CATF WHITE PAPER:
CORN ETHANOL GHG EMISSIONS UNDER VARIOUS RFS IMPLEMENTATION SCENARIOS

April 2013

In 2011, the Clean Air Task Force reviewed the US Environmental Protection Agency's lifecycle greenhouse gas emissions analysis of corn ethanol and found that the Agency severely underestimated the fuel's net GHG emissions. If EPA had analyzed corn ethanol produced during 2010-2015 (when production capacity was still ramping up) rather than corn ethanol produced in 2022 (seven years after EPA expects production to level off), the Agency would have found that corn ethanol's net emissions over 30 years are approximately *28% higher* than the emissions that would result from the use of gasoline over that same period.

CATF's 2011 analysis assumed that Renewable Fuel Standard-driven production of corn ethanol would plateau in 2015 at 15 billion gallons per year. That may not be case. Cellulosic biofuel production is projected to fall far short of the annual targets established in the Energy Independence and Security Act of 2007. For example, the Organization for Economic Cooperation and Development forecasts that a maximum of 4.7 billion tons of RFS-compliant cellulosic biofuel will be available in 2022; EISA targets 16 billions gallons. EPA can address this "cellulosic void" by reducing the overarching annual volume requirements for advanced biofuels and total renewable fuels, or it can allow non-cellulosic advanced biofuels like sugarcane ethanol and biomass-based diesel to make up for the shortfall.[1] If EPA chooses the latter approach, the OECD and others predict that the United States will have to significantly increase the amount of Brazilian sugarcane ethanol that it imports. OECD expects that Brazil, in turn, would likely import US corn ethanol in order to meet its own ethanol blending requirement. The result? A new spike in US corn ethanol production and another increase in damaging GHG emissions, much of it from direct and indirect land use changes.

This white paper revisits CATF's 2011 emissions analysis and then calculates the climate impact that would occur if EPA allows sugarcane ethanol to backfill the cellulosic void and, as a result, unmet ethanol demand in Brazil causes a significant increase in US corn ethanol production.

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[1] Theoretically, EPA might allow conventional biofuels like corn ethanol to fill the cellulosic void. EPA has so far rejected this approach. In its proposed 2013 RFS volume adjustment rule, the Agency properly stated that "we do not believe it would be appropriate to lower the advanced biofuel standard but not the total renewable standard, as doing so would allow conventional biofuels to effectively be used to meet the standards that Congress specifically set for advanced biofuels." 78 Fed. Reg. 9282, 9295/2 (Feburary 7, 2013). In any event, this white paper also analyzes the additional GHG emissions that would result if EPA allowed conventional biofuels to backfill the cellulosic void.

I. GHG Emissions from Corn Ethanol Assuming a 15-Billion Gallon Limit

A. Background: EPA's 2010 Lifecycle Analysis for Corn Ethanol

For the 2010 RFS implementation rule, EPA analyzed the lifecycle GHG emissions associated with corn ethanol based on the expected performance – including technological innovations and efficiency and yield improvements – of the corn ethanol industry in the year 2022; in other words, EPA used 2022 as the starting point for its assessment of corn ethanol's lifecycle GHG emissions. The Agency then analyzed the ethanol's lifecycle GHG emissions over the subsequent 30 years (from 2022 to 2051) and compared them to the GHG emissions that would result from the production and use of gasoline over that same period. Using this approach, EPA concluded that corn ethanol would have 21% less GHG emissions than the baseline gasoline on a lifecycle basis.

EPA achieved this result by running its lifecycle GHG analysis from 2022-2051, rather than when the fuels are actually produced and consumed. The Agency's decision created the following distortions:

- EPA assumed that lifecycle international indirect land use change (ILUC) emissions in 2022 are 60% lower than ILUC emissions in 2012.[2] The agency's analytic approach largely obscures the effect of ILUC.
- EPA assumed that ethanol production emissions in 2022 are 13% lower than present production emissions.[3]

EPA projects that, as a result of EISA, the annual production and consumption of corn ethanol in the United States will increase by 4.5 billion gallons during 2010 to 2015 (rising from 10.5 billion gallons in 2009 to 15 billion gallons in 2015, which is the full increment available to conventional corn ethanol under EISA).[4] EPA should have conducted the 30-year assessment of lifecycle GHG emissions for corn ethanol produced during the ramp-up period (2010-2015) by analyzing the net GHG emissions from incremental corn ethanol beginning in 2010 and ending in 2044 (2044 being the end of the 30-year lifecycle for new ethanol produced in 2015). Instead, as mentioned above, EPA began its analysis well after the point at which the industry is expected to stop adding new corn ethanol production capacity.

