RENEWABLE FUELS ASSOCIATION

THE BEST OF BOTH WORLDS:

ENVIRONMENTAL AND ECONOMIC BENEFITS OF A PLUG-IN HYBRID ELECTRIC FLEX FUEL VEHICLE

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THE BEST OF BOTH WORLDS:

Environmental and Economic Benefits of a Plug-in Hybrid Electric Flex Fuel Vehicle

The transportation sector is the single largest source of greenhouse gas (GHG) emissions in the United States, accounting for nearly 30 percent of total emissions.[1] And more than half of all transportation-related GHG emissions come from light-duty vehicles like passenger cars, SUVs, pickups, and minivans.[2] Given the significant contribution of light-duty vehicles to U.S. GHG emissions, federal and state policymakers, auto manufacturers, businesses, and climate-conscious consumers are more focused than ever on reducing the carbon impacts of personal transportation.

Some have decided that a massive and rapid shift to battery electric vehicles (BEVs) is the best—or only—solution for reducing GHG emissions from the automotive fleet. It is true that BEVs often reduce GHG emissions when compared to standard gasoline-powered vehicles. But when the GHG emissions related to electricity generation, mineral extraction and refining, and battery manufacturing are fully considered, BEVs don't always provide meaningful GHG savings compared to liquid-fueled vehicles with internal combustion engines (ICEs).[3] Carbon intensive fossil fuels like coal and natural gas still account for 60 percent of U.S. electricity generation, while wind and solar account for less than 15 percent.[4]

With BEVs, there are other tradeoffs as well. According to recent surveys, consumers are expressing increasing concern about the high cost of new BEVs, the lack of different makes and models, recharging times, lack of access to charging stations, less driving range, and other factors.[5] At the macro level, the environmental, social, and energy security risks associated with critical mineral supplies (needed for BEV batteries) are also a concern raised by some policymakers, business leaders, and consumers.[6]

But what if the positive attributes of a plug-in electric vehicle could be combined with the convenience, affordability, and environmental benefits of an ICE vehicle that runs on low-carbon liquid fuels like ethanol? **In 2023, the Renewable Fuels Association set out to answer that very question by combining battery electric vehicle technology with E85 flex fuel capability to make a plug-in hybrid electric flex fuel vehicle (PHEFFV)**. The goals of our project:

- Use low-carbon liquid fuel, in conjunction with PHEV and FFV technologies, to show that consumers don't need to sacrifice optionality, convenience, or affordability for superior environmental performance;
- Demonstrate that low-carbon ethanol and clean electricity can be complementary decarbonization solutions for light-duty vehicles; and
- Show that combining two low-carbon technologies provides greater flexibility, reliability, and security for American consumers at a low cost.

After a 15-month study, we found some impressive results. When using E85, the PHEFFV delivered:

- Significant reductions in tailpipe emissions of harmful criteria pollutants like particulate matter (PM) and nitrogen oxides (NOx);
- Substantial lifecycle GHG reductions compared to E10 gasoline and BEVs charged on fossil fuel-heavy electric grids;
- No meaningful loss in average fuel economy compared to E10 gasoline; and
- Lower cost of ownership and operation compared to BEVs.

This report summarizes our study's findings regarding the economic and environmental benefits of combining PHEV and FFV technology in one vehicle.

RFA Combines PHEV and FFV Technology to Make the World's First PHEFFV

In January 2023, RFA purchased a new Ford Escape plug-in hybrid electric vehicle. The Escape is a compact crossover SUV with a 2.5-liter iVCT (intelligent variable cam timing) Atkinson cycle inline four-cylinder internal combustion engine. The engine boasts a 13:1 compression ratio and generates 165 horsepower using 87-octane regular gasoline. The vehicle has an 11.1-gallon fuel tank. It also has a 14.4 kWh lithium-ion battery (with an external charging port) and electric-drive motor.

The combined expected average fuel economy of the Escape is rated at 40.0 miles per gallon (mpg) by the Environmental Protection Agency. Accordingly, the expected range of the vehicle with a full fuel tank is roughly 440 miles.

The electric motor powers the vehicle independently from the ICE. With a fully charged battery, the first 35-40 miles of operation are powered by the electric motor. When the battery is low or depleted, the liquid fuel-powered ICE is activated, providing another 420-440 miles of operation. Operation of the ICE also recharges the battery using regenerative braking. When parked, recharging the 14.4 kWh battery takes approximately 10-11 hours using standard 110-volt electricity, or 3-4 hours using a "Level 2" charging system. Refilling the liquid fuel tank takes approximately 3-5 minutes.

The FFV Conversion

RFA worked with the University of Nebraska's Husker Motorsports program to add flex fuel capability to the Ford Escape PHEV. This was accomplished by installing an FFV conversion kit manufactured by eFlexFuel. The kit uses thermal and ethanol/oxygen sensors to adjust fuel injection in real time. The eFlexFuel kit (pictured below) includes just a few major components, along with related wiring, lines, and connectors, and comes in a small box for a retail price of $749. It was installed on the Escape in less than two hours. After installation, the Escape's ICE was now capable of operating on any fuel containing 0 to 85 percent denatured ethanol. More information on the eFlexFuel kit is available as Appendix C.

BEVs, PHEVs, Hybrids, and FFVs: *What's the Difference?*

Battery electric vehicles (BEVs) have an electric motor instead of an internal combustion engine (ICE). The electric motor is powered by a large battery pack, which is charged by plugging in to a wall outlet or special charging equipment.

Plug-in hybrid electric vehicles (PHEVs) have an electric motor powered by a smaller battery pack *and* an ICE powered by a liquid fuel such as gasoline or low-carbon ethanol fuels. Like a BEV, the battery in a PHEV is charged by plugging in to an external charging source. The battery is also recharged by regenerative braking while driving.

Gasoline Hybrids are powered primarily by an ICE, but also use small electric motors for some operations. The battery is charged only through regenerative braking and operation of the ICE. There is no external charging.

Flex fuel vehicles (FFVs) have ICE engines that are capable of operating on gasoline and any blend of denatured ethanol up to 85 percent.

While gasoline hybrid technology and FFV capability have previously been combined, PHEV and FFV technology have never been united in one vehicle. ***Until now.***

Criteria Pollutant Emissions

Criteria pollutant emissions testing of the Escape PHEFFV was conducted at the University of California Riverside's (UCR) **Center for Environmental Research and Technology** in early 2023. A detailed UCR report on the testing is available as Appendix A.

Two test cycles were used: the Federal Test Procedure (FTP) emissions test cycle and the "US06" cycle. As explained by the UCR researchers, the FTP consists of multiple segments, including a cold-start transient phase, a stabilized or hot-running phase, a hot-soak phase with the engine off, and a hot-start transient phase. The FTP test cycle is meant to simulate longer driving trips with more gradual acceleration and deceleration and steadier speeds. Meanwhile, the US06 Supplemental Federal Test Procedure (SFTP) represents more aggressive, high-speed and/or high-acceleration driving behavior, rapid speed fluctuations, and driving behavior following startup.

When using E85, the Ford Escape PHEFFV demonstrated:

48-79 %

reduction in nitrogen oxides (**NOx**)

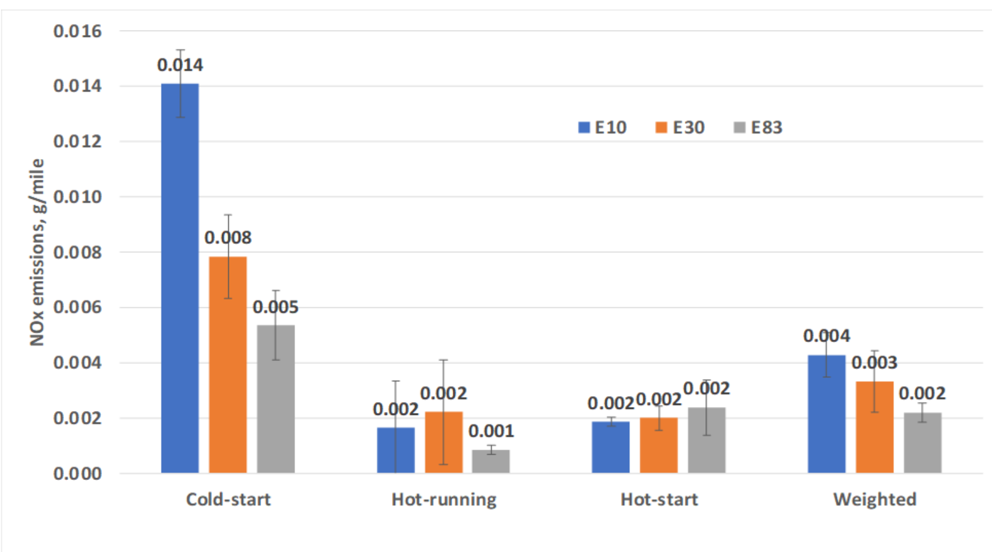
70-76 %

reduction in particulate matter (**PM**)

when compared to operation on E10.

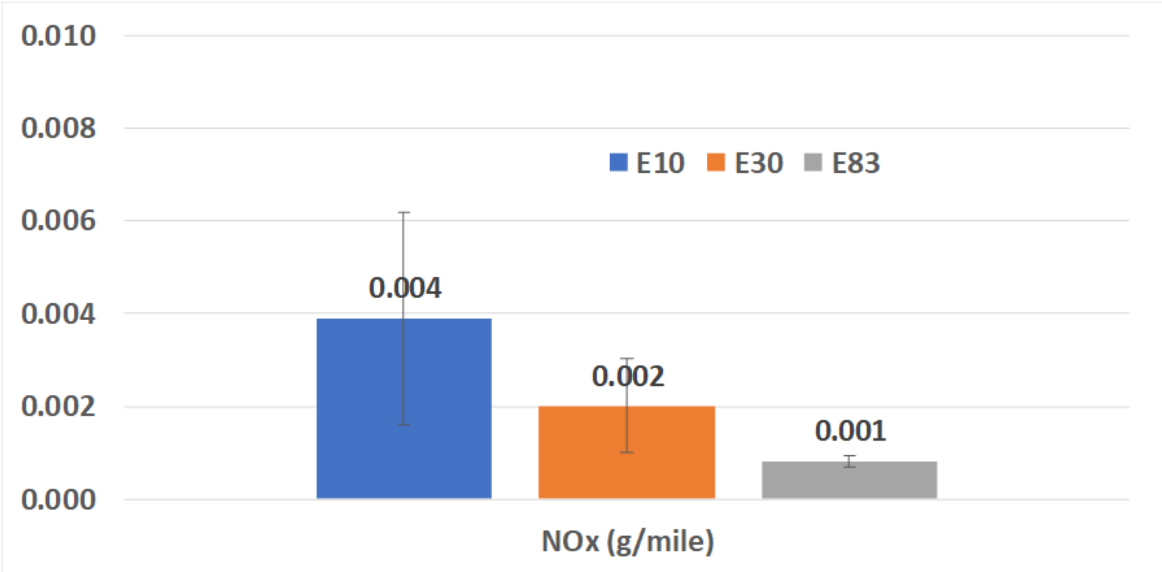
The vehicle was tested three times using the FTP emissions test cycle and three times using US06 cycle on a high-level ethanol blend (E83), a midlevel blend (E30), and regular gasoline (E10). E83 is focused on here since it is similar to the fuel that has predominantly been used in real-world driving of the Escape. Weighted average emissions of nitrogen oxides (NOx) were reduced by 48% using E83 compared to E10 in the FTP cycle (Figure 1) and by 79% in the US06 cycle (Figure 2). Both reductions were statistically significant. The researchers concluded, "Our results indicate that higher ethanol blends will not adversely affect NOx emissions, but rather demonstrate strong reductions."

Figure 1: NOx Emissions by Phase and the Weighted FTP Cycle



Source: University of California, Riverside

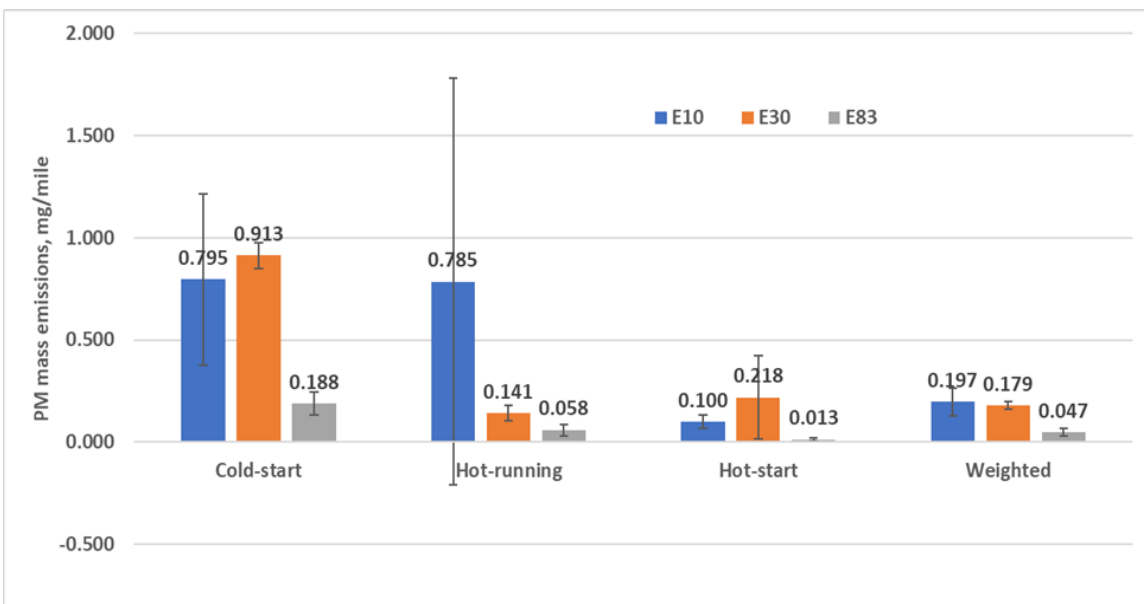
Figure 2: Average NOx Emissions for the US06 Cycle



Source: University of California, Riverside

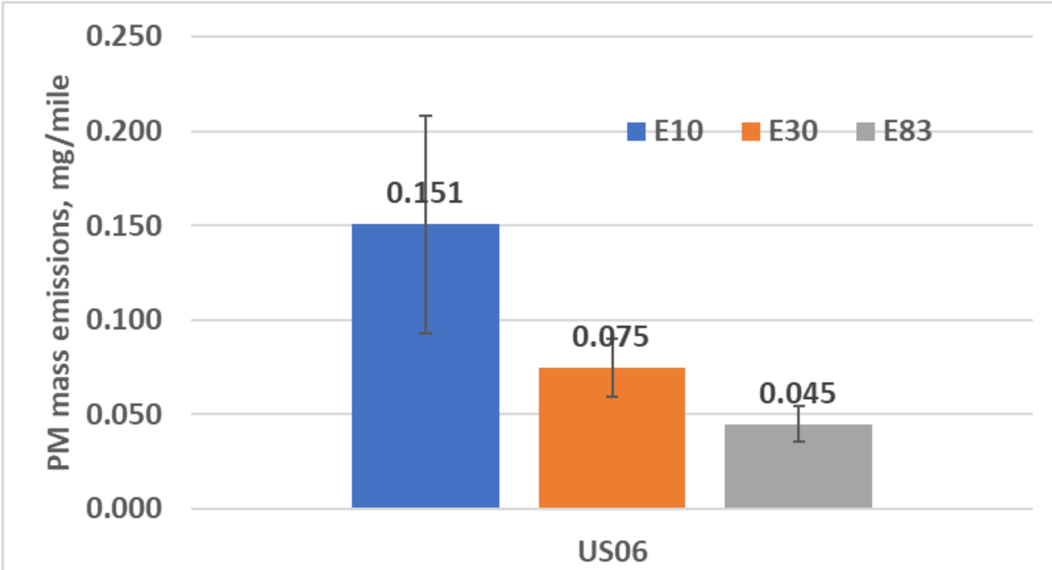
For the FTP cycle, mass emissions of particulate matter (PM) were found to be below the optional California PM mass standard (1 mg/mile) for light-duty gasoline vehicles, and they trended lower as ethanol concentrations increased. Weighted PM mass emissions for E83 were 76% below E10 (Figure 3). For the US06 cycle, there was a 70% decrease in PM mass emissions for E83 compared to E10 (Figure 4). Both were statistically significant.

