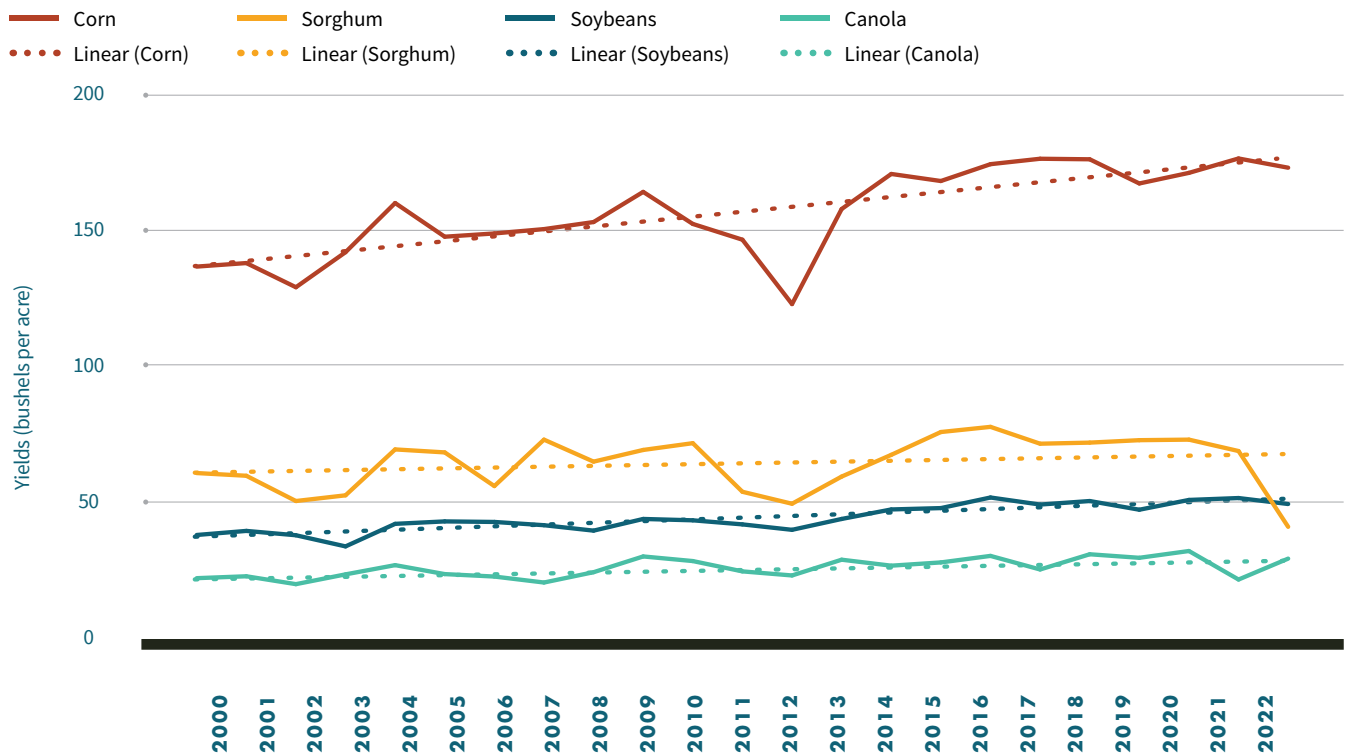
demand within a market. For example, 23% of existing CNG/LNG stations in the United States are located in California,²⁷ which consumes more than 50% of the natural gas vehicle fuel in the country.²⁸

SUPPLY CHAIN CONSTRAINTS: The expansion of renewable electricity generation for EVs and e-fuels faces resource and supply chain constraints for raw materials and electricity transmission components, which can limit the rate of project development. Since the papers summarized in this report were published, a rapid acceleration in electricity demand for data centers and artificial intelligence has exacerbated the challenges in this sector. While conventional biofuels have mature domestic supply chains, some advanced biofuels face immature supply chains for feedstock collection and transportation, especially when sources are

dispersed. Meanwhile, e-fuel technologies are still early in development, requiring significant capital investment. Scaling up depends on securing reliable access to affordable renewable electricity and CO₂.

