Renewable Fuels Association

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What Do Biofuels Displace and Why Does it Matter?

To understand the climate benefits of renewable fuels relative to fossil fuels, it is necessary to compare the lifecycle greenhouse gas (GHG) emissions associated with the production and use of each type of fuel. The total quantity of cradle-to-grave GHG emissions associated with a fuel's production and combustion per unit of energy delivered is often referred to as the fuel's "carbon score." Over the past decade, numerous lifecycle analyses have shown corn ethanol reduces GHG emissions by approximately 25-35% relative to gasoline, while cellulosic ethanol potentially reduces GHG emissions 80-90%. A more recent analysis of newer corn ethanol facilities shows modern processes can reduce GHG emissions by approximately 50% compared to gasoline.[1]

However, the lifecycle analyses completed in recent years compare the carbon score of biofuels like ethanol and biodiesel to the carbon score of *average* gasoline or diesel fuel, rather than the carbon scores of the types of gasoline and diesel that biofuels are displacing at the margins of the world liquid fuel market. The carbon score of a particular biofuel should be compared to the carbon score of the fuel it is displacing. It is widely understood that the resource base for conventional liquid fuels is declining and that new volumes of biofuels are displacing and delaying the need for unconventional high-carbon sources of liquid fuel. Unfortunately, traditional analyses of biofuels do not take this into account.

This paper outlines a methodology for estimating 1.) the weighted carbon intensity of the liquid fuels that are most likely to be displaced by biofuels over the long term; and 2.) the avoided GHG emissions resulting from displacement of high-carbon unconventional fuels with biofuels. The analysis presented here is not meant to be definitive in any way; rather, it is intended to highlight the need for robust economic modeling and additional research focused on the important questions of "what are biofuels displacing?" and "what GHG emissions are being avoided due to more biofuels use?"

This analysis shows that substituting biofuels for marginal fossil-based liquid fuels results in the avoidance of significant GHG emissions that are not currently accounted for in lifecycle analysis. These avoided emissions are *in addition to* the emissions reductions relative to average petroleum fuels that are already counted in traditional analysis. In this analysis, avoided emissions resulting from displacement of unconventional liquid fuels range from approximately 8 to 22 grams of CO2 equivalent per mega joule (g CO2e/MJ) of energy delivered by biofuels.

DETERMINING FUTURE SOURCES OF LIQUID FUEL SUPPLY GROWTH

In its 2009 Annual Energy Outlook reference case, the Energy Information Administration (EIA) projects that world liquid fuels supply will grow 22% from 86.2 million barrels per day (mbpd) in 2007 to 105.4

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[1] See A. Liska et al. "Improvements in Life Cycle Energy Efficiency & Greenhouse Gas Emissions of Corn-Ethanol." *Journal of Industrial Ecology.* Available online 22 January 2009. http://www.ethanolrfa.org/objects/documents/2110/2009_jie_improvements_in_corn_ethanol-liska_et_al.pdf

mbpd in 2030 (Table 1).[2] EIA projects that 42% of liquid fuel growth during this period will be met with unconventional fuels, while conventional sources constitute the remaining 58%. Unconventional fuels examined by EIA include oil from tar sands, extra heavy crude, biofuels, coal-to-liquids, gas-to-liquids, oil shale, and "other" fuels. EIA segments the sources of unconventional fuels growth, as shown in Table 2.

Table 1. EIA Projections of World Liquid Fuels Supply Growth, 2007-2030

	Unconventional	Conventional	Total
2007 *(mbpd)*	4.4	81.8	86.2
2030 *(mbpd)*	12.4	93.0	105.4
% Growth	181%	14%	22%
% of Total Growth	42%	58%	

Source: EIA, 2009 AEO

Table 2. Sources of Growth in Unconventional Liquid Fuels, 2007-2030

Unconventional Source	Share of Unconventional Supply Growth
Bitumen (Tar Sands)	29.9%
Extra Heavy Crude	5.8%
Biofuels	46.1%
Coal-to-Liquids	13.1%
Gas-to-Liquids	3.0%
Oil Shale	1.8%
Other	0.4%

Source: EIA, 2009 AEO

Since the goal of this analysis is to attempt to identify the fuels being displaced by biofuels over the long term, we adjusted EIA's unconventional liquid fuels to exclude biofuels, as shown in Table 3. As displayed in Table 2, biofuels are projected by EIA to account for 46.1% of the unconventional fuel growth. In Table 3, this share of the growth was apportioned to the other unconventional sources in the proportion that they exist without the inclusion of biofuels. In other words, we ask: what fuel sources would be used if biofuels were not available?