Figure 3: PM Mass Emissions by Phase and the Weighted FTP Cycle



Source: University of California, Riverside

Figure 4: Average PM Mass Emissions for the US06 Cycle



Source: University of California, Riverside

The UCR testing also found reductions in other important tailpipe pollutants like carbon monoxide and carbon dioxide when the Escape was operating on E85 and E30.

Lifecycle Greenhouse Gas Emissions

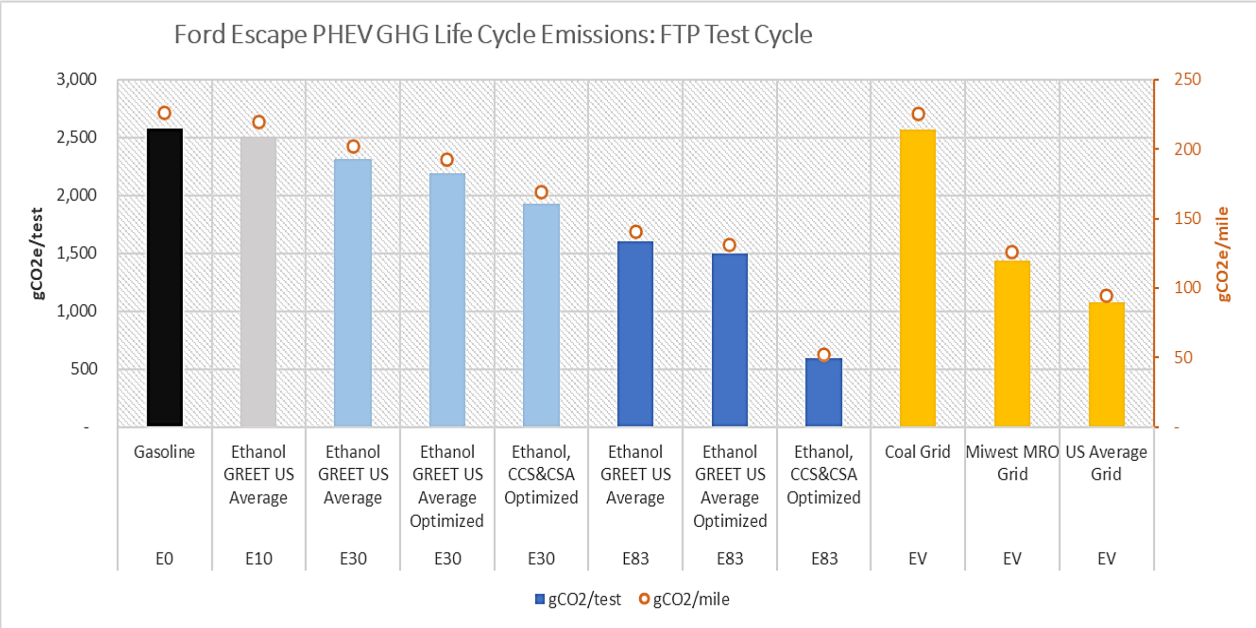
The University of Illinois Chicago and Life Cycle Associates then modeled the lifecycle GHG impacts of the PHEFFV using the Argonne National Laboratory GREET model platform and using the FTP and US06 test cycle data from the UCR study.

A report detailing the lifecycle GHG analysis is attached as Appendix B. The researchers found that using E85 in the Ford Escape PHEFFV offers significant lifecycle GHG benefits.

- Using E85 made from average corn ethanol reduces GHG emissions by 38 percent compared to using ethanol-free gasoline.
- When operating on average E85, the PHEFFV provides similar GHG performance to a BEV charged in the Midwest region.
- The PHEFFV using *any* ethanol blend offers significant GHG savings relative to a BEV charged on a coal-heavy grid, like the mix found in Missouri, Illinois, West Virginia, and elsewhere.
- E85 made from the lowest-carbon ethanol used in an optimized engine (i.e., high-compression ratio like the Ford Escape PHEV; turbo-charging, etc.) provides greater GHG savings than a BEV charged on average U.S. electricity grid.
- The PHEFFV emits approximately 50 grams CO2e/mile when using E85 made from corn ethanol that utilized carbon capture and sequestration (CCS) and climate-smart agriculture practices. This is similar to a BEV operating on the cleanest electricity grids in the United States (like California), and approximately half of the lifecycle emissions associated with a BEV using average U.S. grid electricity.

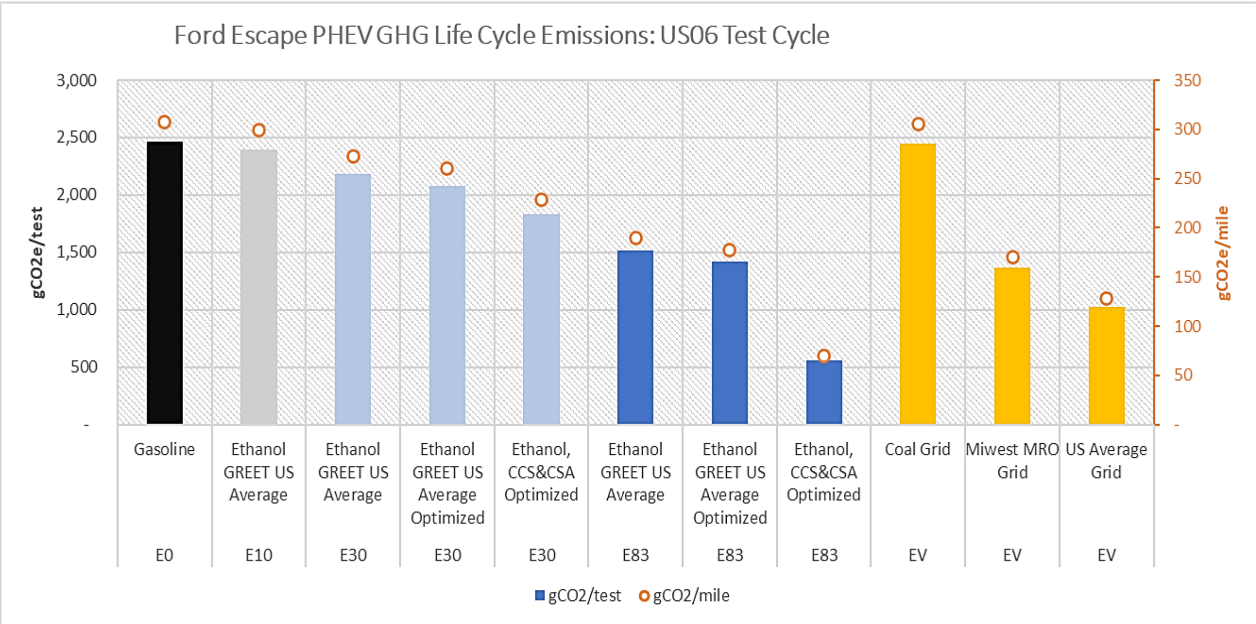
The researchers concluded that the "Ford Escape PHEFFV is a very low emitting car," pointing out that the vehicle's emissions even when running on E10 are considerably lower than the EPA estimate for an average passenger vehicle.

Figure 5: Lifecycle GHG Emissions, Based on the FTP Test for Ethanol Blends



Source: University of Illinois Chicago and Life Cycle Associates

Figure 6: Lifecycle GHG Emissions, Based on the US06 Test for Ethanol Blends



Source: University of Illinois Chicago and Life Cycle Associates

Real-World Fuel Economy

The new Ford Escape PHEV (i.e., prior to the FFV) conversion was rated by EPA to achieve 40.0 miles per gallon of fuel (assuming 87-octane E10). Since installing the FFV conversion kit on the vehicle, RFA has accumulated 33,736 miles of real-world driving miles in a wide variety of driving conditions (i.e., all seasons, high and low temperatures, long trips/short trips, high elevation/low elevation, high traffic/low traffic, etc.). The liquid fuel used for 98 percent of these miles was E85 flex fuel, while E15 was used for 1 percent of the total miles, and E10 was used for the remaining 1 percent. The average speed of the vehicle over 33,736 miles has been 50.8 miles per hour, reflecting a mix of long-trip highway driving and short-trip city driving.

Of total miles, the electric motor powered 8,538 miles, or 25 percent. This includes miles powered by both regenerative braking (i.e., while the ICE is running on E85) and the charged battery.

Ford Escape PHEFFV Fuel Economy

EPA Estimated: 40.0 mpg when operating on 87-octane E10

Real World: 39.4 mpg when operating on high-octane E85 flex fuel

E85 vs. E10: 1.5 % difference

According to information from the vehicle's onboard computer (Figure 7), real-world fuel economy has averaged 39.4 miles per gallon—just 1.5 percent lower than the EPA/NHTSA estimate. Thus, even though the energy density of E85 per volumetric gallon is generally 20 percent lower than E10, the Escape PHEFFV has not experienced any meaningful difference in fuel economy. It is likely that the Escape's 13:1 compression ratio and Atkinson cycle technology enable the ICE to best take advantage of the high-octane and charge-cooling properties of E85 flex fuel. Extensive research conducted by automakers, the Department of Energy, and other entities has shown that high-octane fuels in optimized ICEs (i.e., high-compression ratio, turbo-charged, downsized, downsped, etc.) can deliver superior fuel efficiency and that the traditional impact of ethanol's lower energy density on fuel economy can be partially or completely overcome.[7]

Figure 7: Ford Escape PHEFFV Onboard Computer/Odometer Information

Cost of Ownership and Operation

Compared to a similarly sized BEV crossover SUV with similar options, the Ford Escape PHEFFV offers a lower cost of ownership and operation.

Purchase Price

The 2022 Escape PHEV (prior to FFV conversion) was purchased new for **$39,685**. At the time of purchase, BEVs in the same vehicle class (compact crossover SUV) were generally 20-25 percent more expensive. The 2022 Volkswagen ID.4, for example, had an average retail price of **$47,795** at the time the Escape was purchased (an extra $8,100, or 20 percent). Notably, the advertised range of the Volkswagen ID.4 on a fully charged battery (82kWh) was 245 miles, compared to more than 440 miles for the Escape PHEFFV.

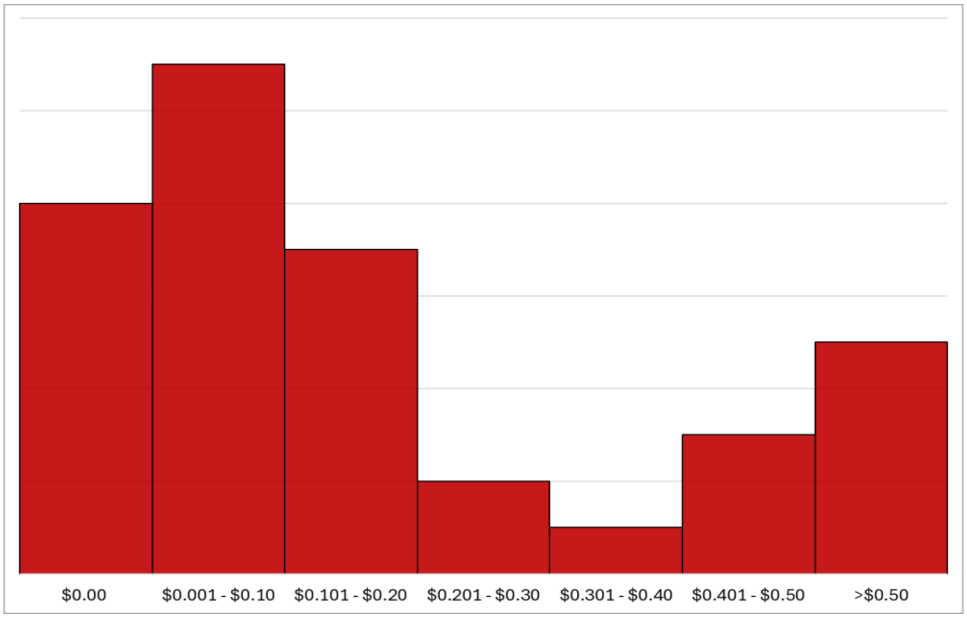
Fuel Cost per Mile

During the period of this study (i.e., nearly 34,000 miles driven), the Escape PHEFFV has been plugged into a public charger 40 times. Public charging costs have averaged $0.34 per mile across all trips the vehicle has taken, even when occasional free charging is factored in. The cost of charging has been highly variable: approximately one in five charges has been free, but nearly as many have had a cost equivalent to $0.50 or more per mile (Figure 8). Residential ("at-home") charging has averaged approximately $0.07 per mile and generally ranged from $0.05-0.09 per mile. Thus, even if 70 percent of charging is assumed to occur at home, the overall average cost when operating on electricity would be about $0.15 per mile.

Meanwhile, use of E85 in the Escape PHEFFV has resulted in an average cost of just $0.07 per mile. Even though 98 percent of the vehicle miles traveled have been powered by E85, simply using E10 would have also resulted in a lower fuel cost per mile. The average observed cost of E10 at stations where E85 was purchased for the vehicle has been equivalent to just over $0.08 per mile, which would have been more affordable than public charging.