FEEDSTOCK AVAILABILITY: While yields per acre for corn and soybeans have steadily increased, a significant share of these crops is already used for biofuel. Concurrent demand from food and feed markets can lead to price increases and concerns about indirect land-use change (ILUC), though studies suggest biofuels are not the primary driver of commodity price volatility. *Balancing the Benefits of Biofuels* found that “per-acre yields of each of the primary biofuel’s feedstocks have been growing steadily over time; the cumulative effect of these trends is the supply of these feedstocks has grown more rapidly than the acreage dedicated to these crops.”²⁹

TEI BALANCING THE BENEFITS OF BIOFUELS REPORT, 2024
FIGURE 17. ANNUAL YIELDS FOR MAJOR U.S. BIOFUEL FEEDSTOCKS (2000–2022)³⁰



Sources: USDA; Stillwater analysis

27 <https://afdc.energy.gov/stations#/find/nearest>

28 <https://www.eia.gov/todayinenergy/detail.php?id=64244#:~:text=More%20natural%20gas%20is%20consumed,million%20registered%20vehicles%20in%202023.>

29 <https://www.transportationenergy.org/research/reports/balancing-the-benefits-of-biofuels/>, 2024, page 5.

30 <https://www.transportationenergy.org/research/reports/balancing-the-benefits-of-biofuels/>, 2024, page 29.

TEI BALANCING THE BENEFITS OF BIOFUELS REPORT, 2024³¹

FIGURE 14. U.S. CROP GROSS ACREAGE USED FOR BIOFUEL PRODUCTION (2010-2022)

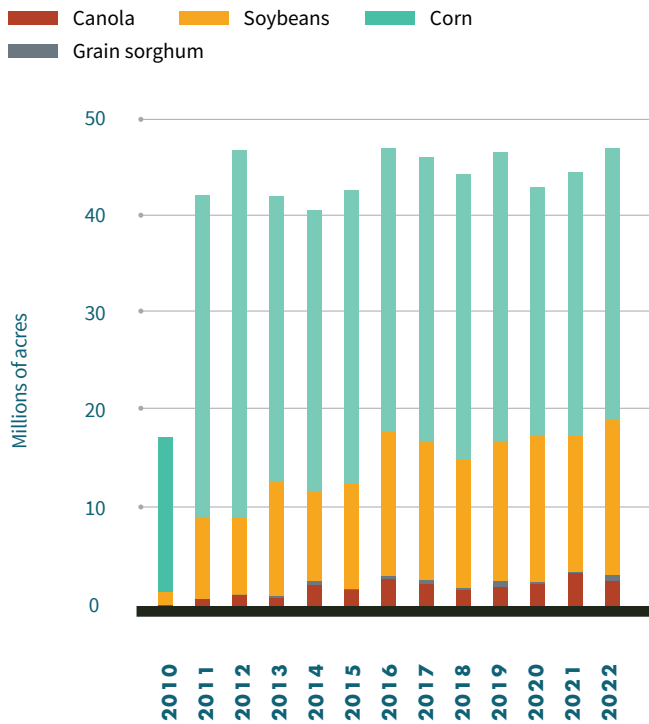
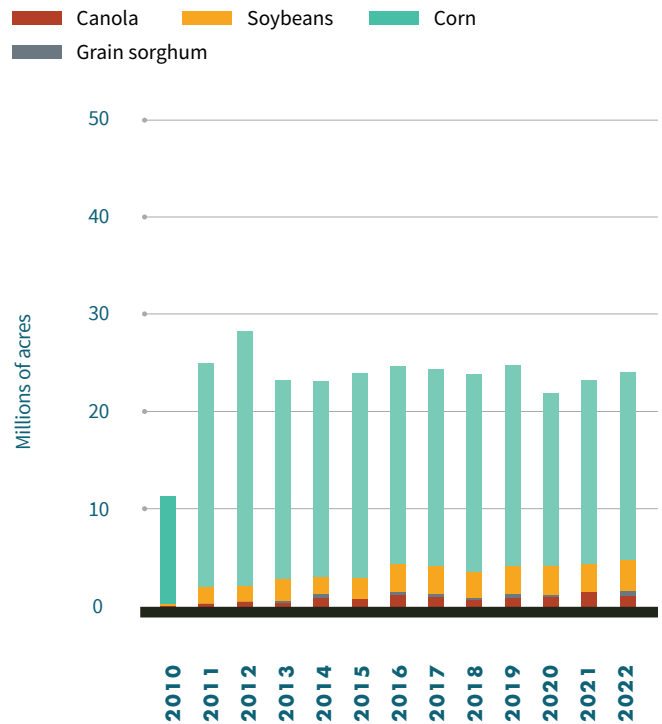
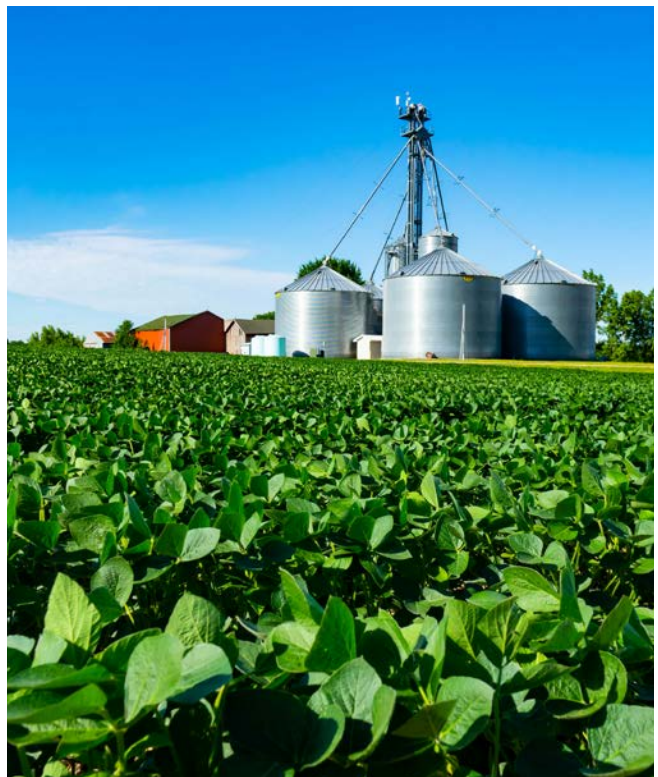