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[2] EPA Spreadsheet, Docket ID No. EPA-HQ-OAR-2005-0161-3173.5(1) (http://www.regulations.gov/search/Regs/home.html#docketDetail?R=EPA-HQ-OAR-2005-0161 ("Spreadsheet EPA-HQ-OAR-2005-0161.3173.5(1)")

[3] *Id*.

[4] See Table 1 in Section II below.

B. CATF Reanalysis of Corn Ethanol Emissions

Using 2022 as a starting point for its analysis, EPA concludes that corn ethanol will meet the 20 percent GHG reduction threshold in EISA. But if the lifecycle GHG emissions analysis starts in 2010 instead, corn ethanol's net emissions over 30 years are approximately *28% higher* than the emissions that would result from the use of gasoline over that same period. Therefore, if EPA had conducted the lifecycle GHG analyses in accordance with its own real-world projections regarding corn ethanol production, it would have concluded that corn ethanol produced by newly built facilities in 2010 to 2015 does not meet EISA's 20% reduction requirement.

CATF's analysis is based exclusively on the assumptions that EPA itself used in analyzing the GHG implications of corn ethanol in promulgating the RFS2 regulations.[5] The only parameter that was changed was the 30-year period being analyzed. Instead of analyzing the net emissions from corn ethanol over 30 years starting in 2022 (as EPA did), CATF relied upon EPA's assumption that no net increases in corn ethanol capacity will occur after 2015 – *i.e.*, the final 4.5 billion gallon increment of corn ethanol production allowed under EISA will come online between 2010 and 2015. Therefore, CATF analyzed the lifecycle GHG emissions from that additional corn ethanol capacity through 2044 (30 years after industry finishes adding new corn ethanol capacity pursuant to the requirements of EISA).

The analysis set forth below compares corn ethanol lifecycle GHG emissions over 30 years as compared to those arising from the equivalent amount of gasoline and demonstrates that the emissions from corn ethanol are approximately 28% higher. Again, all of the assumptions used to develop this analysis are EPA's; the only difference is the time period being analyzed.

According to EPA, new corn ethanol production will grow by a total of 4.5 billion gallons between 2010 and 2015.

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[5] These assumptions are found in the following materials: EPA, "Regulation of Fuel and Fuel Additives: Changes to Renewable Fuel Standard Program" at 75 Fed. Reg. 14,670 (Mar. 26, 2010); EPA, "The Renewable Fuel Standard 2 Regulatory Impact Analysis" (February 2010) (Document ID No. EPA-HQ-OAR-2009-0472-1132) (http://www.regulations.gov/search/Regs/home.html#home); and EPA, Docket ID No. EPA-HQ-OAR-2005-0161-3173.5(1) (http://www.regulations.gov/search/Regs/home.html#docketDetail?R=EPA-HQ-OAR-2005-0161 ("Spreadsheet EPA-HQ-OAR-2005-0161.3173.5(1)").

Table 1: Additions of new corn ethanol[6]

	Total Available Corn Ethanol Volume (billion gallons)	Incremental Increase (billion gallons)	Cumulative Increase (billion gallons)
2009	10.5		
2010	12	1.5	1.5
2011	12.6	.60	2.1
2012	13.2	.60	2.7
2013	13.8	.60	3.3
2014	14.4	.60	3.9
2015	15	.60	4.5

EPA corn ethanol emission rates assume that ethanol refineries are natural gas fired, and that 63 percent of the plants produce dry distillers grains and 37 percent produce wet distiller grains. Emission data below are derived from the EPA spreadsheet used to calculate corn ethanol lifecycle emissions.[7]

Table 2 below summarizes the emission assumptions used in this analysis (which mirror the assumptions used by EPA in its analysis). First year emissions are highest because of the initial indirect land use change driven by increased demand for ethanol in the US. In years 2 to 19 lower ILUC emissions are assumed, and in years 20 to 29 ILUC emissions are lower still.[8] The composite emission rates in the third column reflect the weighting between the processes produce dry distillers grains and those that produce wet distillers grains, as described above.