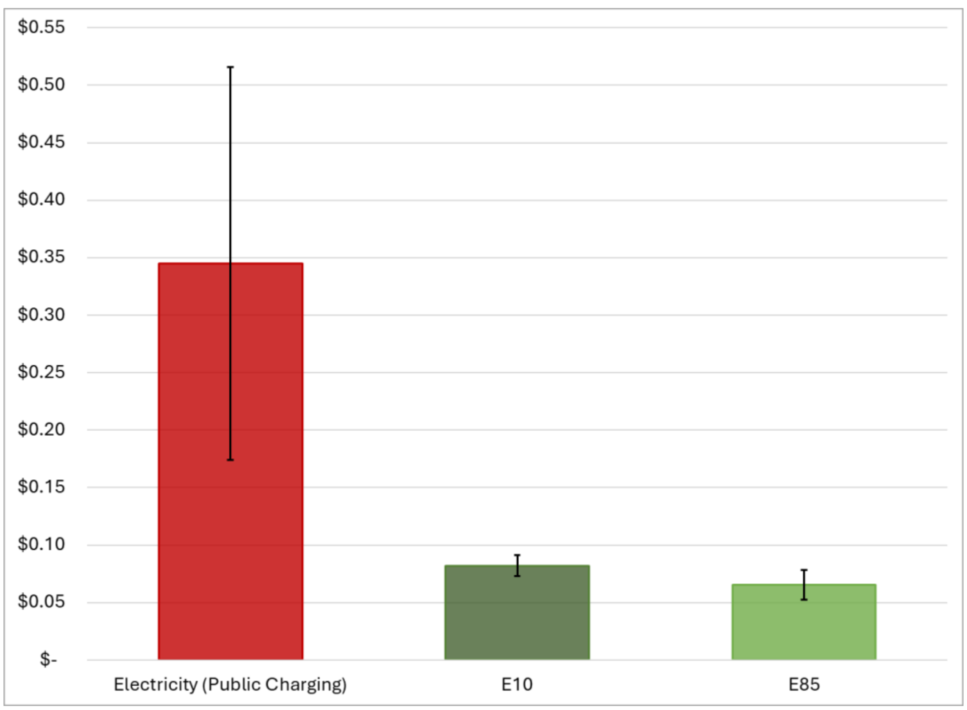
Currently, E85 sells at an average discount of 23 percent to regular (E10) gasoline prices nationally. The affordability of liquid fuels—particularly E85—and the superior fuel economy of the high-compression ratio ICE both contribute to the low fuel cost per mile of the Escape PHEFFV. Moreover, the cost of liquid fuels has been far less variable than that of charging (Figure 9).

Figure 8: Distribution of Public Charging Costs per Mile



Source: RFA

Figure 9: Cost per Mile, by Energy Source



Source: RFA

Note: Error bars represent the interquartile range

Other Ownership Cost Considerations

As noted earlier, the eFlexFuel FFV conversion kit installed on the Escape sells for $749. However, U.S. automakers have stated that adding E85 flex fuel compatibility on the assembly line adds just $70 or less to the production cost of the vehicle.[8]

Meanwhile, for BEV owners that wish to install "Level 2" (240 volt) charging capability at home to expedite the recharging process, J.D. Power reports that they should "be ready to spend anywhere from $1,200 to $2,500."[9] In addition, the National Association of Insurance Commissioners (NAIC) reports that BEVs cost up to $528 per year ($44 per month) more to insure than ICE vehicles.[10]

Reliable data on routine maintenance costs for BEVs compared to PHEV and ICE vehicles is difficult to find and comparisons are not always made on an apples-to-apples basis. While it is true that BEV owners avoid costs for certain maintenance activities (like regular oil changes), BEVs generally experience significantly increased tire wear (and more frequent replacement), more frequent software updates and electrical system maintenance, and battery care and maintenance issues.

Accelerated depreciation and inferior resale values are also concerns raised by EV owners, with prices for used EVs falling 32 percent over the past year (compared to 4 percent for used ICE vehicles).[11] Studies show that EVs generally lose value 6-10 times faster than ICE vehicles.

Conclusions

Reducing GHG emissions and tailpipe pollutants from the light-duty vehicles is a top priority for U.S. policymakers, businesses, and consumers. While some have suggested a massive and immediate shift to BEVs is the best solution for decarbonizing personal transportation, other solutions—like low-carbon ethanol blends—offer enormous potential to achieve meaningful GHG reductions in both the near term and the long term. The Renewable Fuels Association sought to demonstrate that pairing plug-in hybrid electric vehicle (PHEV) technology with ethanol flex fuel vehicle (FFV) technology offers an invaluable opportunity to reduce transportation-related GHG emissions without sacrificing consumer convenience, affordability, and optionality.

RFA purchased a 2022 Ford Escape PHEV and immediately added flex fuel capability using a commercially available conversion kit. Over the course of a 15-month study in which nearly 34,000 miles were driven, the Ford Escape PHEFFV operating on E85 flex fuel demonstrated:

- Reductions in lifecycle GHG emissions that rival, or outperform, the GHG reductions achievable with many BEVs;
- Substantial reductions (when compared to gasoline-powered vehicles) in emissions of harmful tailpipe pollutants like nitrogen oxides (NOx), particulate matter (PM), and carbon monoxide (CO);
- Lower cost of ownership and operation (purchase price, fuel cost per mile) than a similar BEV; and
- No meaningful loss in fuel economy, with the Escape experiencing just a 1.5 percent reduction in miles-per-gallon compared to the EPA estimated rate using E10.

Combining plug-in technology and flex fuel capability makes this vehicle the most adaptable and flexible in the world. It can be refueled with any fuel (electricity, ethanol-free gasoline, E10, E15, mid-level blends, E85) at any time, offering optimal convenience and affordability to the consumer. The PHEFFV overcomes many of the barriers to BEV adoption commonly cited by consumers, including limited driving range, high purchase price, reliability, and lack of refueling (recharging) infrastructure.

Given RFA's positive experience with the Ford Escape PHEFFV, it is not surprising to us that automakers are slowing or softening their BEV ambitions and turning back to plug-in hybrids and gasoline hybrids as a more practical solution. As they refocus on hybrid technology, automakers should also prioritize flex fuel technology and other low-carbon liquid fuel strategies.

Recommendations

RFA's 15-month study of the economic and environmental benefits of a plug-in hybrid electric flex fuel vehicle resulted in a number of important insights and findings. The lessons learned from this study should be used to instruct future policy, regulatory, and research developments. Specifically, RFA offers the following recommendations:

- Federal and state agencies should adopt full "well-to-wheels" (WTW) lifecycle analysis to assess the GHG emissions impacts of various fuel and vehicle combinations. Agencies should abandon biased and unscientific approaches that consider only one narrow phase of the fuel and vehicle lifecycle (e.g., looking only at tailpipe emissions).
- Federal and state regulatory requirements, incentives, tax credits, and subsidies aimed at decarbonizing light-duty vehicles should be applied equitably and based on full WTW lifecycle emission reductions. For example, incentives and compliance credits under federal tailpipe emissions and fuel economy standards should be determined based on the full WTW lifecycle of fuel and vehicle combinations, including consideration of electricity generation sources and emissions related to battery mineral extraction and refining.
- Federal and state regulatory agencies should streamline and simplify regulations regarding the certification of flex fuel conversion kits.
- Automakers should refocus on offering ethanol flex fuel compatibility in a broad range of PHEV and gasoline hybrid makes and models. Federal policymakers should consider incentives to stimulate increased FFV production.
- Automakers, auto industry research cooperatives, and government laboratories should conduct technical research and analysis on the costs and benefits of marrying plug-in hybrid technology with ethanol flex fuel technology on a broad array of vehicle and engine platforms.
- Automakers, auto industry research cooperatives, and government laboratories should conduct additional research to demonstrate and quantify the efficiency and synergies of using high-octane fuels like E30 and E85 flex fuel in optimized engines.

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Colorado Corn Promotion Council; Corn Marketing Program of Michigan; eFlexFuel; Illinois Corn Marketing Board; Indiana Corn Marketing Council; Iowa Corn Promotion Board; Kansas Corn Commission; Minnesota Corn Research & Promotion Council; Missouri Corn Merchandising Council; National Corn Growers Association; Nebraska Ethanol Board; North Dakota Corn Utilization Council; Ohio Corn Checkoff; Pearson Fuels; Renew Kansas; Renewable Fuels Nebraska; South Dakota Corn Utilization Council.

End Notes

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APPENDIX A

Report Summarizing Criteria Pollutant Emissions Testing of 2022 Ford Escape Plug-in Hybrid Electric Flex Fuel Vehicle (PHEFFV)

University of California, Riverside
College of Engineering – Center for Environmental Research and Technology (CE-CERT)

Final Report

Prepared for:

Renewable Fuels Association (RFA)

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1 Introduction

For this program, gaseous and particulate emissions were measured from a light-duty vehicle when operated with an E10 California Reformulated Gasoline and two splash blends of E30 and E83 fuels over triplicate FTP and US06 cycles. Measurements included regulated emissions, fuel economy, PM mass, and emissions of benzene, toluene, ethylbenzene, xylene isomers, 1,3-butadiene, ethanol, and carbonyl compounds.

2 Experimental Procedures

2.1 Test Fuels

Three different fuels were used in this study. The baseline summer-grade E10 fuel (ethanol 10% by volume) was a California Reformulated Gasoline. The summer-grade E10 fuel was sourced from four (4) different refineries that were selected by CARB. Three refineries were in the South Coast Air Basin (SCAB) and one refinery was in the Northern California (Bay Area). The SCAB refineries included PBF Energy (Los Angeles), Phillips 66 (Los Angeles), and Marathon (Wilmington). The Bay Area refinery was Chevron (Richmond). The E10 fuels from all four refineries were collected by C3 Fuels. The E10 fuels were blended together in four equal parts by C3 Fuels to create the final E10 fuel.

The E30 and E83 fuels were created by splash blending denatured ASTM D4806 fuel grade ethanol with the final E10 fuel. Blending took place at C3 Fuels facility. Denatured ethanol (E98) was supplied in-kind by the ethanol industry. Table 2-1 lists the fuel properties and test methods for E10, E30, and E83 fuels.

Table 2-1. Averaged Main Physicochemical Properties of E10 and E15

Property	Test Method	Unit	E10	E30	E83
RVP (EPA Equation)	D5191	psi	7.43	7.01	4.98
DVPE (ASTM Equation)		psi	7.30	6.88	4.83
CARVP (California Equation)		psi	7.19		
Research Octane Number	D2699Mdp	ON	91.13	99.7	107.6
Motor Octane Number	D2700Mdp	ON	83.53	88	89.8
API Gravity	D4052		59.15	56.20	48.78
Specific Gravity			0.74	0.7538	0.7849
Density at 15C		g/ml	0.74	0.7536	0.7847
Heat of Combustion, Gross	D4809	BTU/lb	19264.33		
		MJ/kg	44.81		
		cal/g	10702.50		
Heat of Combustion, Net		BTU/lb	17982.00		
		MJ/kg	41.83		
		cal/g	9990.30		

Methanol	D4815	Vol%	<0.2	0.17	0.05
Ethanol		Vol%	9.66	29.95	82.60
Isopropanol		Vol%	<0.2		
tert-Butanol		Vol%	<0.2		
n-Propanol		Vol%	<0.2		
Methyl tert-butyl ether		Vol%	<0.2		
sec-Butanol		Vol%	<0.2		
Diisopropylether		Vol%	<0.2		
Isobutanol		Vol%	<0.2		
Ethyl tert-butylether		Vol%	<0.2		
tert-Pentanol		Vol%	<0.2		
n-Butanol		Vol%	<0.2		
tert-amyl methyl ether		Vol%	<0.2		
Total Oxygen		Wt%	3.59	11.12	
Carbon	D5291 CH	wt%	82.80	75.1	56.74
Hydrogen		wt%	14.05	13.58	13.14
Sulfur	D5453	ppm	6.25	3.66	1.27
Benzene	D5580	Vol%	0.60	0.47	
Toluene		Vol%	4.04	3.13	
Ethylbenzene		Vol%	0.94	0.81	
p,m-Xylene		Vol%	3.85	3.07	
o-Xylene		Vol%	1.36	1.07	
C9 plus Aromatics		Vol%	8.74	6.9	
Total Aromatics		Vol%	19.53	15.46	
Olefin	D6550	Mass %	5.03	4.36	
Distillation	D86				
IBP		deg F	101.63	108.8	133.6
5%		degF	129.53	135.2	161.0
10%		degF	135.33	141.4	165.4
15%		degF	139.07	145.5	167.7
20%		degF	142.70	149.4	169.2
30%		degF	149.20	155.6	170.8
40%		degF	157.27	160.3	171.7
50%		degF	204.50	163.8	172.1
60%		degF	228.07	166.5	172.4
70%		degF	248.70	169.2	172.7
80%		degF	275.20	255.8	173.0
90%		degF	313.63	302.0	173.4
95%		degF	342.07	333.6	174.1
Final Boiling Point		degF	394.07	388.9	-1.0
Recovered		mL	99.07	98.7	97.8

Residue		mL	0.70	0.8	1.0
Loss		mL	0.23	0.5	1.2
Particulate Matter Index			1.15	1.09	

2.2 Test Vehicle

The test vehicle used for the emissions testing was provided to UCR's CE-CERT by RFA. The vehicle was a 2022 model year Ford Escape SEL plug-in hybrid equipped with a naturally aspirated sequential multi-port fuel injection (SFI) engine. The main technical specifications are provided in Table 2-4.

Table 2-2. Vehicle specifications

Year/Make/Model	2022/Ford/Escape SEL Plug-in hybrid
Vehicle class (EPA)	LDT2
Odometer (miles)	3060
Engine size (L)	2.5
Fuel injection type	SFI
Max power (hp@rpm)	165@6250
Max torque (Nm@rpm)	155@4000
Air system	Naturally aspirated
Number of cylinders	4 (inline)
Engine compression ratio	13.0:1
Emissions standard	USEPA: T3B30 CA: SULEV30
Aftertreatment systems	TWC, WR-HO2S, HO2S, EGR, EGRC

2.3 Test Sequence, Randomization, and Fuel Conditioning

The vehicle was tested three times using the Federal Test Procedure (FTP) emissions test cycle and three times using US06 cycle on each fuel. The entire FTP consists of three segments, including a cold-start transient phase (0-505 s), a stabilized or hot-running phase (506-1372 s), a hot-soak phase with the engine off (9-10 min), and a hot-start transient phase (0-505 s). The FTP has a duration of 1877 s, total distance of 11.04 miles, an average speed of 21.2 mph, and a maximum speed of 56.7 mph. The FTP test cycle is shown in Figure 2-1.

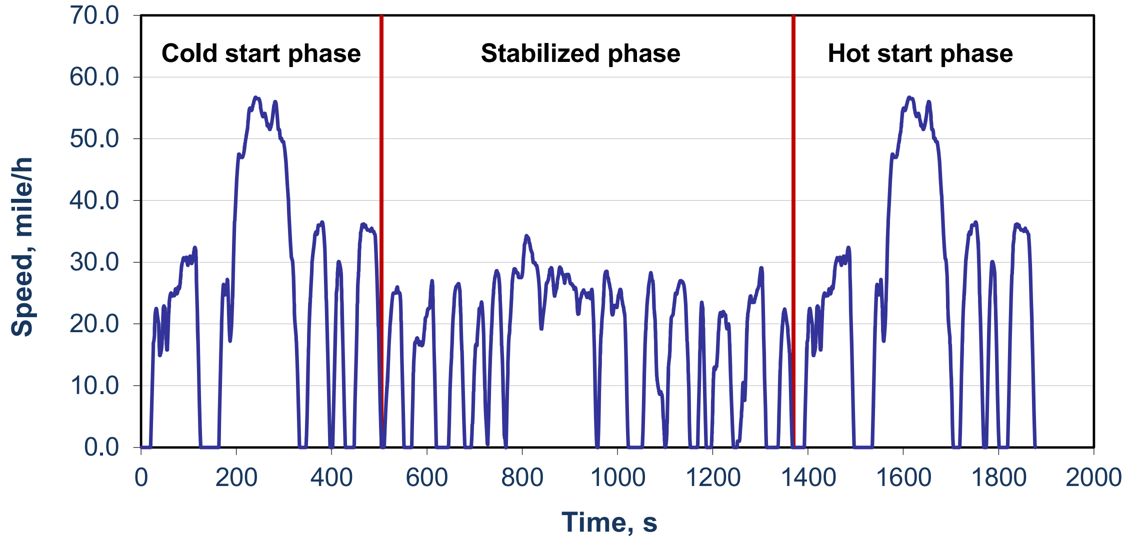


Figure 2-1. FTP cycle

The US06 Supplemental Federal Test Procedure (SFTP) was developed to address the shortcomings with the FTP-75 test cycle in the representation of aggressive, high speed and/or high acceleration driving behavior, rapid speed fluctuations, and driving behavior following startup. The cycle represents an 8.01-mile (12.8 km) route with an average speed of 48.4 miles/h (77.9 km/h), maximum speed 80.3 miles/h (129.2 km/h), and a duration of 596 seconds. The US06 test cycle is shown in Figure 2-2.