FIGURE 15. U.S. CROP NET ACREAGE USED FOR BIOFUEL PRODUCTION (2010-2022)



Sources: USDA; Stillwater analysis

Although the supply of UCO and animal fats is expanding, the growth in demand for low CI fuels, like sustainable aviation fuels, could potentially affect availability. While offering significant potential, cellulosic feedstocks (e.g., corn stover, dedicated energy crops like miscanthus) face challenges in large-scale commercialization due to high up-front costs, technological hurdles in conversion, and farmer risk aversion. And for e-fuels, while the U.S. has theoretically vast renewable energy potential, the cost and ability to develop additional renewable electricity capacity are critical practical constraints.³¹



³¹ <https://www.transportationenergy.org/research/reports/balancing-the-benefits-of-biofuels/>, 2024, page 25.

SCALABILITY OF DECARBONIZATION

OPTIONS: Many advanced biofuel and e-fuel production pathways are still in early development stages (i.e., they have low technology readiness levels, or TRLs), requiring significant research and development and capital investment for commercial scale. Most biofuels and alternative fuels are more costly than petroleum fuels without government policy support. Higher costs of production and acquisition represent a major barrier to widespread adoption of some alternative fuels, forcing them to rely heavily on sustained policy incentives.

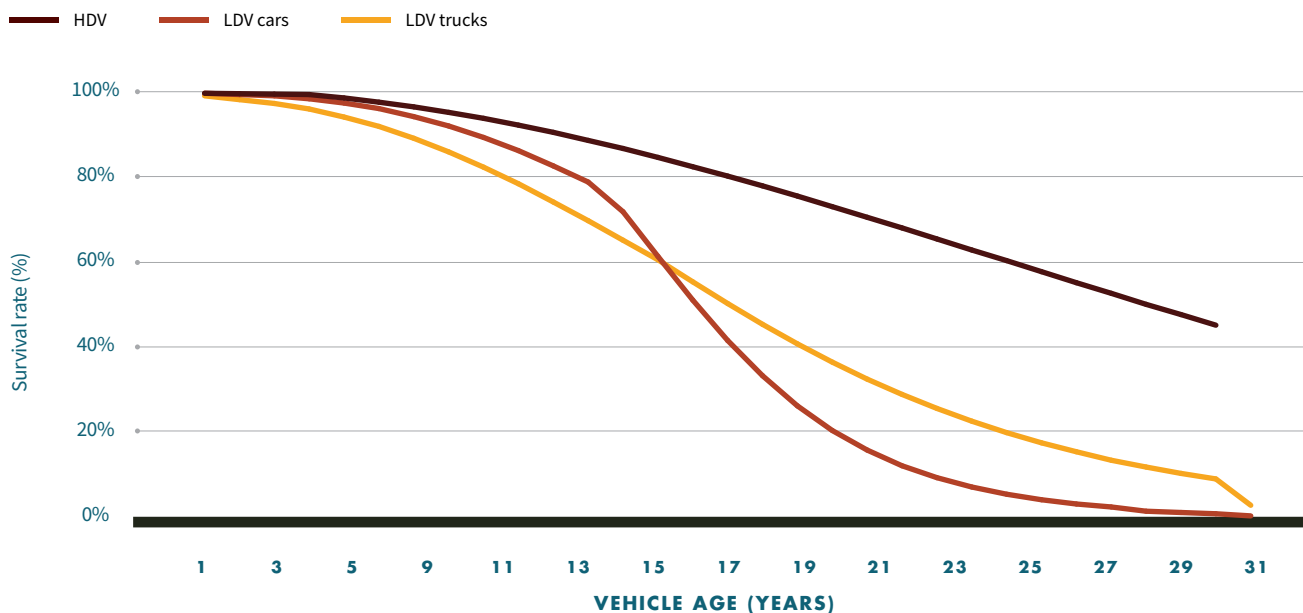
Another factor affecting the scalability of options is the fact that the existing vehicle fleet turns over slowly (e.g., heavy-duty vehicles can remain on the road for more than 30 years). This means that even with rapid sales of new low-emission vehicles, legacy vehicles will dominate the fleet for decades, limiting the speed of overall fleet decarbonization available through new vehicle technologies.³²