Table 3. Adjusted Sources of Growth in Unconventional Liquid Fuels, 2007-2030

Unconventional Source	Share of Unconventional Supply Growth
Bitumen (Tar Sands)	55.5%
Extra Heavy Crude	10.7%
Biofuels	***0.0%***
Coal-to-Liquids	24.2%
Gas-to-Liquids	5.6%
Oil Shale	3.3%
Other	0.7%

Source: EIA, 2009 AEO; RFA calculations

[2] We used EIA's *global* liquid fuel supply projections rather than U.S.-only projections to account for the global nature of the liquid fuel supply and to address the issue of leakage (i.e., the use of lower-carbon fuels in the U.S. may serve only to "shuffle" higher-carbon fuels and related emissions elsewhere in the global fuels market). However, it should be noted that the U.S. liquid fuel mix in the future could be more carbon intensive than the global mix, due to heavy reliance on oil imports, abundant domestic coal supplies, and proximity to Canadian tar sands.

We assumed in the worst case the void left by excluding biofuels in unconventional fuel growth would be filled only by marginal sources in the proportions shown in Table 3. In the best case, we assumed the void would be filled by EIA's overall projected growth mix of 58% conventional sources and 42% unconventional sources. Thus, it can be assumed, under the best and worst cases, that new biofuels would replace the liquid fuels sources shown in Table 4 by share.

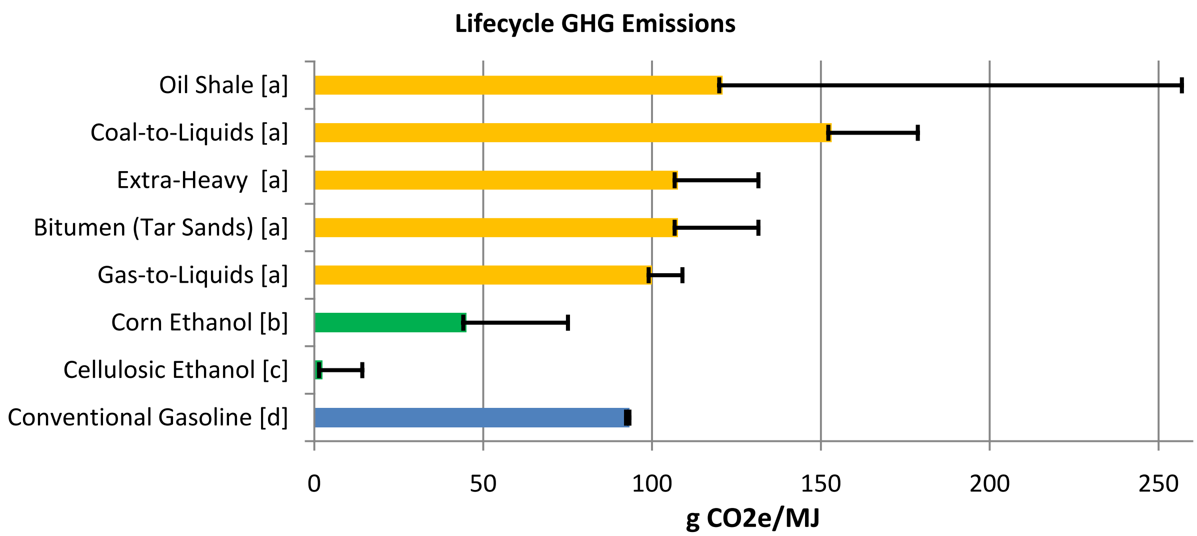
Table 4. Types and Shares of Liquid Fuels Displaced by Biofuels

Source	Worst Case	Best Case
Conventional	58.0%	69.6%
Bitumen (Tar Sands)	23.3%	16.9%
Extra Heavy Crude	4.5%	3.3%
Coal-to-Liquids	10.2%	7.4%
Gas-to-Liquids	2.4%	1.7%
Oil Shale	1.4%	1.0%
Other Unconventional	0.3%	0.2%