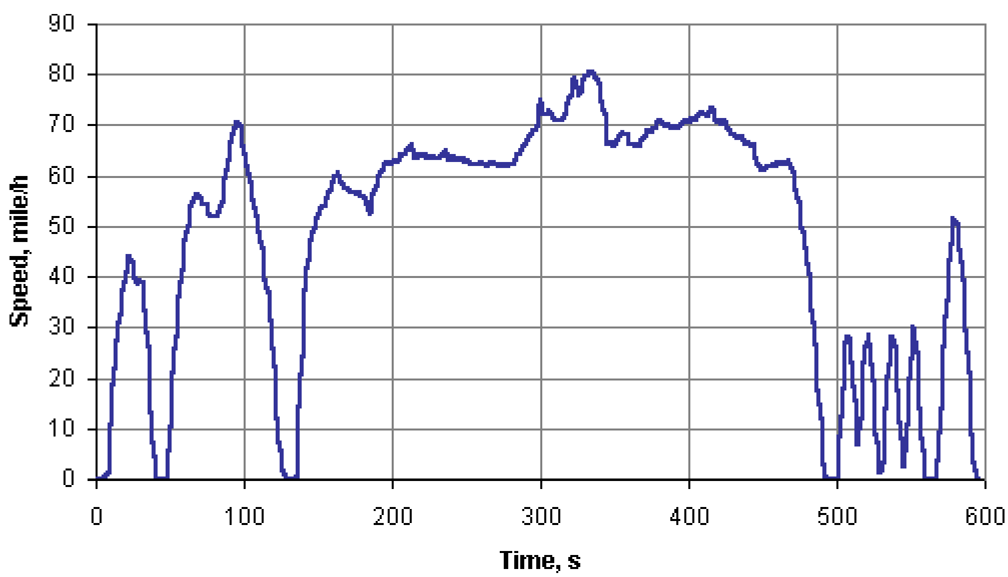


Figure 2-2. US06 cycle

2.5 Emissions Testing

Vehicle emissions measurements were conducted in CE-CERT's new state-of-the-art Light-Duty Laboratory (LDL). The centerpiece of this laboratory is a new AVL CVS AMA SL (Slim Line) system of the i60 generation using AVL's iGEM test cell automation and with an AVL dilution tunnel. The AVL CVS SL system was used to obtain standard bag measurements for THC, CO, NOx, NMHC, CH4, and CO2. The AVL CVS AMA SL system includes a flame ionization detection (FID) for THC and NMHC emissions, methane cutter (Cutter FID SL) for CH4 emissions, a chemiluminescence analyzer for NOx emissions, and a non-dispersive infrared (NDIR) analyzer for CO and CO2 emissions. All gaseous emissions were determined according to the U.S. EPA protocols for light-duty emission testing as given in the CFR, Title 40, Part 86. The LDL utilized a 48-inch Burke E. Porter single-roll electric chassis dynamometer, capable of testing vehicles weighing up to 12,000 lbs.

Fuel economy was determined using the carbon balance method, as discussed later in the report.

A schematic of the experimental setup is shown in Figure 2-3.

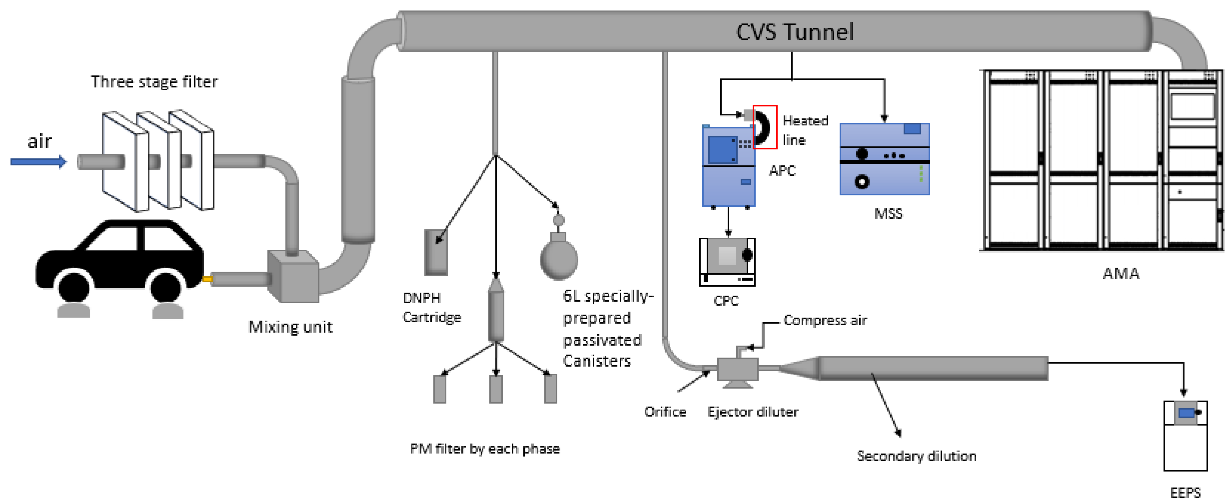


Figure 2-3. Schematic of Experimental Setup

For the FTP cycle, gravimetric PM mass samples were collected for each of the three individual phases of the FTP (i.e., cold-start, hot-running, and hot-start) and weighted PM mass over the FTP cycle were calculated based on PM mass data from each phase of the FTP. For the US06 cycle, only one filter was used to collect PM mass samples throughout the entire duration of the US06 cycle. Samples were flow-weighted based on CE-CERT's new sampling system that was built following the procedures in 40 CFR 1066 and associated references in 40 CFR Part 1065. PM samples were collected on 47 mm diameter 2 µm pore Teflon filters (Whatman brand) with flow-weighting MFCs and weighed with a 1065-compliant ultra-precision microbalance in a temperature and humidity controlled clean chamber. Buoyancy corrections for barometric pressure differences will also be made for the PM filter weights as per CFR 1065.

PM mass emissions were reported after background corrections. For this program, two (2) filter tunnel blanks were collected over the FTP and US06 cycles. The first tunnel blank was collected before the start of the testing campaign and the second was collected at the end of the testing campaign. The tunnel blank tests were performed just like regular FTP and US06 tests, except the exhaust sample line was collecting ambient air. Three filters were used to sample each phase of the FTP during the six tunnel blank tests and one filter was used to sample US06 during the two tunnel blank tests.

Carbonyl compounds (aldehydes and ketones) were measured in triplicate only for the FTP. Carbonyls were sampled on 2,4-dinitrophenylhydrazine (DNPH) coated silica cartridges (Waters Corp., Milford, MA) from the main CVS tunnel using a mass flow controller to regulate the flow to 1 L/min through the cartridge. The DNPH cartridges were eluted with 2 mL of acetonitrile and analyzed with a high-performance liquid chromatography, HPLC, (Waters 2690 Alliance System with 996 Photodiode Array Detector) following the US EPA TO-11A method. One cumulative sample was collected throughout the entire FTP cycle.

Speciated hydrocarbons were measured in triplicate only for the FTP. Hydrocarbon species were collected using a 6 L specially prepared SUMMA passivated canister, which will be connected to the CVS system. Analysis of the hydrocarbon species was conducted using a Gas Chromatography/Mass Spectrometry/Flame Ionization Detector (GC/MS/FID) analytical system according to the EPA TO-12/PAMS method and the EPA TO-15A. One cumulative sample was collected over the entire FTP cycle. Table 2-5 provides a list of species analyzed for this program.

Tunnel blanks for the carbonyl compounds and hydrocarbon species were obtained for both the FTP and US06 cycles.

Table 2-3. Hydrocarbon species analysis method

Ethylene Acetylene Ethane Propylene Propane Isobutane 1-Butene 1,3-Butadiene n-Butane trans-2-Butene cis-2-Butene Isopentane 1-Pentene n-Pentane Isoprene trans-2-Pentene cis-2-Pentene 2,2-Dimethylbutane Cyclopentane 2,3-Dimethylbutane 2-Methylpentane 3-Methylpentane	EPA TO-12/PAMS

1-Hexene n-Hexane Methylcyclopentane 2,4-Dimethylpentane Benzene Cyclohexane 2-Methylhexane 2,3-Dimethylpentane 3-Methylhexane 2,2,4-Trimethylpentane n-Heptane Methylcyclohexane 2,3,4-Trimethylpentane Toluene 2-Methylheptane 3-Methylheptane n-Octane Ethylbenzene m/p-Xylenes Styrene o-Xylene Nonane Isopropylbenzene n-Propylbenzene m-Ethyltoluene p-Ethyltoluene 1,3,5-Trimethylbenzene o-Ethyltoluene 1,2,4-Trimethylbenzene n-Decane 1,2,3-Trimethylbenzene m-Diethylbenzene p-Diethylbenzene n-Undecane n-Dodecane	
ethanol naphthalene	EPA TO-15A

3 Emissions Testing Results

This section outlines the experimental results of this program and discuss their statistical significance. Emissions of interest are NOx, CO, THC, NMHC, CH_4, CO_2, solid particle number, particle size distribution, black carbon, formaldehyde, acetaldehyde, 1,3-butadiene, benzene, toluene, ethylbenzene, m/p-xylenes, and o-xylene.

The weighted FTP and US06 emission results for the testing on the testing vehicle are presented in the figures in this section. The results for each test cycle/fuel combination represent the average of all test runs done on that combination. The error bars represent the standard deviation over the triplicate tests for each fuel. This same format is used for the figures throughout this section. The individual emissions test results for the testing vehicle are provided in Appendix A.

Statistical analysis was performed using a simple 2 tailed t-test p value for the comparison between fuels on each pollutant. For the statistical analyses, results are statistically significant for $p \leq 0.05$ or marginally statistically significant for $0.05 < p \leq 0.1$ for this discussion.

3.1 THC, NMHC and CH_4 Emissions

Figure 3-1, Figure 3-2, and Figure 3-3 show the weighted THC, NMHC, and CH_4 emissions, respectively, over the FTP cycle. THC and NMHC emissions showed strong increases with E30 and E83 fuels compared to E10. For the FTP cycle, the weighted THC emissions for E30 and E83 fuels showed a marginally statistically significant increase of 66% and a statistically significant increase of 381%, respectively, compared to E10. Similarly, the weighted NMHC emissions for E30 and E83 showed a marginally statistically significant increase of 53% and a statistically significant increase of 250%, respectively, compared to E10. CH4 emissions also showed large, statistically significant increases for E30 and E83 fuels compared to E10.

For the US06 cycle, THC and NMHC emissions were found in very low concentrations. The only statistically significant difference in NMHC emissions was seen between E10 and E83. CH_4 emissions were below the detection limits for E10 and E30 fuels over the US06.