Further, policy uncertainty is a significant impediment. Inconsistent or short-term policy signals (e.g., expiring tax credits, debates over mandate schedules, lack of clear e-fuel eligibility) create market risks that deter long-term investment in production capacity and infrastructure, hindering scalability. Finally, competition for limited low-carbon feedstocks and inconsistent levels of policy support for different decarbonization pathways (e.g., crop-based biofuels, waste-based biofuels, e-fuels) and across various transport modes (e.g., road, aviation, maritime, rail) can limit the scalability for any single option.

Achieving significant emissions reductions from the existing fleet requires overcoming a complex web of interwoven constraints, and the reports emphasize that a diversified and adaptable strategy is essential to navigate these challenges and accelerate decarbonization.

TEI DECARBONIZING COMBUSTION VEHICLES REPORT, 2023

FIGURE 5. VEHICLE SURVIVAL RATE FOR CARS, TRUCKS, AND HEAVY-DUTY TRUCKS³²



Source: Oak Ridge National Laboratory Transportation Energy Data Book Edition 40, Tables 3.14, 3.15, 3.16.

32 <https://www.transportationenergy.org/research/reports/decarbonizing-combustion-vehicles-a-portfolio-approach-to-ghg-reductions/>, 2023, page 23.



THEME 6.

Economics of Decarbonization

The reports provide a comprehensive overview of the economics of decarbonization options, addressing the financial implications for vehicle and fuel producers, distributors, retailers, and consumers. A recurring theme is that some low-carbon options are currently more expensive than their fossil-fuel counterparts, necessitating government policy support to bridge this cost gap and incentivize adoption.

FUEL PRODUCERS: The production of biofuels, especially advanced and cellulosic types, often faces economic hurdles. For example, cellulosic ethanol production is complex and more expensive than cornstarch fermentation. The primary challenge for Fischer-Tropsch (FT) diesel is its high capital cost per unit of capacity, making it uneconomical without incentives compared to petroleum fuels. While RD production capacity is growing rapidly, RD remains considerably more expensive than petroleum diesel and is only cost effective where layers of state and federal incentives exist. BD production costs have also been high, especially when feedstock prices rise. E-fuels are currently the most expensive low-carbon fuels to produce, costing 2.5 to 4 times more than fossil fuels even when using low-cost renewable electricity.

Producers have relied heavily on government policies like the federal Renewable Fuels Standard (RFS), state Low Carbon Fuel Standards (LCFS), and IRA tax credits to make low-carbon fuel production economically viable. The absence of guaranteed market demand creates uncertainty for producers, potentially leading them to prioritize export markets with stronger demand signals. For corn ethanol, carbon capture and sequestration (CCS) investments can significantly lower ethanol production CI, making it more competitive and potentially eliminating the need for Brazilian sugarcane ethanol imports.

DISTRIBUTORS AND RETAILERS:

Transitioning from E10 to E15 can require investments in tanks and pumps at retail sites to satisfy regulatory requirements for demonstrating compatibility.³³ Expanding E85 availability requires significant investment at retail sites for compatible dispensers and underground equipment, posing a major hurdle, while the availability of FFVs that can operate on E85 is limited.³⁴ However, because B5 is considered the same as diesel fuel by ASTM's D975 definition, there are no compatibility issues with this product making it relatively easier to distribute than other alternative fuels. But increasing blend levels of BD beyond 5% to take advantage of its CI benefits may require additional investment by some stakeholders in the supply chain. The value of renewable identification numbers (RINs) and LCFS credits can significantly influence the profitability of blending and selling biofuels but are also subject to policy adjustments.