Table 2: Emission rates used in this analysis[9]

	Annual Emission rate (g CO_2e per mmBtu)		
	Dry Distillers Grains	Wet Distillers Grains	Composite
First year	1,721,152	1,709,111	1,716,697
Years 2-19	86,574	74,533	82,119
Years 20-29	56,276	44,236	51,821
Gasoline			98,204

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[6] *See* Table I.A.1-1 in EPA's RFS2 Regulations,75 Fed. Reg. at 14,674.
[7] Spreadsheet EPA-HQ-OAR-2005-0161-3173.5(1).
[8] Spreadsheet EPA-HQ-OAR-2005-0161.3173.5(1).
[9] Calculations derived from Spreadsheet EPA-HQ-OAR-2005-0161.3173.5(1))

Total emissions are heavily front-loaded because for each year new that ethanol production is added, there is an initial large pulse of ILUC emissions. Table 3 below presents corn ethanol emissions for 2010-2016. 2016 is the first year that new ethanol is not added, which accounts for the substantial drop in emissions. Figure 1 below presents these same data graphically, alongside comparable emissions from an energy equivalent amount of gasoline. The volumes on which this figure is based are presented in Table 1, above.

As Table 3 and Figure 1 demonstrate, by 2015, corn ethanol will have added 745 million tons of carbon dioxide equivalent ("CO_2e") to the atmosphere in contrast to 149 million tons arising from an energy equivalent amount of gasoline.

Table 3: Emissions from new corn ethanol and an energy equivalent amount of gasoline 2010-2016 (tons CO_2e)

	Gasoline	Corn Ethanol
2010	12,432,626	217,333,714
2011	17,405,677	97,329,751
2012	22,378,728	101,488,257
2013	27,351,778	105,646,763
2014	32,324,829	109,805,269
2015	37,297,879	113,963,775
2016	37,297,879	31,188,796
7-Year Cumulative	149 MT	745MT

Figure 1[10]

