Comparison of Carbon Dioxide Emissions from Gasoline and E85

Report to American Lung Association of Minnesota – Clean Air Fuels Alliance
Prepared by Ronald Timpe & Ted Aulich
University of North Dakota Energy & Environmental Research Center
12 January 2005

Vehicles, Fuels, and Greenhouse Gases

Vehicle and other fuel combustion emissions can modify the composition of the atmosphere, increasing its ability to trap heat. Gases that are effective in trapping heat are called greenhouse gases (GHGs) and include all of the gases in vehicle emissions. The major component of GHG emissions is carbon dioxide (CO_2). Reduction of CO_2 emissions has become a concern worldwide. To emphasize this concern and encourage more efficient vehicles, the European Union has set a 2006 voluntary CO_2 emissions target of 193 grams per vehicle mile (1). Meeting this target even within this decade will be challenging, since it will likely require major technology-driven efficiency improvements. However, significant emissions reductions can be achieved in the more immediate future by strategic combinations of available technologies and improved fuels. This report describes automobile fuel impacts on CO_2 emissions and includes findings of an exhaust emissions-based comparison of commercial automobile fuels.

The E85 Alternative

E85 is an alternative fuel comprising 85% denatured ethanol and 15% gasoline. Because fuel ethanol usually comprises about 5% gasoline (added as a denaturant to make ethanol undrinkable), summer-blend E85 actually contains about 80% ethanol and 20% gasoline (2). As with gasoline, the volatility of E85 is seasonally adjusted to ensure adequate vapor pressure for engine starting in winter, and to ensure against the occurrence of engine-stopping vapor lock and excessive fuel evaporation in summer. To meet winter fuel volatility requirements, winter-blend E85 will typically contain about 70% ethanol, as per American Society of Testing and Materials (ASTM) Designation D5798-96: Standard Specification for Fuel Ethanol (Ed75-Ed-85) for Automotive Spark-Ignition Engines. Real environmental benefits are realized when using E85 in place of conventional gasoline. A key benefit derives from the fact that ethanol is made from renewable biomass, and biomass growth utilizes carbon derived from CO_2 pulled out of the atmosphere, which means that burning ethanol results in a near-neutral impact on atmospheric CO_2 level.

Automobile Fuel Life Cycle Energy Use and Emissions

The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) model developed by Argonne National Laboratory (Argonne) enables an estimate of well-to-wheel energy and emission impacts of conventional and alternative transportation fuels and current and advanced vehicle technologies. The term “well-to-wheel” (WTW) refers to all energy and emission impacts associated with the complete life cycle of a specific fuel, including all aspects of fuel recovery, processing, transportation, and utilization in a specific vehicle propulsion system. The GREET model is capable of calculating WTW energy use (in British thermal units per mile [Btu/mi]) and emissions (in grams per mile [g/mi]) for specific combinations of transportation fuels and vehicle technologies (2). WTW energy and emission impacts are the sum of well-to-tank (WTT) and tank-to-wheel (TTW) impacts, which derive from all aspects of fuel production and delivery to a vehicle tank, and utilization in a vehicle, respectively. Funding for the Argonne work was provided by General Motors Corporation (GM) as part of a GM effort to analyze WTW energy use and GHG emission impacts of advanced fuel–vehicle systems. Three energy companies—BP, ExxonMobil, and Shell—actively participated in the study by providing input and review.

As a means of empirically measuring the primary component of TTW emissions from gasoline and E85, the University of North Dakota Energy & Environmental Research Center (EERC) and the Minnesota Center for Automotive Research (MnCAR) at Minnesota State University–Mankato compared a series of conventional commercial gasolines and E85 on the basis of combustion emissions. Commercial samples of nonoxygenated gasoline, 10% ethanol-blended gasoline, (E10), and E85 were collected, analyzed, and monitored for tailpipe emissions using a chassis dynamometer and a 2004 E85-capable Ford Explorer Sport Trac.

E85–Gasoline WTW Energy and Emissions Comparison

CO_2 is a major GHG and the predominant emission produced during combustion of carbon-containing fuels. Table 1 compares gasoline and E85 on the basis of CO_2 emitted per million Btu. As shown, the amount of CO_2 emitted from gasoline and E85 is nearly equal (0.2% difference) on a Btu basis. However, the difference between the two fuels in total fuel life cycle energy use per vehicle mile traveled is more pronounced, as shown in Table 2.