CONSUMERS: There are several lower-carbon fuels available for ICEVs, but their compatibility with vehicles and their economic value to consumers can vary. For example, E15 can be used in vehicles manufactured in 2001 or later (its use is prohibited in most boats, motorcycles and small engines) and often offers a slightly lower price at the pump compared to E10. E15 provides more octane than E10 but contains slightly less energy per gallon, which could offset some

RECENT CHANGES TO THE FEDERAL RFS AND IRS TAX INCENTIVE PROVISIONS

have altered who is eligible to receive incentives and how those incentives may continue to provide financial support for low carbon fuels.

Under the newest RFS rules, biofuels generated from foreign feedstocks, for example, will be penalized and unable to generate the same number of credits as those using domestic feedstocks.

Under the IRS 45Z incentives, credits are no longer available for those blending biofuels, such as biodiesel with diesel fuel. Rather, the blender credit is now a producer's tax credit (PTC) for all biofuels which meet thresholds (50% or greater) on emission reductions to create the incentive. This includes sustainable ag practices and indirect land use impacts. In 2026, the indirect land use impacts will not be included in credit determination.

All of these credits are designed to ensure that low carbon biofuels are competitive with gasoline and diesel. Changing and disruptive policies often add uncertainty to long-term investments.

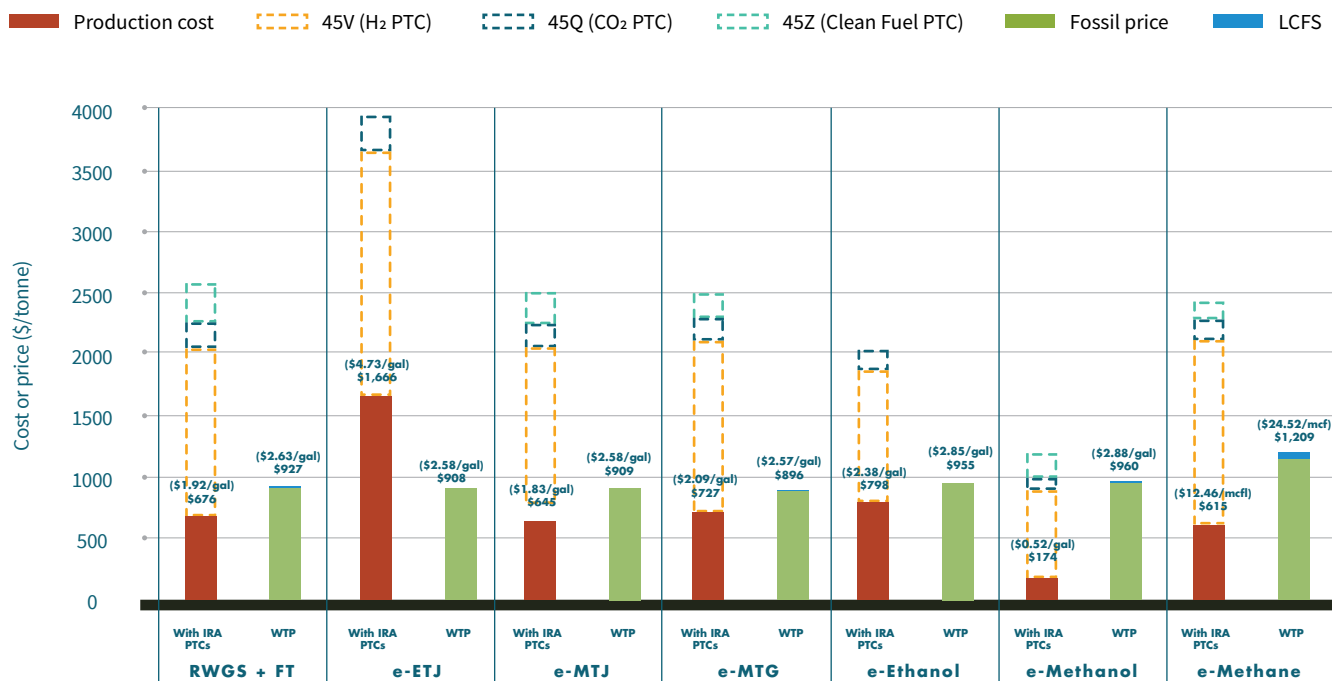
of its economic value. E85 can only be used in FFVs and generally needs to be priced at a significant discount to gasoline to compensate for its lower energy density. RD has a competitive advantage as its use does not suffer from a fuel economy loss compared to petroleum diesel and it can be used in most diesel engines at any blend level up to 100%. However, both RD and BD blends higher than B20 can be susceptible to flow problems in cold weather. Both RD and BD can be priced higher than petroleum diesel in some markets, despite government incentives.