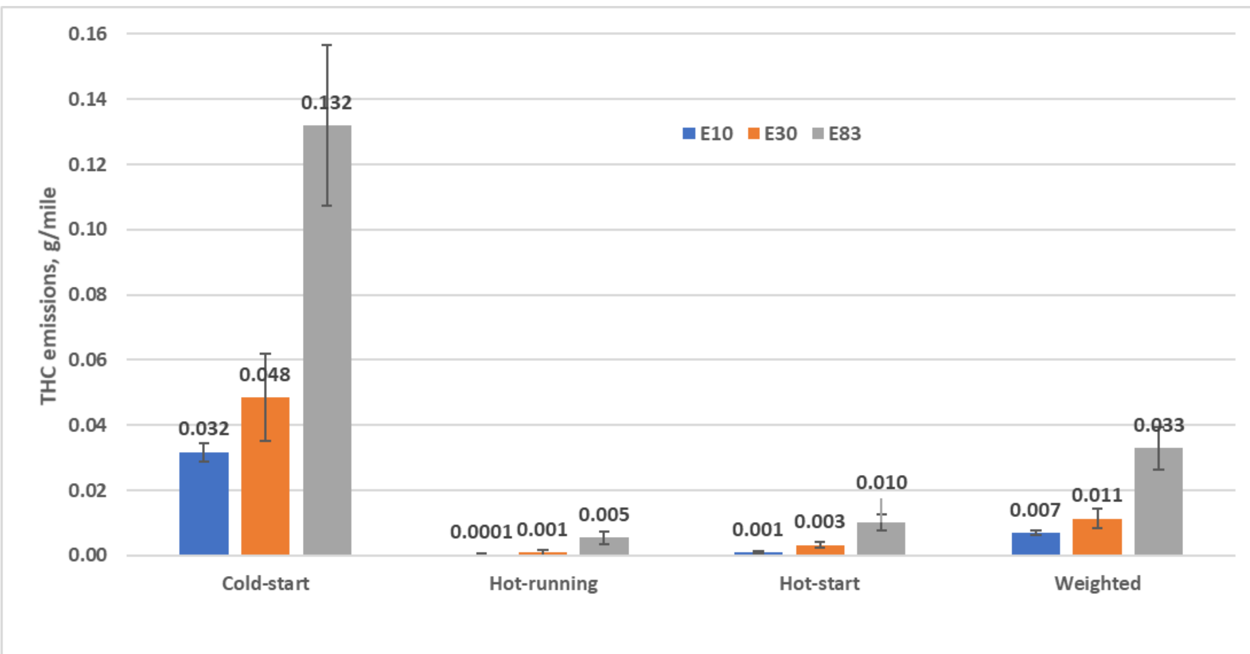


Figure 3-1. THC emissions by phase and the weighted FTP cycle

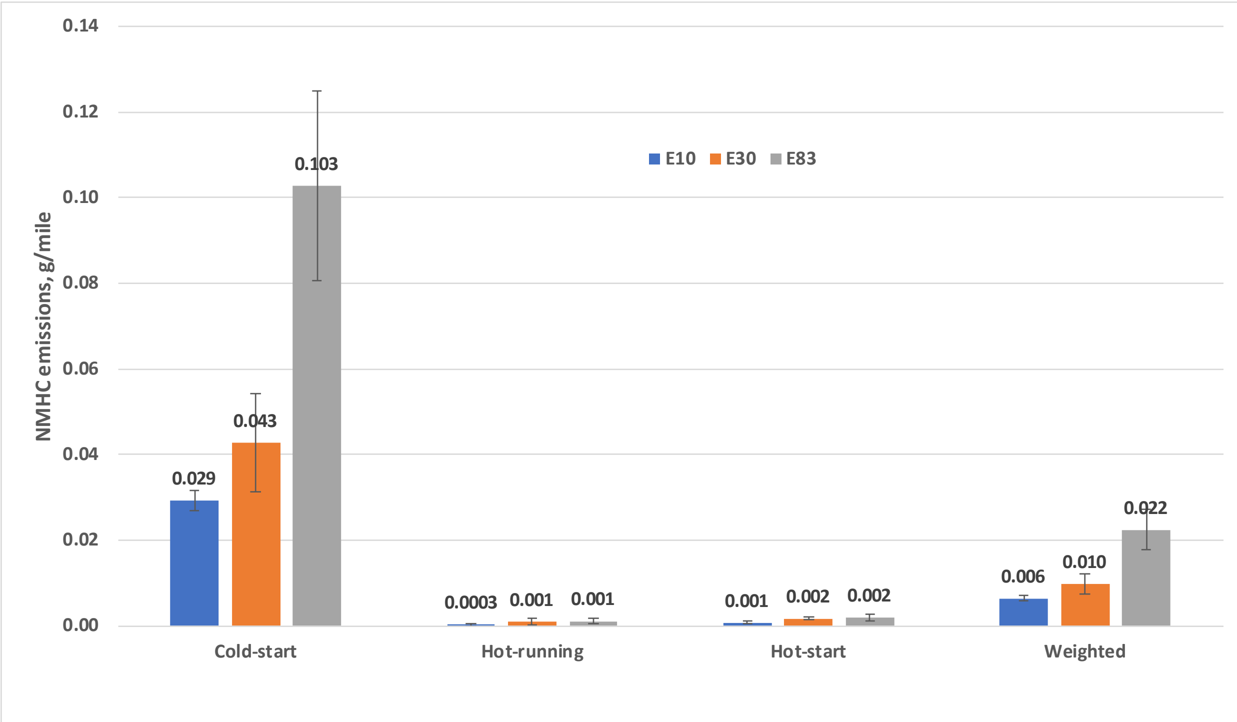


Figure 3-2. NMHC emissions by phase and the weighted FTP cycle

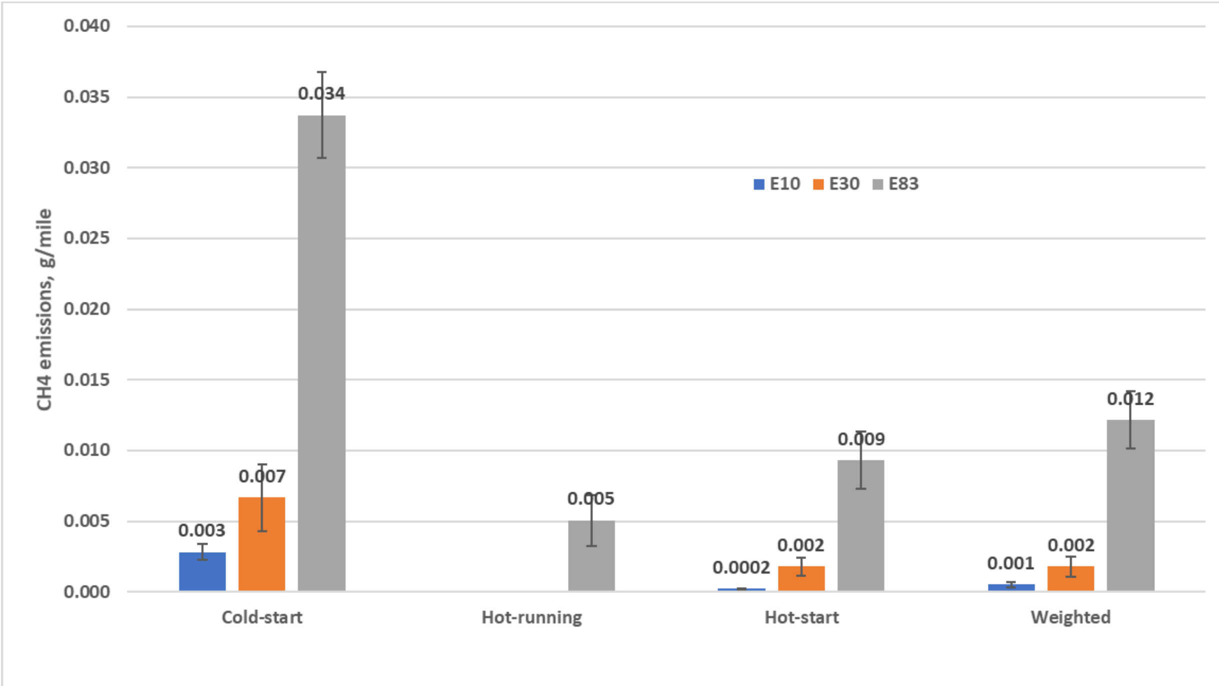


Figure 3-3. CH_4 emissions by phase and the weighted FTP cycle

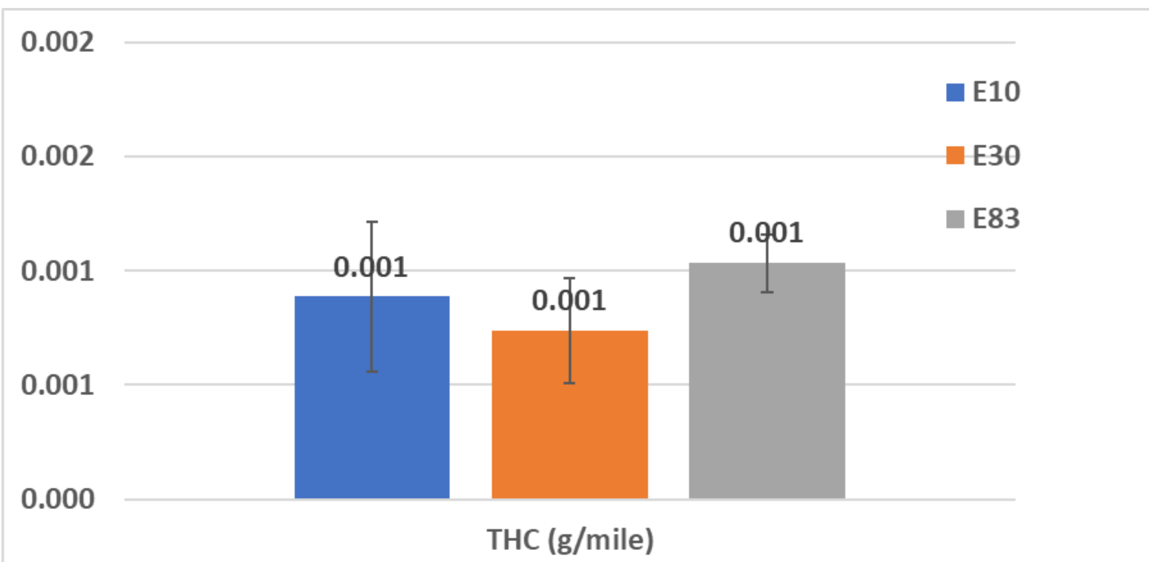


Figure 3-4. Average THC emission results for the US06 cycle

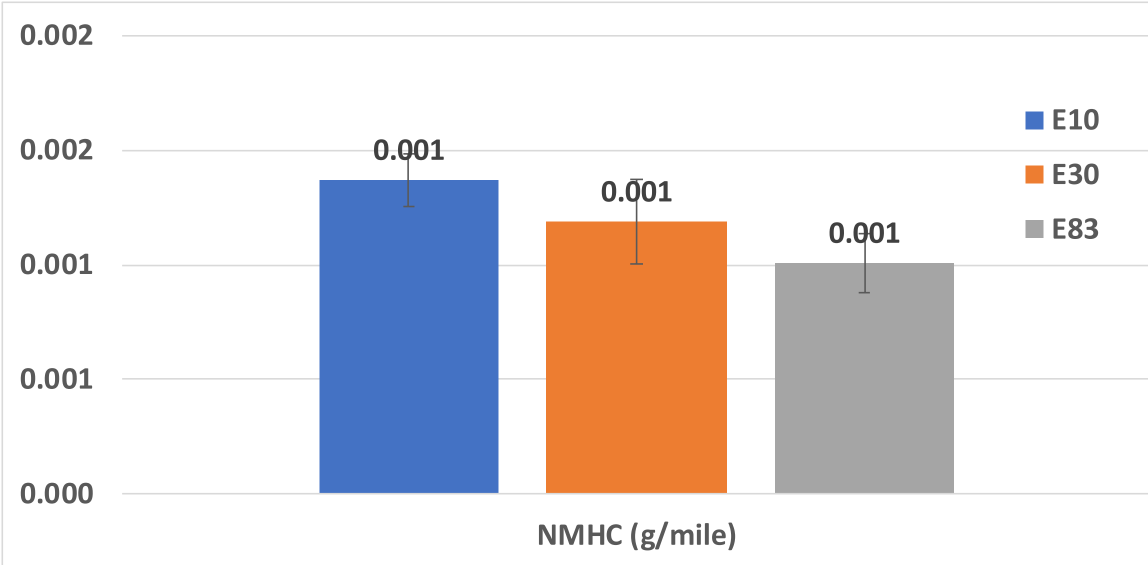


Figure 3-5. Average NMHC emission results for the US06 cycle

3.2 CO Emissions

Figure 3-6 and Figure 3-7 show the CO emissions for the FTP and US06 cycles, respectively. CO emissions with the use of E30 and E83 fuels trended higher for the FTP and US06 cycles compared to E10. However, the differences in CO emissions for both fuels were not statistically significant.

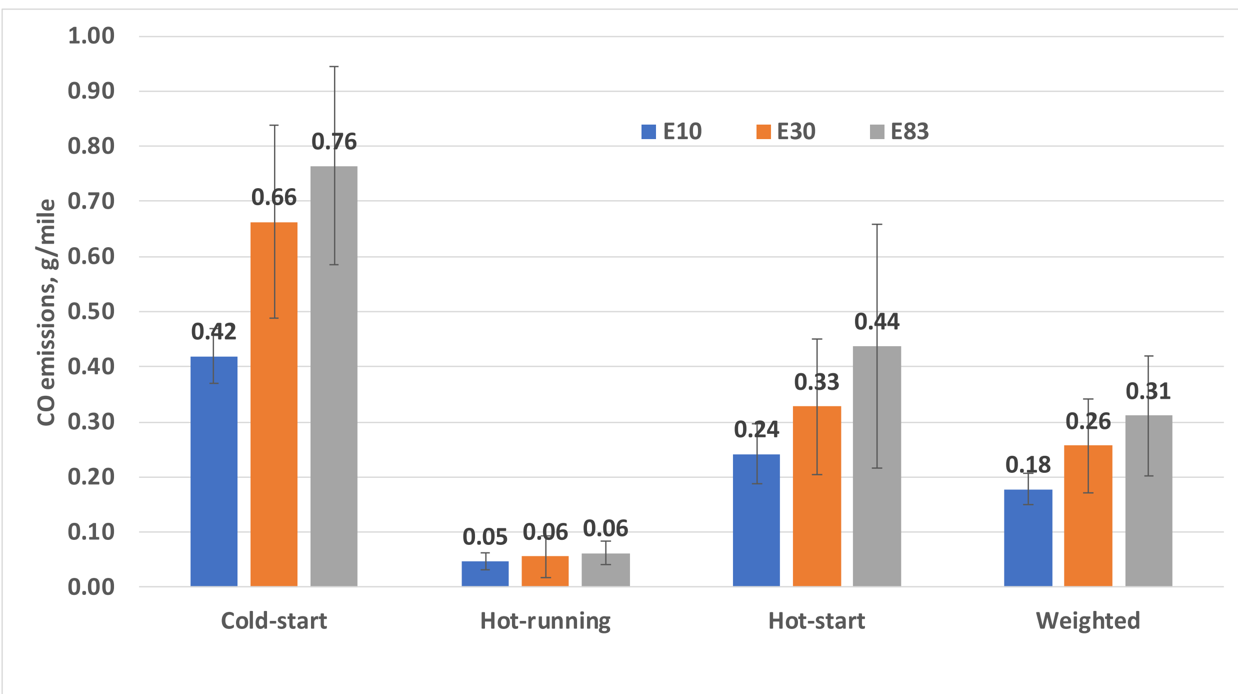


Figure 3-6. CO emissions by phase and the weighted FTP cycle

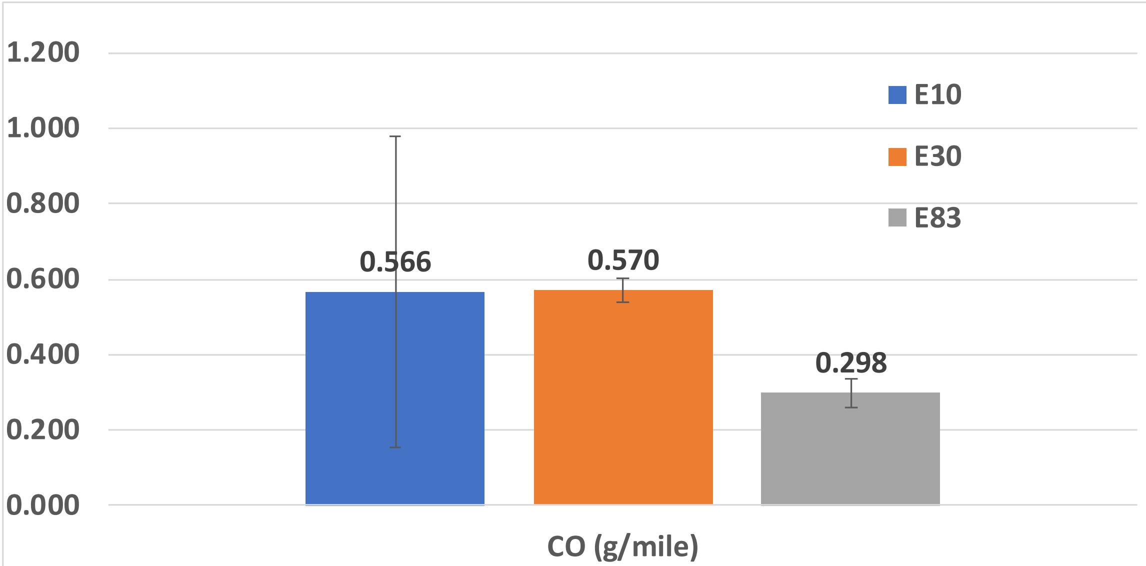


Figure 3-7. Average CO Emission results for the US06 cycle

3.3 NOx Emissions

Figure 3-8 and Figure 3-9 show the NOx emissions for the FTP and US06 cycles, respectively. For the FTP weighted NOx emissions, both E30 and E83 fuels showed reductions compared to E10. The use of E83 fuel resulted in a 48% reduction in weighted NOx emissions compared to E10, at a statistically significant level.

For the US06 NOx emissions, E83 showed a marginally statistically significant reduction of 79% compared to E10.

Our results indicate that higher ethanol blends will not adversely affect NOx emissions, but rather demonstrate strong reductions.

