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

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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.

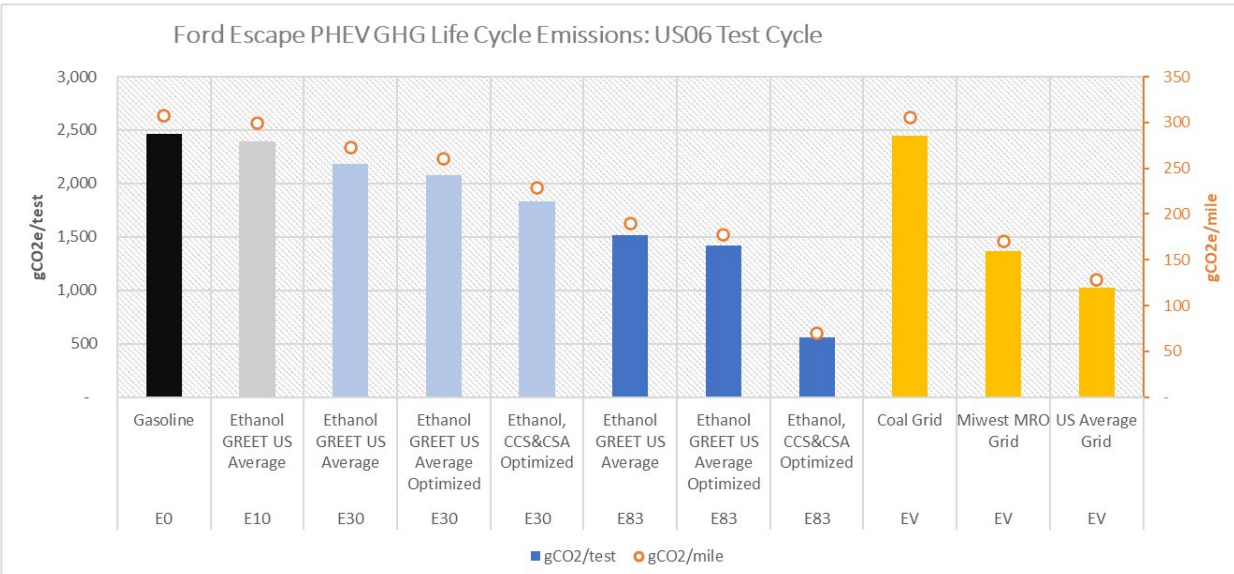

Figure 1: Life Cycle GHG Emissions Results for US06 Test

[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.

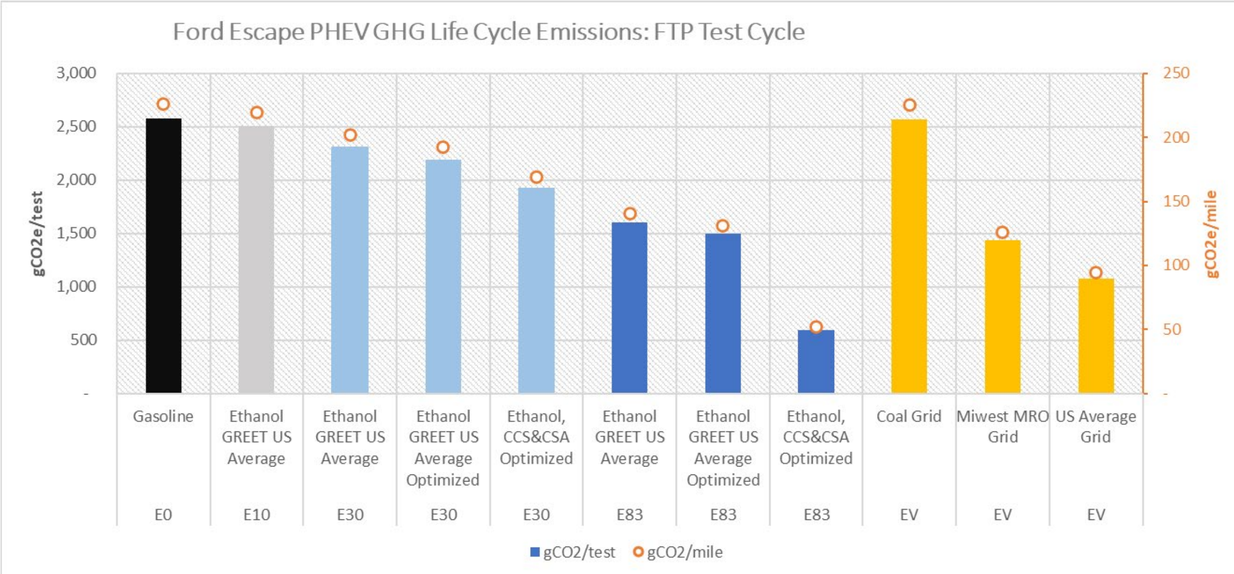

Figure 2: Life Cycle GHG Emissions Results for FTP Test

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	

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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