³³ <https://www.ecfr.gov/current/title-40/chapter-I/subchapter-I/part-280/subpart-C/section-280.32>

³⁴ See Reference 11.

TEI EFUELS REPORT, 2024

FIGURE 6-6. PRODUCTION COSTS AND POLICY SUPPORT FOR FUTURE NOAK PLANTS
(ALL FUEL PATHWAYS)³⁸



Life Cycle Analysis Comparison reviewed several models evaluating the total cost of ownership (TCO) for consumers and found that this is expected to be attractive for those purchasing EVs,³⁵ even though the upfront purchase cost, potential for battery replacement and uncertain residual value remain challenges to perceived value. Other studies, however, have found that while EVs might provide lower operating costs, the TCO may not be favorable.³⁶ For vehicles using biofuels and e-fuels, TCO is significantly impacted by unsubsidized production costs. For example, e-gasoline in a new ICEV is projected to remain 25%–30% more expensive per mile than fossil gasoline by 2040, requiring policy incentives to be competitive for consumers. However, when evaluating

the costs of production from future plants (a.k.a., nth of a kind or “NOAK”) and applying a stack of policies in effect in 2024, several e-fuel pathways can compete with the willingness-to-pay threshold.³⁷



35 <https://www.transportationenergy.org/research/reports/life-cycle-analysis-comparison-electric-and-internlife-cycle-analysis-comparison-electric-and-intern>, 2022, pages 53-62.

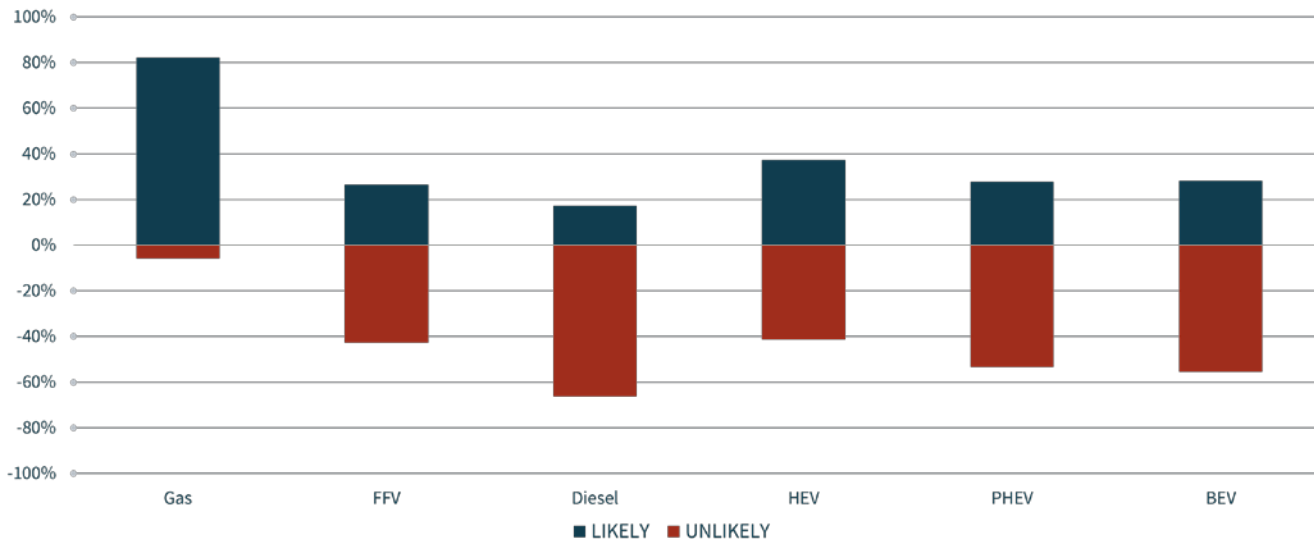
36 <https://www.sciencedirect.com/science/article/pii/S1361920924004309?via%3Dihub>

37 <https://www.transportationenergy.org/research/reports/e-fuels-evaluating-the-viability-of-commercially-deploying-e-fuels-in-road-transport/>, 2024, pages 107-108.

38 <https://www.transportationenergy.org/research/reports/e-fuels-evaluating-the-viability-of-commercially-deploying-e-fuels-in-road-transport/>, 2024, pages 108.