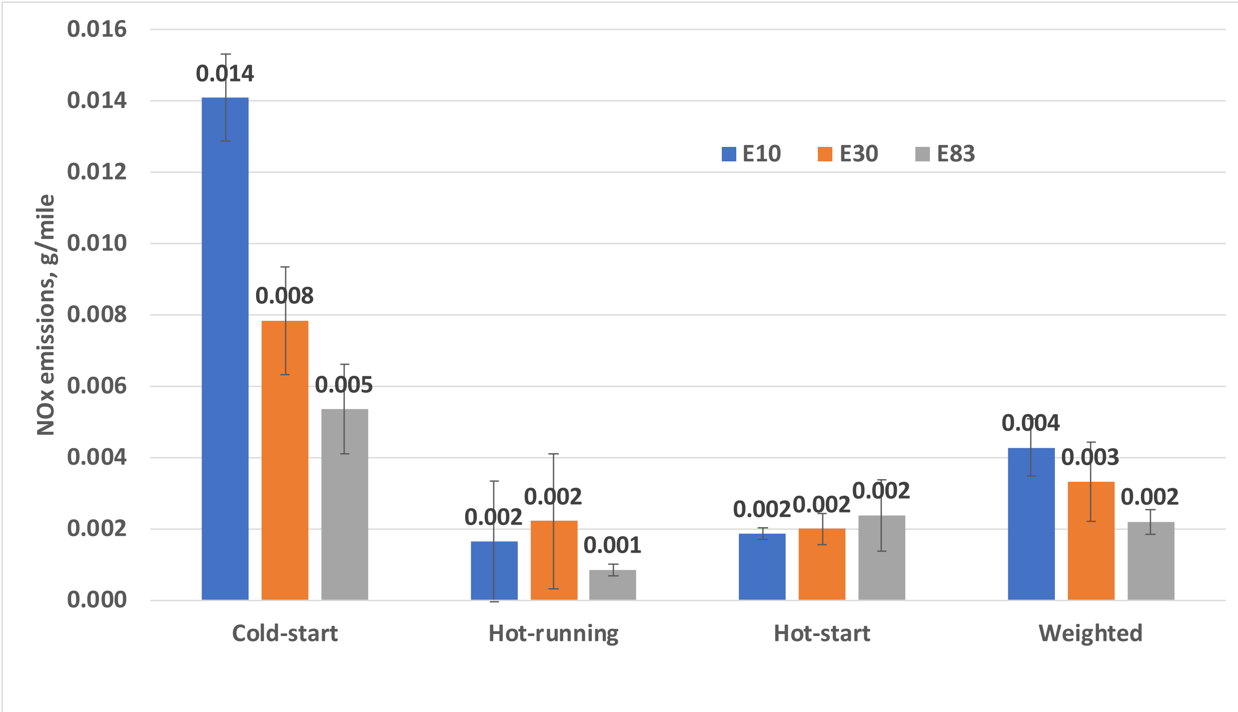


Figure 3-8. NOx emissions by phase and the weighted FTP cycle

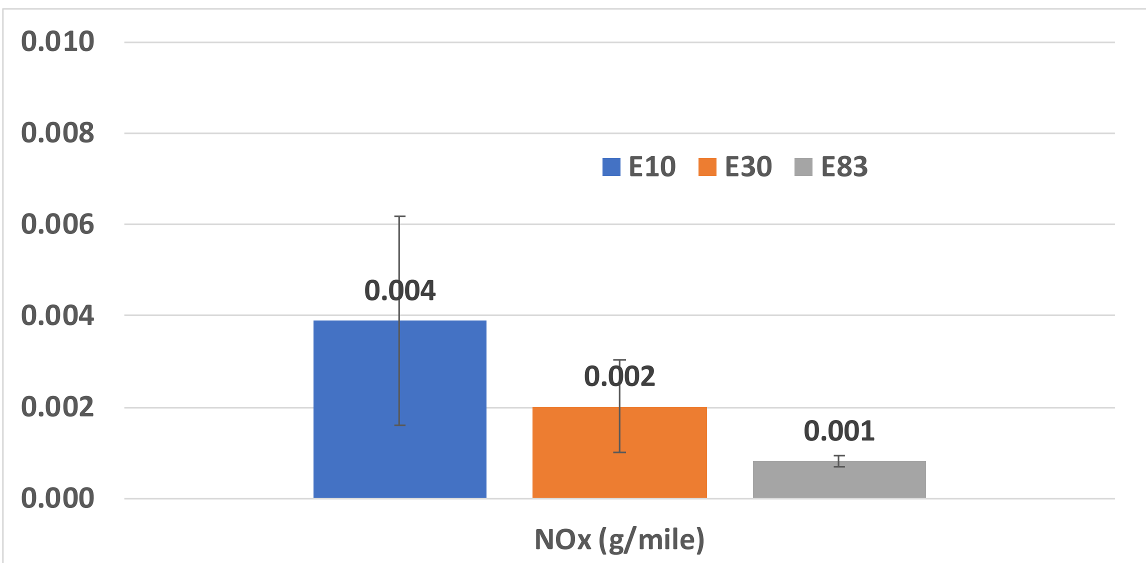


Figure 3-9. Average NOx emission results for the US06 cycle

3.4 CO_2 Emissions and Fuel Economy

Figure 3-10 and Figure 3-11 show the CO_2 emissions for the FTP and US06 cycles, respectively. CO_2 emissions trended lower for E30 and E83 than E10, but these differences were not statistically significant. For the US06 cycle, E30 and E83 trended lower for CO_2 emissions, with E83 showing a statistically significant reduction of 3% compared to the base E10.

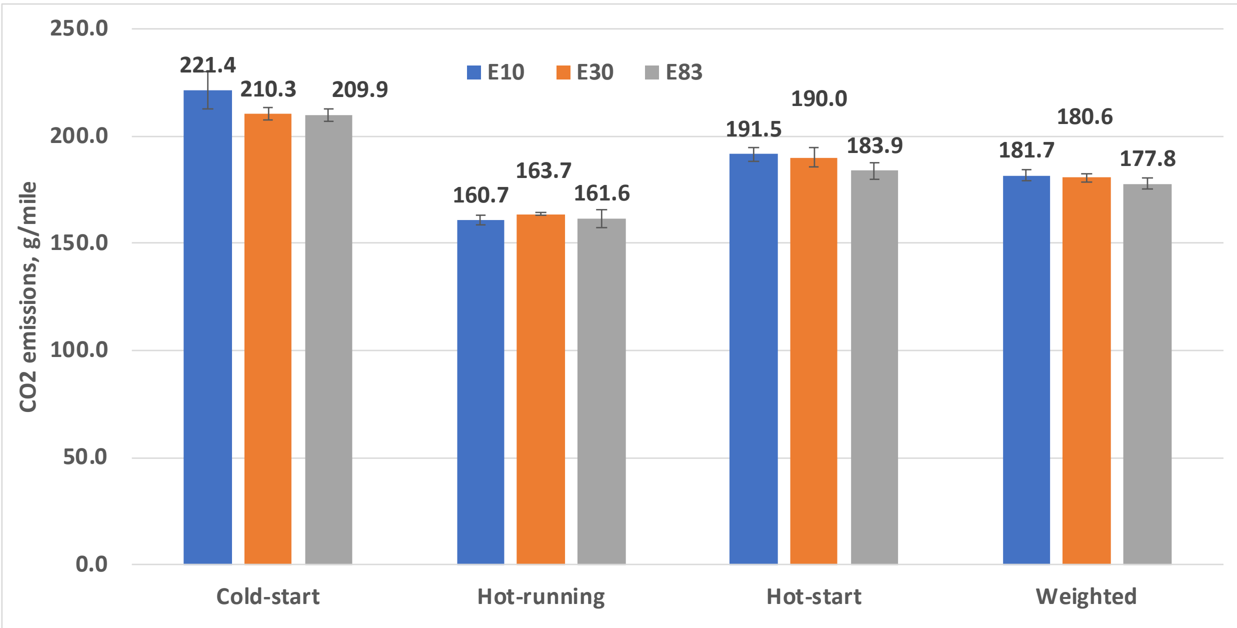


Figure 3-10. CO_2 emissions by phase and the weighted FTP cycle

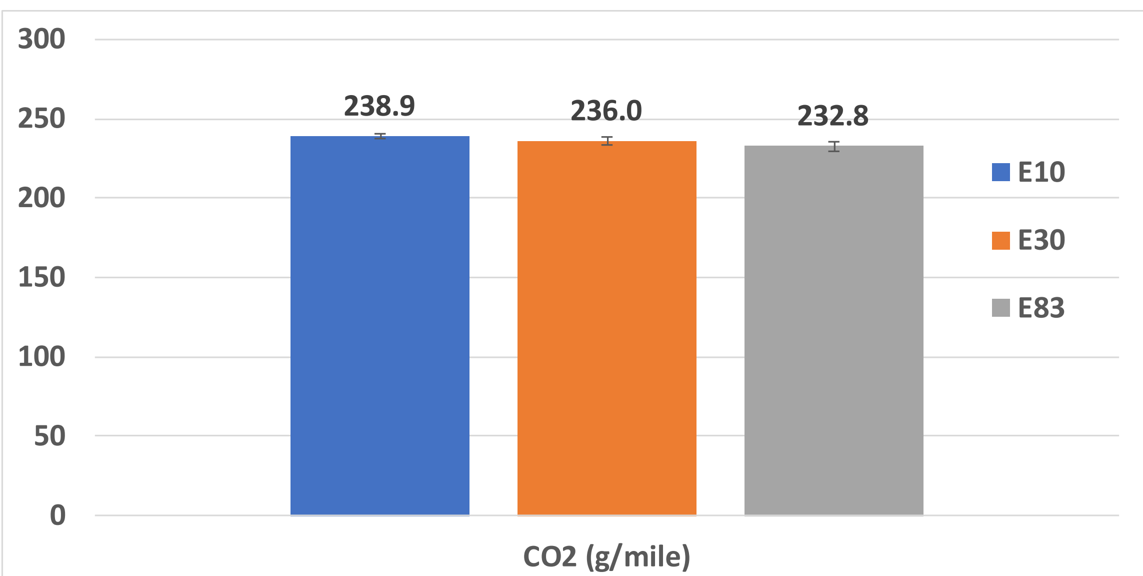


Figure 3-11. Average CO_2 emission results for the US06 cycle

Figure 3-12 and Figure 3-13 present the fuel economy results for the FTP and US06 cycles, respectively. The carbon balance method was used to calculate fuel economy. The carbon balance method provides the best comparison between the differences in energy content between different fuels. The equation used is shown below:

$$Fuel\ economy\ (mpg) = \frac{CWF_{fuel} \times SG_{fuel} \times 3781.8}{(CWF_{HC} \times HC) + (0.429 \times CO) + (0.273 \times CO_2)}$$

$HC: HC\ Emission\ Rate\ \left(\frac{g}{mile}\right)$
$CO: CO\ Emission\ Rate\ \left(\frac{g}{mile}\right)$
$CO_2 : CO_2\ Emission\ Rate\ \left(\frac{g}{mile}\right)$
$CWF_{fuel}, CWF_{HC}: Carbon\ Weight\ Fraction\ of\ the\ Test\ Fuel$
$SG_{fuel}: Specific\ Gravity\ of\ the\ Test\ Fuel$

The higher ethanol blends resulted in lower fuel economy, as expected. For the FTP cycle, the weighted fuel economy had a statistically significant decrease of 7% and 26% for E30 and E83, respectively, as compared to E10. For the US06 test cycle, a similar statistically significant decrease of 6% and 25% was observed for E30 and E83 fuels, respectively, as compared to E10. The lower fuel economy for the higher ethanol blends was due to their lower energy content compared to E10.

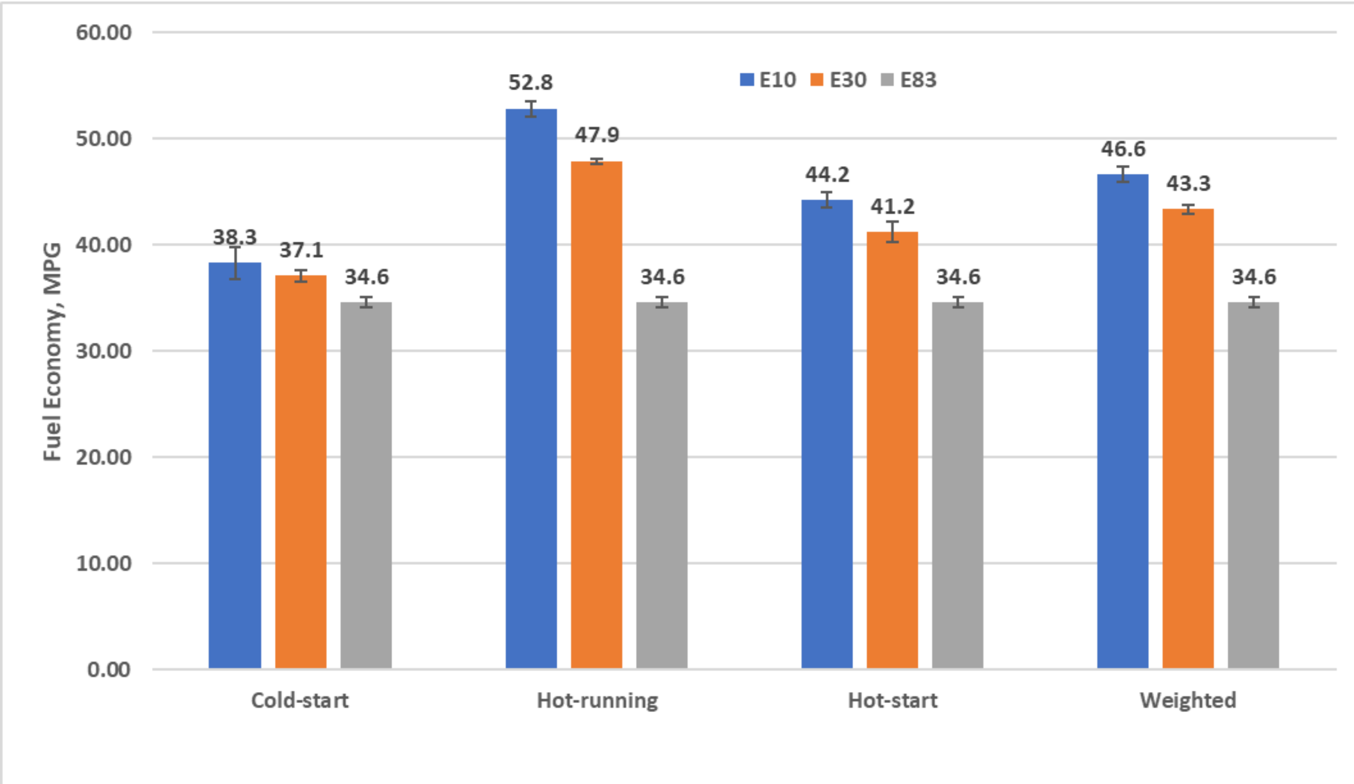


Figure 3-12. Average fuel economy results based on carbon balance for FTP cycle

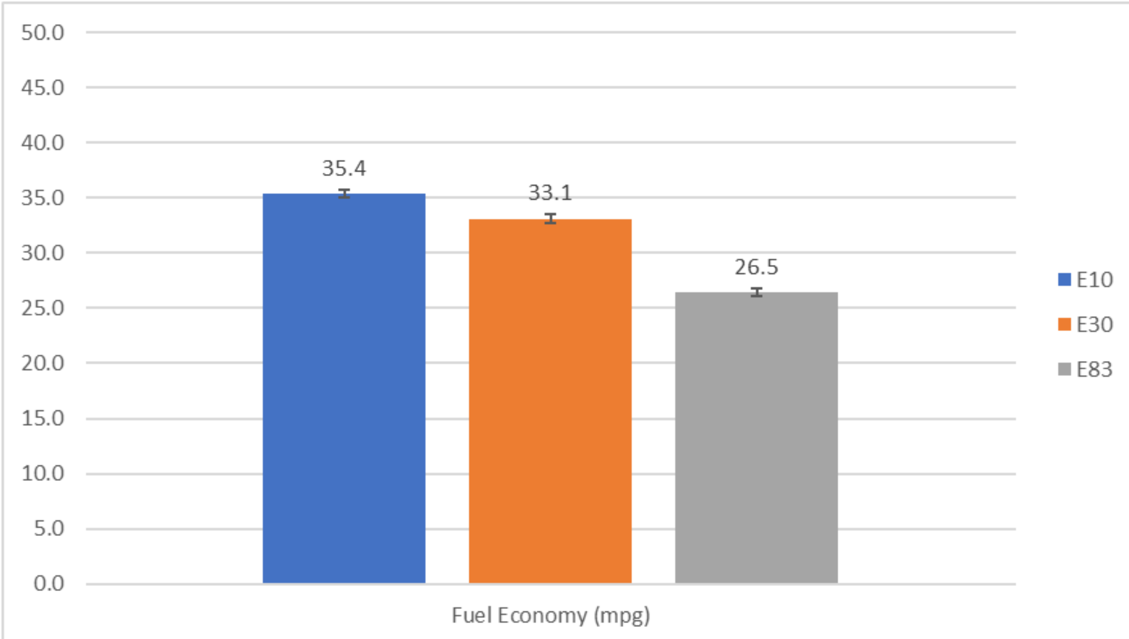


Figure 3-13. Average fuel economy results based on carbon balance for the US06 cycle

3.5 PM Mass and Solid Particle Number Emissions

Figure 3-14 and Figure 3-15 show the weighted PM mass emissions over the FTP and US06 cycles, expressed in mg/mile

For the FTP cycle, PM mass emissions were found below the optional California PM mass standard (1 mg/mile) for light-duty gasoline vehicles and trended lower with higher ethanol blending. The use of E83 showed a statistically significant reduction in the weighted PM mass emissions of 76% relative to E10.