Source: EIA, 2009 AEO; RFA calculations

DETERMINING THE CARBON INTENSITY OF THE FUELS DISPLACED BY BIOFUELS

The fossil-based unconventional fuel sources discussed here emit significantly more lifecycle GHG emissions than both biofuels and conventional fossil fuel sources. Thus, an effect of replacing these marginal liquid fuel sources with biofuels is that significant future GHG emissions are avoided that would have otherwise occurred. A comparison of the lifecycle carbon intensity of two types of ethanol, conventional gasoline, and five marginal liquid fuel sources is shown below.



Notes:

a. Farrell & Sperling. A Low Carbon Fuels Standard for California. Part I: Technical Analysis. Aug. 1, 2007.
b. Low est. = Midwest nat. gas dry mill (Liska et al., 2009). High est. = Midwest wet mill (CARB, 2009).
c. Low estimate = Huang, 2007. High estimate = Wang et al., 2007.
d. EPA, 2009. See footnote 3.

To estimate the magnitude of avoided emissions, we examined the lifecycle carbon intensity of the unconventional sources included in EIA's projections and derived a weighted average (Table 5) based on the percentage shares shown in Table 4. Avoided emissions are those that are *above* the average lifecycle emissions of 2005 gasoline, which is derived overwhelmingly from conventional oil. Only those avoided emissions above the average gasoline baseline are accounted for here, as GHG reductions relative to gasoline that result from biofuels use are already accounted for in traditional lifecycle analysis. The benchmark used here for gasoline lifecycle GHG emissions is the 2005 average gasoline baseline as calculated by U.S. EPA for the RFS2 lifecycle analysis.[3]

Table 5. Lifecycle Carbon Score for Conventional Gasoline and Unconventional Liquid Fuels

Source	GHG Emissions (g CO2e/MJ) *Low*	*High*
Conventional Gasoline [a]	93.3	93.3
Bitumen (Tar Sands)[b]	107.7	131.5
Extra Heavy Crude [b]	107.7	131.5
Coal-to-Liquids [b]	153.2	178.7
Gas-to-Liquids [b]	100.0	109.0
Oil Shale [b]	120.9	256.9
Other [c]	97.5	102.5
Worst Case Weighted Avg.	**104.0**	**115.3**
Best Case Weighted Avg.	**101.0**	**109.2**
Worst Case Avoided Emissions [d]	***10.7***	***22.0***
Best Case Avoided Emissions [e]	***7.7***	***15.9***

Notes:
- *Table 5 shows direct lifecycle GHG emissions only*.