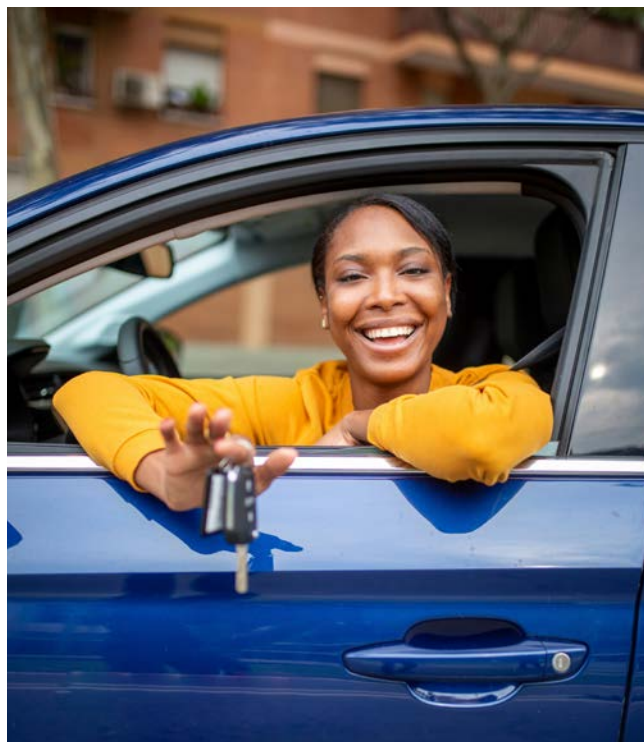
TEI CONSUMER SURVEY: 2025 DRIVER BEHAVIORS AND PERSPECTIVES REPORT, 2025

FIGURE 66. LIKELY TO CONSIDER BUYING OR LEASING⁴⁰



While cost analysis is important, consumer acceptance often is influenced by a range of factors other than cost and may be based upon perception, general preferences or even biases toward certain options. In addition, not all consumers are open to change when considering the vehicle they purchase. In [Consumer Survey: 2025 Driver Behaviors and Perspectives](#) TEI found that fewer than 30% of consumers who said they might acquire a new vehicle within two years said they would consider something other than a gasoline or hybrid vehicle.³⁹ This resistance to change and the sheer ubiquity of gasoline stations makes ICEVs convenient for consumers and presents an opportunity to reduce emissions through the provision of low-CI fuels.⁴⁰

In summary, the economics of decarbonization options generally have been characterized by higher initial costs for producers and consumers, offset by various government incentives and, in some cases, lower operating costs. However, for some fuels like E10 and E15 the result has been lower costs for the consumer. The reports emphasize that policy plays a



crucial role in creating a viable economic environment for low-carbon fuels and vehicles, shaping their competitiveness across the entire supply chain and driving consumer adoption.

39 <https://www.transportationenergy.org/research/reports/consumer-survey-2025-driver-behaviors-and-perspectives/>, 2025, pages 46-47.

40 Ibid.



Conclusions

These reports collectively demonstrate that transportation decarbonization is not a binary BEV-versus-fuel debate, but rather a layered combination of trade-offs, timelines, technology, and consumer perceptions. While market and policy developments may have changed the landscape for some of these topics, the observations and conclusions presented in these studies were consistent with the conditions that prevailed when they were written. Further, the underlying concepts within each report have not significantly changed with time even as some of the associated details have evolved.

Common threads include life cycle rigor, infrastructure and scaling limitations, evolving policy incentives, and the need for sector-specific tailoring. Thematic convergence across these independent studies, which were written by a variety of expert analysts, strengthens their collective argument for a pragmatic, portfolio-based decarbonization approach. An enduring lesson is that there is no single solution. Effective strategy blends policies, fuels, vehicles, and infrastructure in ways tailored to the market and diversity of the fleet.

Additional evaluation of the studies did find occurrences of contradiction or tension across the reports. Most of these could be attributed to three key factors.

1. Unit Versus Market Evaluation: An example of this can be found in looking at the GHG emissions reduction advantage of BEVs relative to ICEVs that was demonstrated in [Life Cycle Analysis Comparison](#) and the conclusion in [Decarbonizing Combustion Vehicles](#), which found that GHG emissions could be greater by using low-carbon biofuels in the existing fleet. On the surface, these may seem like contradictions, but in reality both are accurate. [Life Cycle Analysis Comparison](#) was comparing one vehicle against another and found that on this basis the BEV did deliver superior GHG emissions reduction potential than the ICEV in most scenarios. However, when considering the size of the existing fleet and the time it takes to convert that fleet to a new vehicle technology, leveraging biofuels would deliver greater emissions reductions in the near and medium terms than would waiting for BEVs to gain significant market share. Recognizing the scope and perspective of any analysis is essential to ensure the findings are understood appropriately.