Table 1 – Fuel Volumetric Energy Content and Combustion Emissions of CO_2

Fuel	CO_2 emission, grams/million Btu
Conventional Nonoxygenated Gasoline	76,477
E85	76,289

Table 2, which contains data developed using the GREET model, shows that gasoline and E85 are significantly different in total life cycle energy use. The table shows that a greater portion of the energy available in E85 is consumed during the WTT (production) portion of the fuel life cycle than for gasoline (54% versus 23%). The high WTT energy use for E85 is a function of the energy required to produce the biomass (typically corn) utilized as ethanol feedstock, and the subsequent conversion of corn to ethanol. In contrast, production of gasoline requires significantly less energy. However, in spite of its lower volumetric energy content, E85 generates significantly less CO_2 per mile than gasoline on a total fuel lifecycle basis, since a large portion of ethanol combustion CO_2 emitted to the atmosphere is derived from CO_2 that was recently removed from the atmosphere during growth of the biomass utilized for ethanol production.

Table 2 – WTW Energy and CO_2 Emissions Comparison Between E85 and Gasoline

Fuel	E85	Gasoline
Approximate energy content, Btu/gallon	83,000	115,000
Btu consumed per mile (WTW basis) by typical vehicle	10,579	6,949
WTT energy use share, %	54	23
TTW energy use share, %	46	77
Grams CO_2 emitted per mile (WTW basis) by typical vehicle	205	577

Tailpipe Emissions Comparison

During the summer of 2004, EERC and MnCAR performed a tailpipe emissions-based comparison of three major-brand Minneapolis–St. Paul E10 gasolines (Holiday, BP, and SuperAmerica [SA]), an E85 fuel, and a Wisconsin nonoxygenated gasoline. All five fuels were procured through purchasing at the pump, and analyzed in accordance with ASTM procedures. Sulfur, aromatics, benzene, and ethanol content were determined via ASTM D5453, D1319, D5769, and 4815, respectively, for the non-ethanol and E10 gasolines, and via D5453, D5769, D5769, and 5501, respectively, for the E85. Table 3 lists key fuel properties.

Table 3 – Key Fuel Analysis Results

Fuel	Sulfur, ppm[1]	Aromatics, vol%[2]	Benzene, vol%[2]	Ethanol, vol%[2]
Holiday E10	51	24.0	1.0	9.8
SA E10	76	22.9	1.1	9.8
BP E10	115	23.3	2.0	9.8
Non-ethanol	94	26.6	1.5	0
E85	13	4.0	0.2	79.1

[1] Parts per million, weight basis
[2] Volume percent

The tailpipe emissions comparison utilized a 2004 Ford Explorer Sport Trac flexible fuel vehicle equipped with a 4.0-liter engine. The Explorer, which at the time of testing had been operated for about 8,000 miles, is EPA-certified as a low-emission vehicle and capable of operating on 100% gasoline, E85, or any combination of E85 and gasoline. Emissions tests were conducted at MnCAR, utilizing a SuperFlow chassis dynamometer interfaced with a California Analytical Instruments exhaust gas emissions analysis system. In generating the emissions data, the dynamometer was operated utilizing the 505-second-duration "hot start" portion of the EPA-developed FTP-75 driving cycle, which simulates urban driving and includes accelerations and decelerations at varying rates, cruising at constant speeds, and idling. Average speed over the test duration is about 27 miles per hour (mph) and top speed achieved is 57 mph. The FTP-75 is used by vehicle manufacturers and EPA to determine if new vehicles meet federal emission standards.

Emissions test results are shown in Table 4 and Figures 1–2. Data for each fuel are average values calculated from the results of three identical "hot-start 505" emissions tests. Also provided in Table 4 are the THC, CO, and NO_x emission specifications of the California Air Resources Board Super Ultra Low Emission Vehicle (SULEV) standard, which is the toughest existing emission standard nationwide with the exception of the zero emission vehicle (ZEV) standard. To get SULEV certification, a vehicle needs to generate THC, CO, and NO_x tailpipe emissions at or below the values shown in the table. Although lower in fuel efficiency than the other fuels, the E85 was also lower in THC, NO_x, and CO_2 emissions, and the E85 was the only fuel that enabled the Explorer to generate below-SULEV levels of THC, NO_x, and CO emissions. Although E85 generated the highest CO emission, oxidation of the CO emission to CO_2 in ambient air would add only 1.3 grams to the CO_2 emissions, resulting in an E85 CO_2 emission still lower than those of the other fuels.