For the US06 cycle, E30 showed a marginally statistically significant decrease in PM mass of 50% compared to E10. E83 showed a statistically significant decrease of 70% in PM mass emissions compared to E10.

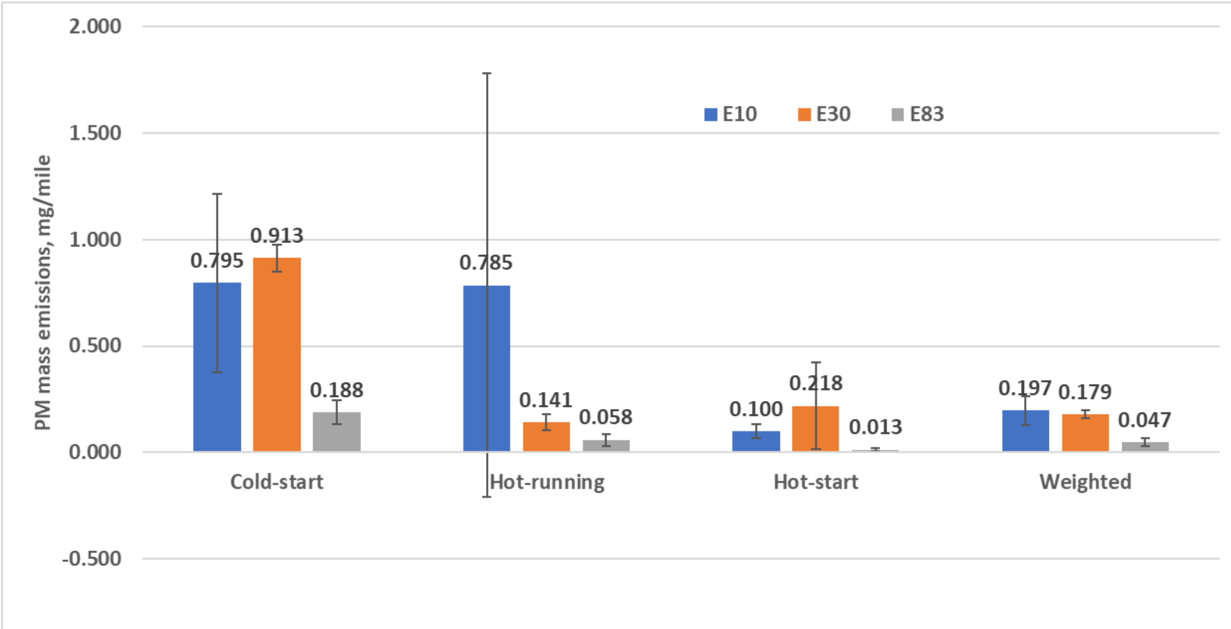


Figure 3-14. PM mass emissions for the weighted and its individual phase of the FTP cycle

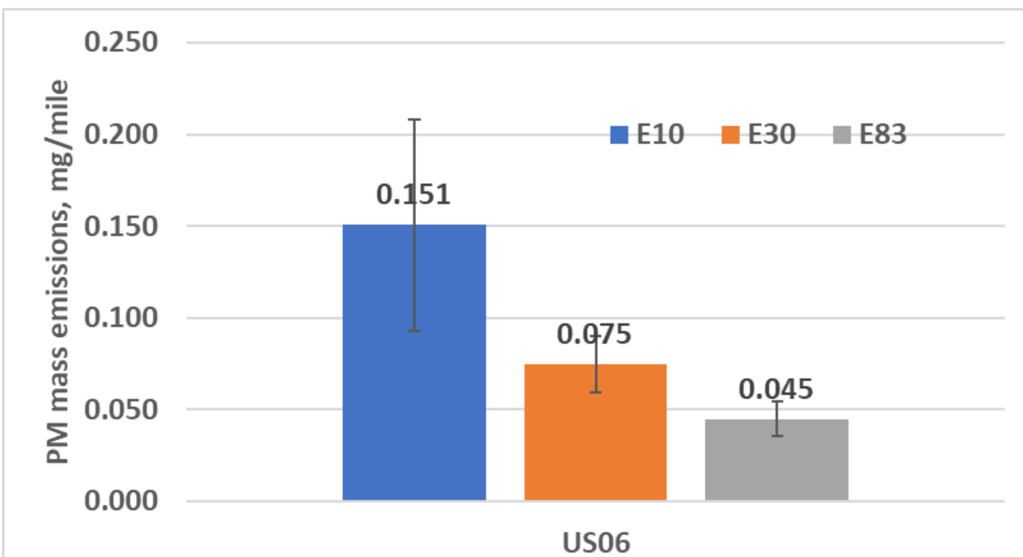


Figure 3-15. Average PM mass emissions results for the US06 cycle

Solid particle number (SPN>23 nm) emissions over the FTP and US06 cycles are shown in Figure 3-16 and Figure 3-17, respectively. For the FTP cycle, E30 and E83 trended lower for SPN>23 weighted emissions, with E30 showing a reduction of 37% compared to E10 and E83 showing a statistically significant reduction of 65% compared to E10. For the cold-start phase, SPN>23 emissions showed reductions of 41% and 74%, respectively, for E30 and E83 compared to E10. Hot-start SPN>23 emissions were 29% lower for E30, but 18% higher for E83 compared to E10. For the Hot-running phase, E30 showed reduction in SPN emissions of 27% and E83 showed marginally significant reduction of 64% compared to E10.

The cold-start period significantly contributed to the total SPN>23 emissions for all fuel combinations. Hot-running and hot-start SPN>23 emissions were significantly lower than the cold-start phase.

For the US06 cycle, E30 and E83 showed decreases in SPN emissions of 73% and 16%, respectively, compared to E10.

The reduction of aromatic hydrocarbons via dilution effects and the presence of oxygen were the main contributing factors for the reductions in PM mass and SPN emissions with E10 and E83 fuels.

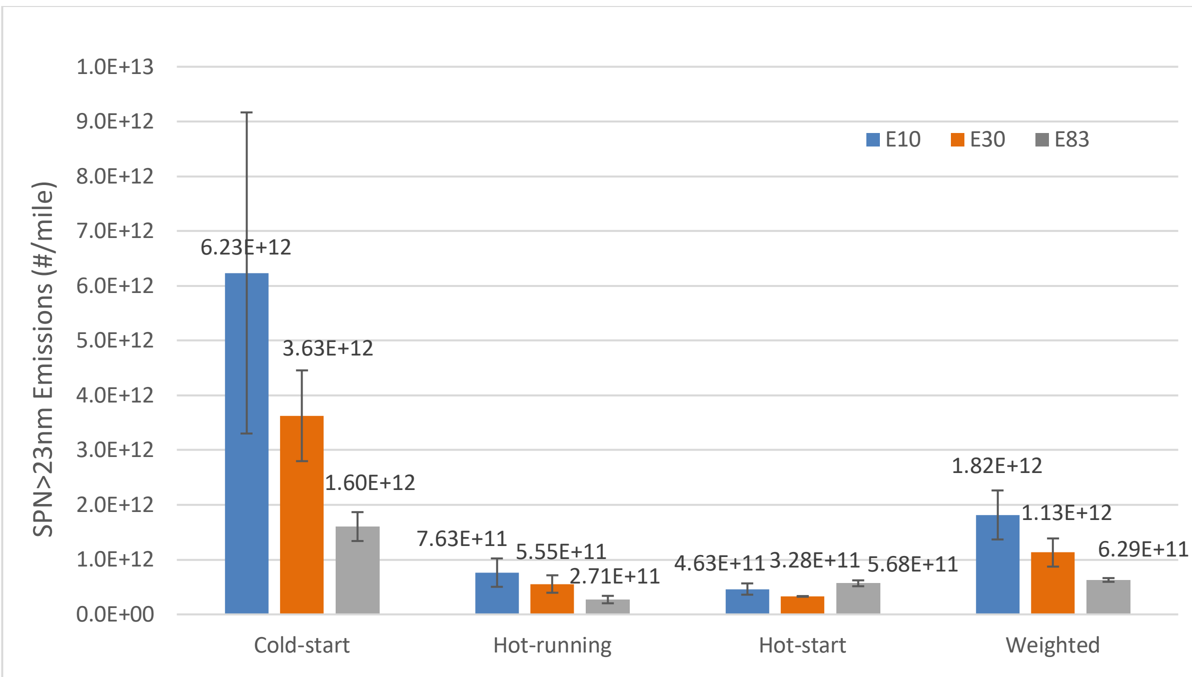


Figure 3-16. Solid Particle Number (>23 nm) Emissions for the weighted and its individual phase of the FTP cycle

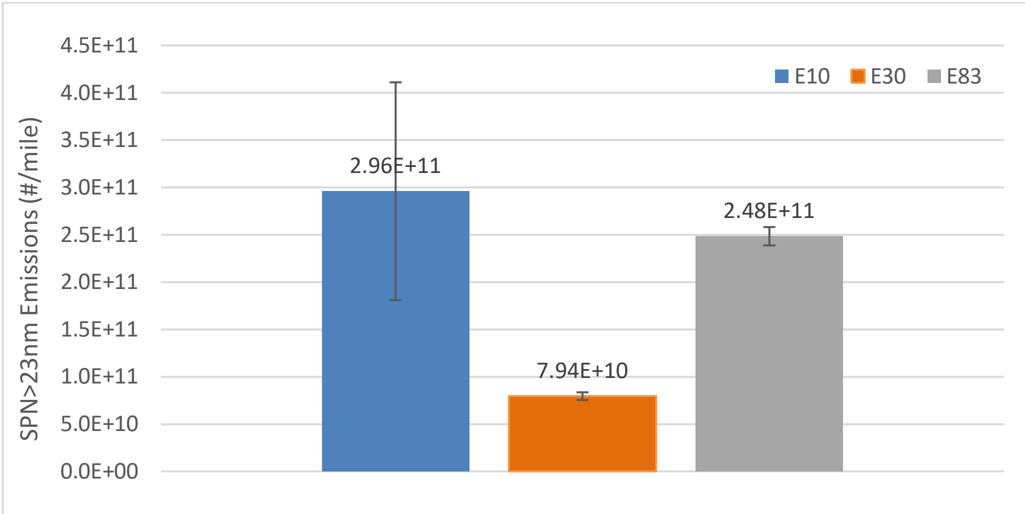


Figure 3-17. Average Solid Particle Number (>23 nm) Weighted Emissions Results for US06 cycle

APPENDIX B

Comparison of Full Lifecycle GHG Emissions: Ford Escape FFV-PHEV Using Ethanol Blends vs. Battery Electric Vehicle

Steffen Mueller, Principal Economist, University of Illinois at Chicago, Energy Resources Center and Stefan Unnasch, Managing Director, Life Cycle Associates, LLC

Comparison of Full Lifecycle GHG Emissions: Ford Escape FFV-PHEV Using Ethanol Blends vs. Battery Electric Vehicle

Date: September 20, 2023

Prepared by: Steffen Mueller, Principal Economist, University of Illinois at Chicago, Energy Resources Center and Stefan Unnasch, Managing Director, Life Cycle Associates, LLC

Prepared for: Renewable Fuels Association

The Renewable Fuels Association (RFA) recently converted a new (2023) Ford Escape PHEV to be capable of running on ethanol blends up to E85. The University of California, Riverside (UCR) tested the vehicle on two driving cycles (US06 and FTP) and collected emissions data. The University of Illinois at Chicago and Life Cycle Associates obtained the emissions data and calculated life cycle greenhouse gas (GHG) emissions from the test results based on the Argonne National Laboratory Greenhouse Gas Regulated Emissions in Technologies model. The UCR-provided emissions data is reproduced in Appendix A.

Figure 1 and Figure 2 show the results of the life cycle GHG emissions analysis for the US06 and FTP driving cycles, respectively, with detailed values listed in Appendix B. The emissions are shown both in grams of carbon dioxide equivalent emitted during each test cycle and on a per-mile basis. UCR indicated that the state of charge of the battery was close to the same before and after each test resulting in all electric miles coming from battery regeneration.

The GHG emissions of ethanol-blended fuels also depend on the specific production pathway of ethanol. As part of the present analysis, we evaluated blend feedstocks based on the current average GHG emissions of corn ethanol, as well as corn ethanol produced with carbon capture and sequestration (CCS) and advanced climate smart agriculture (CSA). CSA practices such as reduced tillage, cover cropping, reduced nitrogen applications, use of denitrification inhibitors when used in combination can lead to carbon neutral impacts of agriculture to life cycle emissions of corn ethanol. Specifically, we modeled the emissions when operating the vehicle on gasoline without ethanol (E0), operating the vehicle on E10, as well as on E30 and E85 both with CCS & CSA.