2. Potential Versus Reality: “Decarbonizing Combustion Vehicles” noted that e-fuels, while in their infancy and facing several challenges in the path to maturity, “present an almost ideal way to decarbonize the ICEV fleet.”⁴¹ This statement of potential is encouraging and led to the publication of [E-fuels](#), which explored the viability of e-fuels. That report found that e-fuels’ role in the transportation sector is expected to be limited, largely due to high production costs and competition from biofuels and direct vehicle electrification. This reflects TEI’s ongoing efforts to explore practical and viable market options for reducing transportation emissions and exemplifies the need to dive deep into these options to better understand their real potential.

3. Technology Neutrality Versus Prescriptive Policy: Several reports make the case for life cycle-based, technology-neutral policies, yet [The Case for Developing an ESG Plan](#) emphasizes alignment with climate frameworks like the 26th United Nations Climate Change conference (COP26) and investor expectations, which increasingly assume electrification. This presents a tension between market-led neutrality and top-down prescriptive standards from regulators and financial stakeholders. The lesson in this apparent tension is the disconnect between sustainable market transitions and policy. For example, several governments throughout the world have adopted policies to prohibit the sale of ICEVs by a certain date. This approach assumes there are no other options for achieving emissions reduction objectives, stifles innovation, and sacrifices potential emissions reduction in the near term in favor of assumed greater reductions in the long term. This does not represent a contradiction among TEI reports, but rather a reflection of the broader discourse and debate in the market over how best to reduce emissions.

41 [Decarbonizing Combustion Vehicles](#), 2023, page 162.

TEI believes apparent contradictions such as these serve as evidence of the necessity of taking an expansive approach to evaluating viable options in the market. Sometimes, an initial assessment of an option may yield a conclusion that, upon more careful examination, is not as straightforward as originally thought. Several of the research papers included in this overview were developed in response to findings in prior studies, leading to a more thorough study of various options.

As highlighted in the reports included in this compilation, TEI’s approach to emissions reduction in the transportation sector supports a multifaceted approach that could yield the greatest reduction in emissions in the shortest amount of time at the lowest cost to the market and consumer. Attempting to achieve all these objectives may complicate the approach, but successfully satisfying the priorities of the environment and economy will yield a more sustainable strategy and increase the likelihood of success.



About the Transportation Energy Institute

The Transportation Energy Institute, founded by NACS in 2013, is a 501(c)(4) nonprofit research-oriented think tank dedicated to evaluating the market issues related to vehicles and the fuels that power them. By bringing together diverse stakeholders of the transportation and fuels markets, the Institute helps to identify opportunities and challenges associated with new technologies and to facilitate industry coordination to help ensure that consumers derive the greatest benefit.

The Transportation Energy Institute commissions and publishes comprehensive, fact-based research projects that address the interests of the affected stakeholders. Such publications will help to inform both business owners considering long-term investment decisions and policymakers considering legislation and regulations affecting the market. Research is independent and unbiased, designed to answer questions, not advocate a specific outcome. Participants in the Transportation Energy Institute are dedicated to promoting facts and providing decision makers with the most credible information possible so that the market can deliver the best in vehicle and fueling options to the consumer.

For more about the Transportation Energy Institute visit transportationenergy.org

TRANSPORTATION ENERGY INSTITUTE STAFF

John Eichberger

Executive Director
jeichberger@transportationenergy.org

Jeff Hove

Vice President
jhove@transportationenergy.org

Marjorie Frankel

Director, Marketing and Communications
mfrankel@transportationenergy.org

Liz Menz

Director, Research & Engagement
lmenz@transportationenergy.org

Karl Doenges

Executive Director,
Charging Analytics Program
kdoenges@convenience.org

Meagan Ray

Administrative and Project Manager
mray@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.

©2025 Transportation Energy Institute

Disclaimer: The opinions and views expressed herein do not necessarily state or reflect those of the individuals on the Transportation Energy Institute Board of Directors and the Transportation Energy Institute Board of Advisors or any contributing organization to the Transportation Energy Institute. Transportation Energy Institute makes no warranty, express or implied, nor does it assume any legal liability or responsibility for the use of the report or any product or process described in these materials.



TRANSPORTATION
ENERGY INSTITUTE

(703) 518-7970
TRANSPORTATIONENERGY.ORG
@TEI_INSTITUTE

1600 DUKE STREET
SUITE 700
ALEXANDRIA, VA 22314