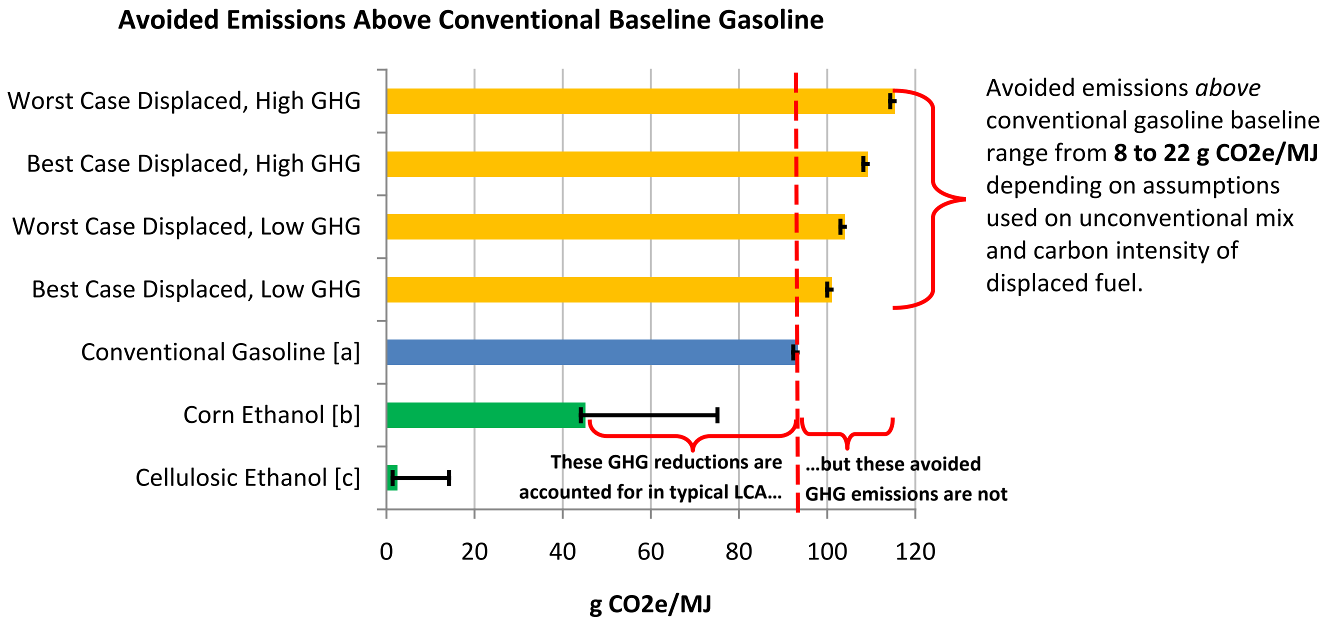
a. EPA. Federal Register, Vol. 74, No. 99. May 26, 2009. Table VI.C.1-1, pg. 25041. See footnote 3.
b. A. Farrell & D. Sperling. A Low Carbon Fuels Standard for California. Part I: Technical Analysis. Aug. 1, 2007. Table 3-2, pg. 54.
c. EIA does not define "other" unconventional fuels. We conservatively assumed the carbon score of "other" unconventional fuels would be ~5% higher than conventional for the low case and ~10% higher for the high case.
d. = Worst case weighted avg. – Conventional gasoline
e. = Best case weighted avg. – Conventional gasoline

RESULTS

Thus, based on this analysis, it can be argued that the use of biofuels between 2007 and 2030 leads to the additional **avoidance of 7.7 to 22 g CO2e per MJ** of new biofuel used above baseline gasoline levels. The case could be made that without biofuels, fossil-based unconventional sources would account for a much larger share of future liquid fuel supply growth than analyzed here, and conventional sources

[3] EPA's lifecycle GHG emissions for 2005 baseline gasoline = 2,951,858 g CO2e./mmBTU (over 30 years). To be consistent with other carbon score values, we converted EPA's baseline gasoline value to 93.3 g CO2e./MJ.

would make up a much lower share. In fact, under EIA's 2009 Annual Energy Outlook "high price" case, unconventional liquid fuel sources contribute 60% more volume to 2030 total supply than in the reference case. Obviously, the avoided GHG emissions resulting from increased biofuels use under the "high price" case would be significantly greater than in the scenarios discussed in this paper.



Notes:

a. EPA, 2009. See footnote 3.

b. Low est. = Midwest nat. gas dry mill (Liska et al., 2009). High est. = Midwest wet mill (CARB, 2009)

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CONCLUSION

Avoided emissions from unconventional sources currently are not accounted for in most lifecycle GHG analyses, including EPA's analysis conducted for the RFS2 rulemaking. In EPA's analysis, the lifecycle GHG emissions of 2022-era biofuels are compared only to the lifecycle GHG emissions of average 2005 gasoline and diesel, not the emissions associated with the liquid fuels that biofuels are likely to displace. While EPA is bound by the statute to use a 2005 baseline for gasoline and diesel, one option to address biofuels' displacement of higher-carbon liquid fuel sources in the future could be to provide GHG avoidance "credits" to the 2022 carbon scores of various biofuels.

Quantifying the liquid fuel sources that are being displaced by biofuels and determining the associated GHG impacts is no simple task. However, there is little disagreement that it is inappropriate to simply assume incremental volumes of biofuels will displace "average" liquid fuels sources now and in the future. Though the methodology presented here is simple, the results of this brief analysis demonstrate that the increased use of biofuels likely results in significant avoided GHG emissions from marginal liquid fuel sources. Further, the results point to the need for rigorous economic modeling and research to more accurately determine the unconventional fuels being displaced by biofuels and the associated GHG emissions impacts.