Higher ethanol blends have been used in various vehicle tests which showed that optimized engines can achieve increased energy economy ratios.[1] We added scenarios to E30 and E85 which incorporate

[1] National Academies of Sciences, Engineering, and Medicine. 2022. Current Methods for Life-Cycle Analyses of Low-Carbon Transportation Fuels in the United States. Washington, DC: The National Academies Press. https://doi.org/10.17226/26402. Page 114 states: "The reviewed studies show that optimized higher octane fuel engines may at least partially or more than fully compensate for ethanol's lower volumetric fuel economy (due to its lower heating value) and result in increased energy economy ratio, which is defined as the energy consumption in British thermal unit (joule) of the conventional E10 vehicle divided by that of the alternative fuel (Unnasch and Browning, 2000). For example, Oak Ridge National Laboratory research finds that high-octane fuel can provide "an improvement in vehicle fuel efficiency in vehicles designed and dedicated to use the increased octane" (Theiss et al., 2016)."

results from previous engine tests for that fuel in optimized engines where the engines gained five percent (E30) and seven percent (E85) in additional efficiency from the higher octane of that fuel.[2]

For comparison we added scenarios of the PHEV vehicle operation with electricity sourced from the plug of different electricity grids: a) electricity generated from coal-only which is reflective of many international regions that add significant amounts of coal generation capacity such as China, Japan, and India, b) the U.S. Midwest Grid (MRO eGRID interconnect subregion which covers a significant part of the corn belt, see Appendix C), c) and the US average electricity grid. The results are shown in Figure 1 for US06, Figure 2 for FTP, and the summary table in Appendix B.

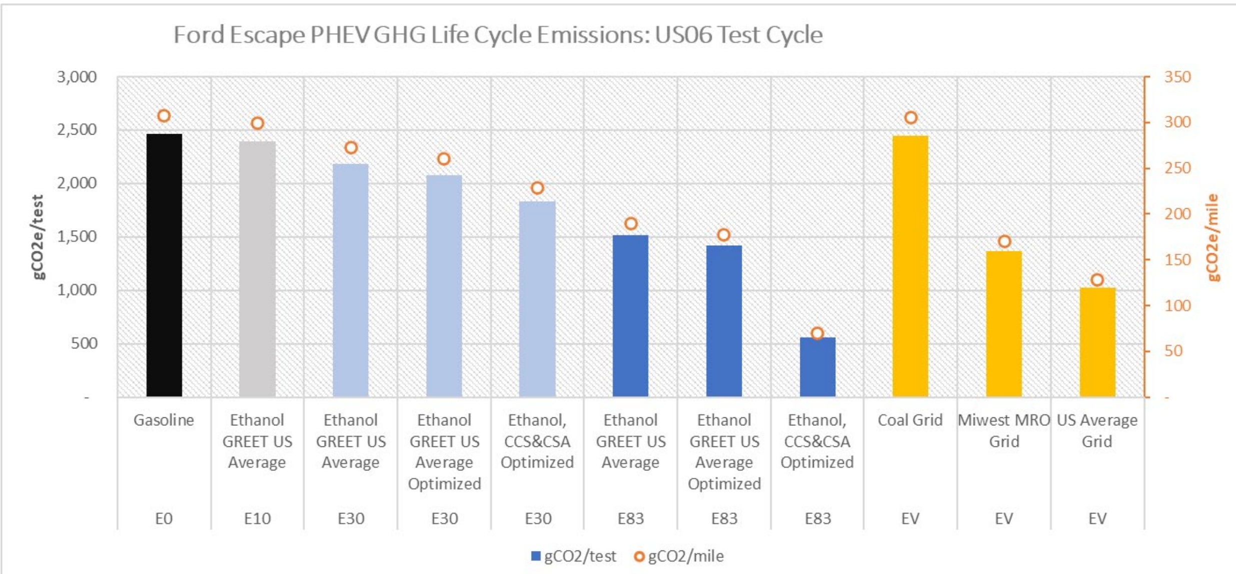


Figure 1: Life Cycle GHG Emissions Results for US06 Test

[2] For E30 we assumed an EER of 1.05 per: ORNL/TM-2018/814 National Transportation Research Center; EFFECTS OF HIGH-OCTANE E25 ON TWO VEHICLES EQUIPPED WITH TURBOCHARGED, DIRECT-INJECTION ENGINES, Brian West et al. Published: September 2018. For E83 we assumed an EER of 1.07 per GREET 2022.

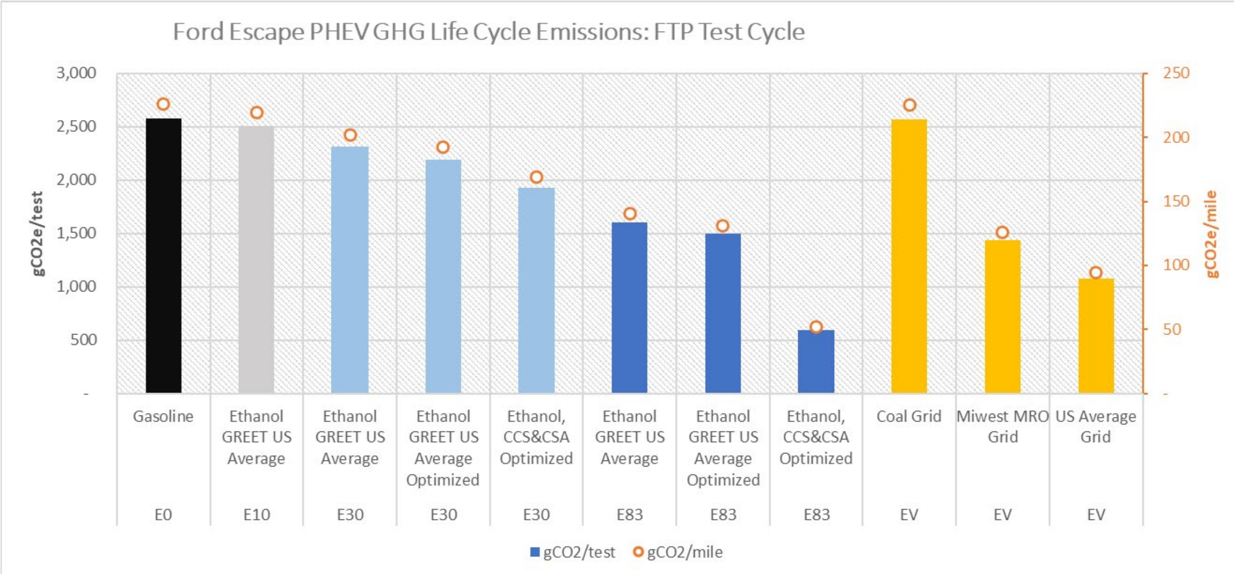


Figure 2: Life Cycle GHG Emissions Results for FTP Test

Selected findings are as follows:

- The Ford Escape PHEV is a very low emitting car with emissions on standard corn ethanol E10 less than 300 gCO_2e/mile on US average E10. For comparison, the US Environmental Protection Agency states that the average passenger vehicle emits about 400 grams of CO_2e/mile.[3]
- All ethanol blended fuels provide significant GHG savings relative to the vehicle charged on a selective coal-only grid. In countries with coal fired electricity generation, therefore, utilizing hybrid vehicles with ethanol blends can significantly reduce the PHEV vehicle's emissions profile.
- Mid-level ethanol blends (E30) where the ethanol is produced with CCS&CSA in an optimized engine provide at least 25% GHG savings relative to E0.
- The Ford Escape PHEV when operated on E85 provides 38% emissions savings relative to E0.
- E85 ethanol blends in an optimized engine provide approximately the same GHG savings as an EV charged on the Midwest electricity grid.
- E85 in an optimized engine where the ethanol is produced with CCS&CSA provides significant lower emissions than a similar EV vehicle charged on the US average electricity grid. That vehicle achieves GHG emissions savings of 77% relative to E0.

[3] US Environmental Protection Agency: Greenhouse Gas Emissions from a Typical Passenger Vehicle; https://www.epa.gov/greenvehicles/greenhouse-gas-emissions-typical-passenger-vehicle

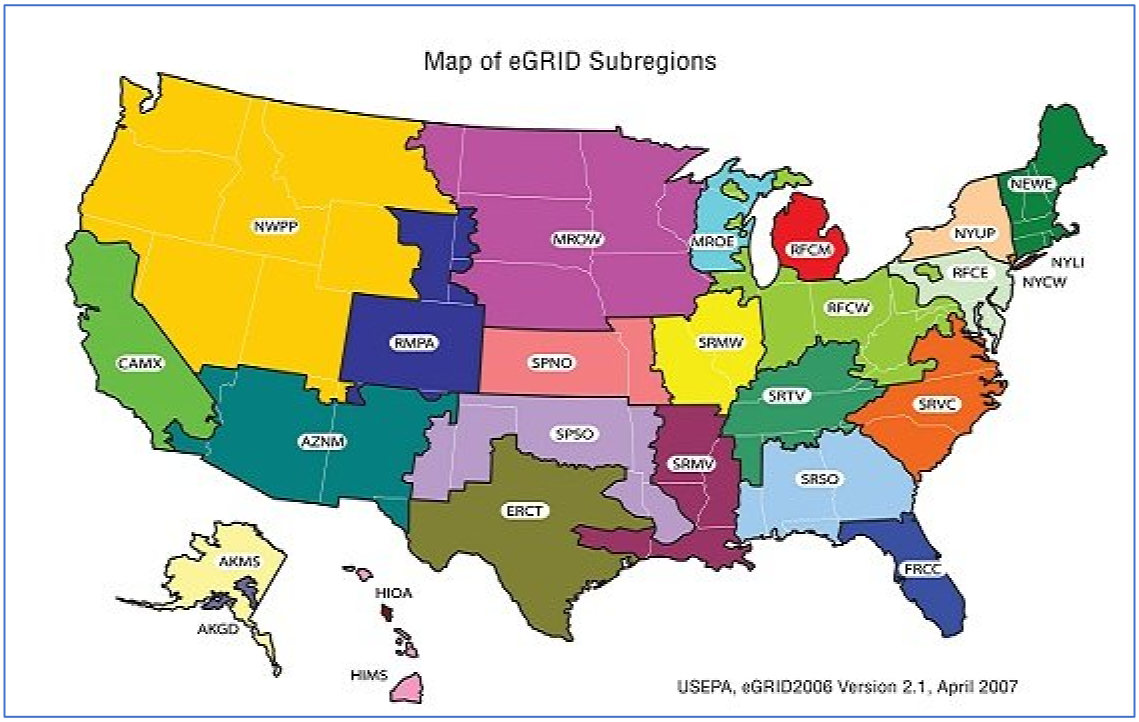
Appendix A: Input Data

US06		Direct Emission Data						
date	Oil type	CO2 (g/mile)	CO (g/mile)	CH4 (g/mile)	THC (g/mile)	emiles	Fuel Miles	Total Miles
	E0					1.11	6.90	8.01
20230202	E10	240.84	1.04	0.000	0.001	1.09	6.92	
20230206	E10	237.85	0.29	-0.001	0.001	1.10	6.91	
20230207	E10	238.13	0.37	-0.001	0.001	1.13	6.88	
20230208	E30	232.91	0.54	-0.001	0.000	1.05	6.96	
20230209	E30	237.04	0.58	-0.001	0.001	0.62	7.39	
20230210	E30	238.00	0.59	0.000	0.001	1.47	6.54	
20230215	E83	236.34	0.28	0.000	0.001	1.10	6.91	
20230216	E83	231.46	0.34	0.000	0.001	1.34	6.67	
20230217	E83	230.52	0.28	0.000	0.001	1.44	6.57	
FTP		Direct Emission Data						
date	Oil type	CO2 (g/mile)	CO (g/mile)	CH4 (g/mile)	THC (g/mile)	emiles	Fuel Miles	Total Miles
	E0					3.61	7.43	11.04
20230202	E10	184.27	0.20	0.001	0.008	3.62	7.42	
20230206	E10	181.86	0.18	0.000	0.007	4.07	6.97	
20230207	E10	179.04	0.15	0.000	0.006	3.14	7.90	
20230208	E30	182.62	0.34	0.003	0.015	3.87	7.17	
20230209	E30	179.90	0.26	0.002	0.009	4.47	6.57	
20230210	E30	179.26	0.17	0.001	0.010	3.19	7.85	
20230215	E83	179.82	0.25	0.011	0.028	4.23	6.81	
20230216	E83	178.43	0.44	0.014	0.040	3.81	7.23	
20230217	E83	175.10	0.25	0.011	0.031	4.40	6.64	

Appendix B: Emissions Results

		US06 gCO2e/test	FTP gCO2e/test	US06 gCO2e/mile	FTP gCO2e/mile	US06 gCO2e/mile Savings Relative to E0	FTP gCO2e/mile Savings Relative to E0
E0	Gasoline	2,463	2,576	307	226	0%	0%
E10	Ethanol GREET US Average	2,395	2,506	299	220	-3%	-3%
E30	Ethanol GREET US Average	2,186	2,302	273	202	-11%	-11%
E30	Ethanol GREET US Average Optimized	2,082	2,193	260	192	-15%	-15%
E30	Ethanol, CCS&CSA Optimized	1,828	1,926	228	169	-26%	-25%
E83	Ethanol GREET US Average	1,518	1,600	190	140	-38%	-38%
E83	Ethanol GREET US Average Optimized	1,419	1,496	177	131	-42%	-42%
E83	Ethanol, CCS&CSA Optimized	561	591	70	52	-77%	-77%
EV	Coal Grid	2,450	2,571	306	225	-1%	0%
EV	Miwest MRO Grid	1,367	1,435	171	126	-44%	-44%
EV	US Average Grid	1,027	1,078	128	95	-58%	-58%

Appendix C: Map of eGRID Subregions



APPENDIX C

How Does the eFlexFuel Kit Work?

HOW DOES THE EFLEXFUEL KIT WORK?

The operating principle behind eFlexFuel is based on processing the fuel injection signals that are received from the car engine's electronic control module (ECM). The innovative eFlexFuel kit controls the fuel injection process, with each of your vehicle's fuel injectors controlled separately to optimize flow. As a result, eFlexFuel adapts perfectly to different fuel injection approaches.

All the electrical and fuel line connectors you need are provided, and once the device is installed, there's no need to adjust it or make any other changes to your vehicle.

eFlexFuel is an Adaptive System

The ethanol content is detected by the eFlexFuel ethanol sensor that's connected to your vehicle's fuel line. Our device operates in real-time and adjusts the fuel injector signals according to the ethanol content reading. Since the device works automatically, there's no need for adjustments. eFlexFuel E85 flex fuel conversion kits do not interfere with the signals coming from the injectors to EMC, so all OEM engine safety and driving conditions related features remain unaltered.

Changing the Injector's Opening Time

The chemical properties of the E85 fuel differ from gasoline meaning that more fuel needs to be injected during the injection cycle. The increase in fuel, accomplished by keeping the injectors open longer, is dependent on the ethanol content of your fuel. This is automatically regulated by eFlexFuel control unit.

E85 Fuel & Cold Start Function

One concern some have with using E85 fuel is a decline in cold start ability, which is a direct result of the fuel's significantly higher ethanol content. The eFlexFuel converter kit includes an external temperature sensor that regulates the device's operations according to the engine temperature and automatically adds fuel feed if needed, allowing for startup in all weather conditions – including extreme cold. In fact, eFlexFuel has been tested in temperatures as low as -22°F. This adaptation is only active when the engine is starting. It may take a few more attempts to start up in extreme cold than it would during warm weather conditions, but this issue disappears once the engine is sufficiently warmed up.

Learn more about eFlexFuel at www.eFlexFuel.com/us

Learn more about ethanol at www.EthanolRFA.org