Table 4 – Tailpipe Emissions Test Results

Fuel	Average Tailpipe Emission, grams/mile				Fuel Efficiency, miles/gallon
	THC	CO	NO_x	CO_2	
Holiday E10	0.016	0.436	0.027	531	17.1
SA E10	0.019	0.267	0.054	525	17.2
BP E10	0.022	0.341	0.051	525	17.2
Non-ethanol	0.032	0.543	0.044	531	16.8
E85	0.002	0.820	0.018	510	14.2
SULEV	0.01	1.0	0.02	--	--

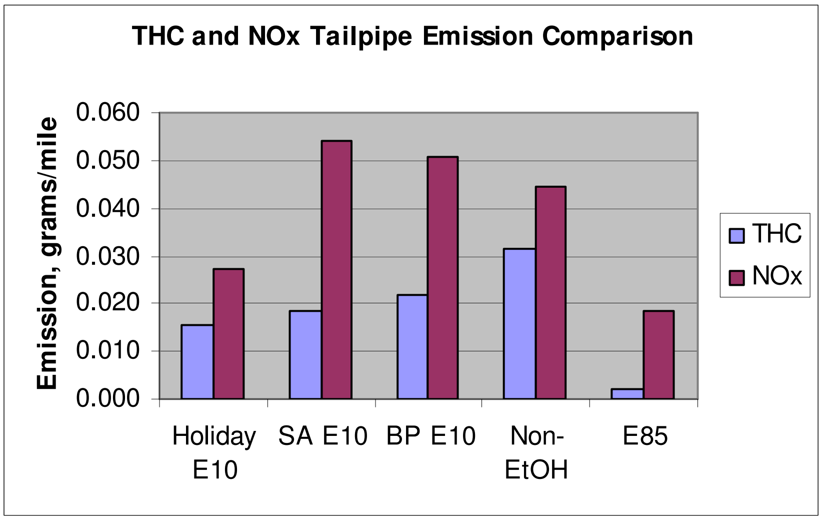

Figure 1. Comparison of fuels based on THC and NO_x tailpipe emissions from 2004 E85-capable Ford Explorer operated on 505-second-duration hot-start portion of EPA FTP-75 driving cycle.

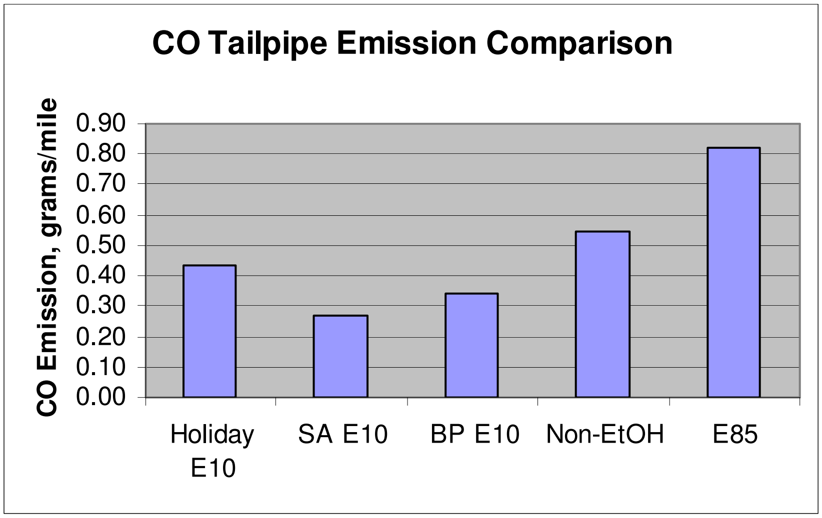

Figure 2. Comparison of fuels based on CO tailpipe emission from 2004 E85-capable Ford Explorer operated on 505-second-duration hot-start portion of EPA FTP-75 driving cycle.

GHG Reduction Potential of E85

At 15,000 miles per year, the approximate 372 gram/mile per vehicle CO_2 emission reduction achievable by switching from gasoline to E85 (WTW basis—see Table 2) translates to an annual per-vehicle reduction of 6.1 tons of CO_2. If the approximately 5 million E85-capable vehicles on the road today were to burn E85 instead of gasoline, this would effect a CO_2 emission reduction of 31 million tons per year. For comparison, a typical 500-megawatt coal-fired power plant emits about 3.8 million tons of CO_2 per year.

Acknowledgement

This material is based upon work supported by the Cooperative State Research, Education, and Extension Service, U.S. Department of Agriculture, under Agreement No. 00-38819-8989.

References

1. Greene, D.L., Schaefer, A., "Reducing Greenhouse Gas Emissions from U.S. Transportation," prepared for Pew Center on Global Climate Change, 2003.
2. Wang, M., He, D., Finizza, A., Weber, T., Miller, M., Masten, D., Skellenger, G., Wallace, J.P., "Well-to-Wheel Energy Use and Greenhouse Gas Emissions of Advanced Fuel/Vehicle Systems –North American Analysis," General Motors Corporation, Argonne National Laboratory, BP, ExxonMobil, Shell, 2001.