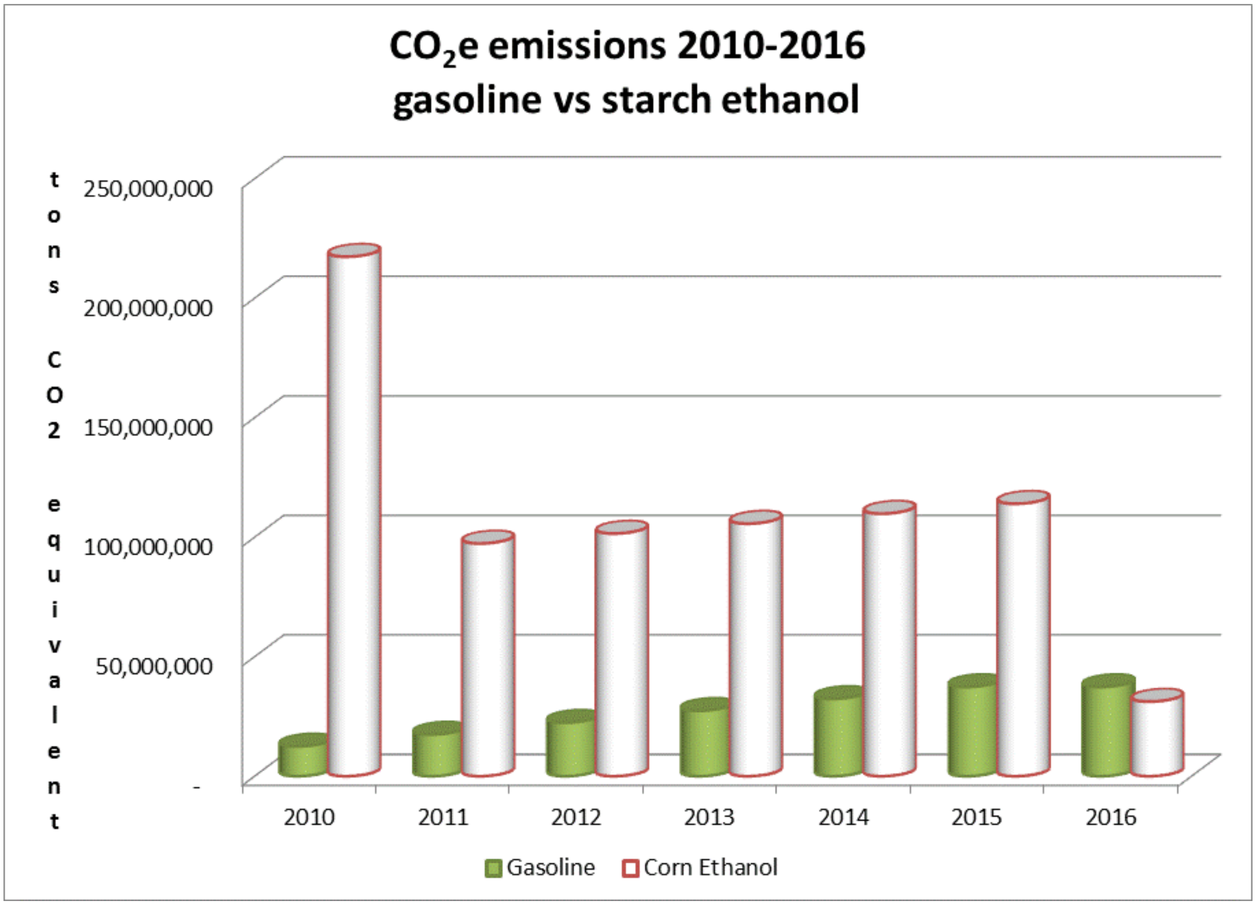
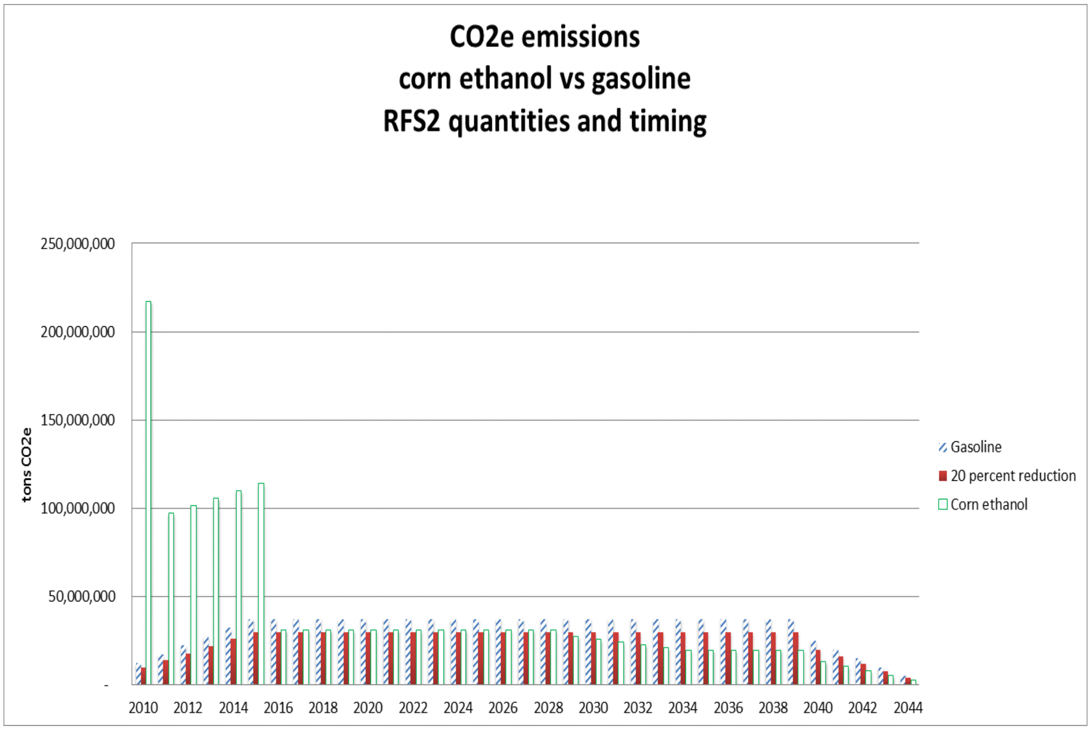


Figure 2 below presents year-by-year GHG emissions for corn ethanol and baseline gasoline, from 2010 through 2044. A 20 percent reduction below the baseline gasoline emissions level is also shown.

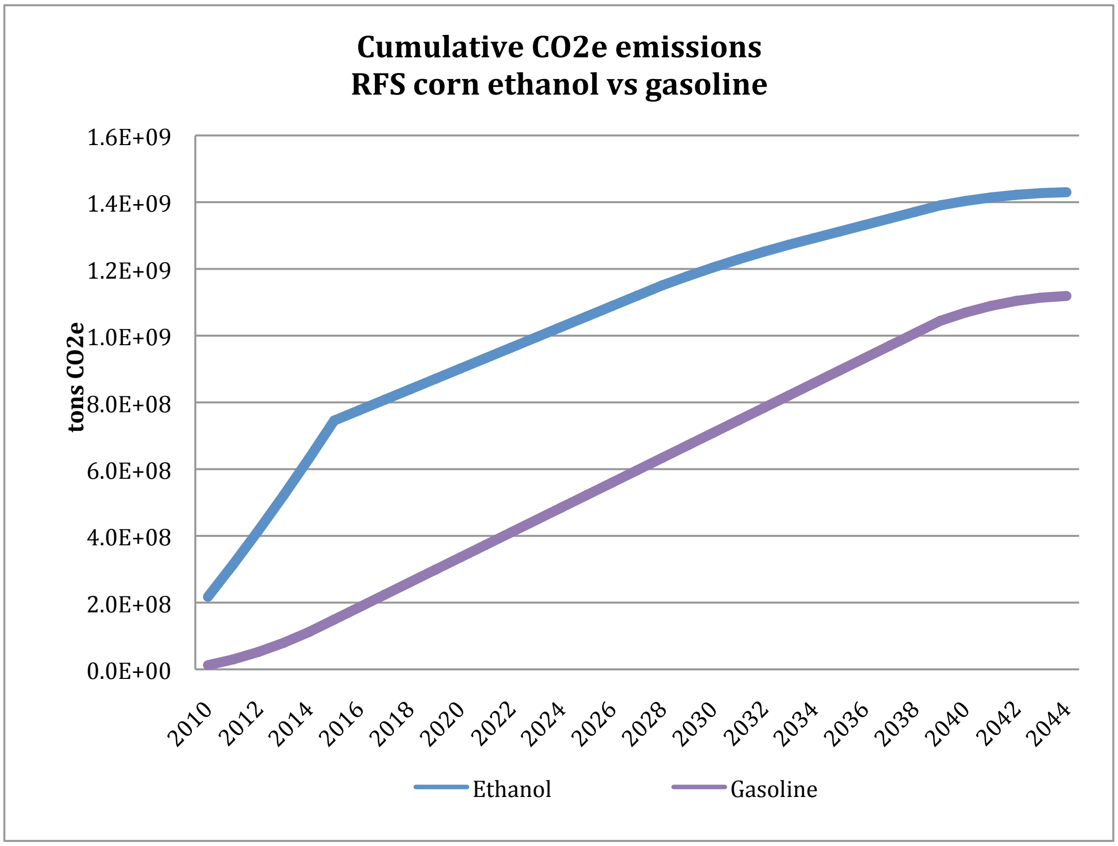
[10] Calculations derived from Spreadsheet EPA-HQ-OAR-2005-0161.3173.5(1)

Figure 2



And finally, Figure 3 (below) presents the cumulative emissions from the period 2010-2044 from corn ethanol and gasoline. This analysis is carried though 2044 to capture a full 30 years of emissions from each year-class of new ethanol (i.e., the 30-year lifecycle for ethanol added ends in 2044). In 2044, cumulative GHG emissions from corn ethanol equal about 1.4 billion tons; the emissions from an energy equivalent amount of gasoline equal 1.1 billion tons. The cumulative emissions from the production and use of gasoline do not exceed those from corn ethanol until 2054. In other words, when the lifecycle analysis encompasses the years when corn ethanol production and consumption actually increases pursuant to EISA, it shows that the 30-year lifecycle GHG emissions from corn ethanol are approximately 28% higher than those from gasoline.

Figure 3



II. New GHG Emissions from Corn Ethanol if Advanced and/or Conventional Biofuels Are Allowed to Backfill the Cellulosic Void

The Clean Air Act, as amended by EISA 2007, establishes annual cellulosic biofuel consumption targets for 2010-2022, but instructs EPA to adjust actual volume requirements for cellulosic fuels so that they match "the projected volume available during the calendar year."[11] So far, EPA has had to reduce the volume requirements each year, and industry analysts uniformly expect that cellulosic biofuel production will continue to fall short of EISA targets through 2022. EISA also authorizes EPA to make corresponding reductions to the overarching advanced biofuel and total renewable fuel volume requirements when it reduces the cellulosic requirement, but so far EPA has declined to use that authority and has instead allowed advanced biofuels like sugarcane ethanol and biomass-based diesel to make up for the shortfall in cellulosic production.

[11] CAA §211(o)(7)(D).

In *Agricultural Outlook 2012-2021*, a joint publication of the Organization for Economic Cooperation and Development and the UN Food and Agricultural Organization, the agencies write that "until now" EPA's adjustments to the annual cellulosic volume requirement "did not have important impacts on agricultural and biofuel markets because the level of the cellulosic shortfall was small." Going forward, that is no longer the case. "[B]y 2021," the agencies write, "the amounts will be much larger and EPA's decision will likely have impacts on agricultural markets."[12] Accordingly, Agricultural Outlook 2012-2021 "identifies the effect of three alternative implementation options" available to EPA.

- Option 1 assumes that EPA lowers the total and advanced biofuel mandates;
- Option 2 assumes that EPA maintains the mandates, and that the shortfall in US production is made up with imports of Brazilian sugarcane ethanol; US corn ethanol production rises to satisfy unmet demand in Brazil.
- Option3 assumes that EPA maintains the total mandate but lowers the advanced mandate, allowing the cellulosic void to be filled by additional US corn ethanol.

As far as the GHG emissions associated with corn ethanol are concerned, OECD's Option 1 is not materially different from situation CATF analyzed in 2011 (described above). US corn ethanol production is expected to level off at around 15 billion gallons per year.

Under both Options 2 and 3, however, US corn ethanol production would rise above the 15 billion "soft ceiling" created by EISA. In OECD's Option 2, additional corn ethanol is produced to replace the Brazilian sugarcane ethanol exported to the United States (i.e., the United States would increase the amount of Brazilian sugarcane ethanol it imports because sugarcane ethanol qualifies as an "advanced biofuel" under the RFS2; meanwhile, Brazilian consumers would import relatively cheaper corn ethanol from United States to meet Brazil's ethanol blending requirements). In OECD Option 3, conventional biofuels are allowed to directly fill the cellulosic void, so production of US corn ethanol increases.

The following table summarizes assumptions about US corn ethanol production for three OECD scenarios for 2021 relative to the assumptions we use in our RFS2 analysis:

Table 3: Assumptions about US corn ethanol production (RFS2 Baseline, OECD Scenarios)

Scenario	Total production (billion gallons)	Incremental production (relative to 10.5 billion gallon base) (billion gallons)	New annual increment 2016-2021 (additions over 6 years) (billion gallons)
RFS2	15	4.5	--
OECD-FAO Option 1	14.85	4.35	-.025
OECD-FAO Option 2	16.65	6.15	.275

[12] OECD-FAO, *Agricultural Outlook 2012-2021* 96 (2012) (http://www.oecd.org/site/oecd-faoagriculturaloutlook/)

OECD-FAO Option 3	21	10.5	1

The OECD-FAO report provides projections for only a single year, 2021. For this analysis, the addition of new corn ethanol is evenly spread out over six years, from 2016-2021.

The following graph (Figure 4) presents total annual CO_2 emissions from Options 2 and 3, along with CATF 2011 projections for the RFS2 and gasoline.

Figure 4: Annual Corn Ethanol CO_2 Emissions (RFS2 Baseline, OECD Options, Gasoline)

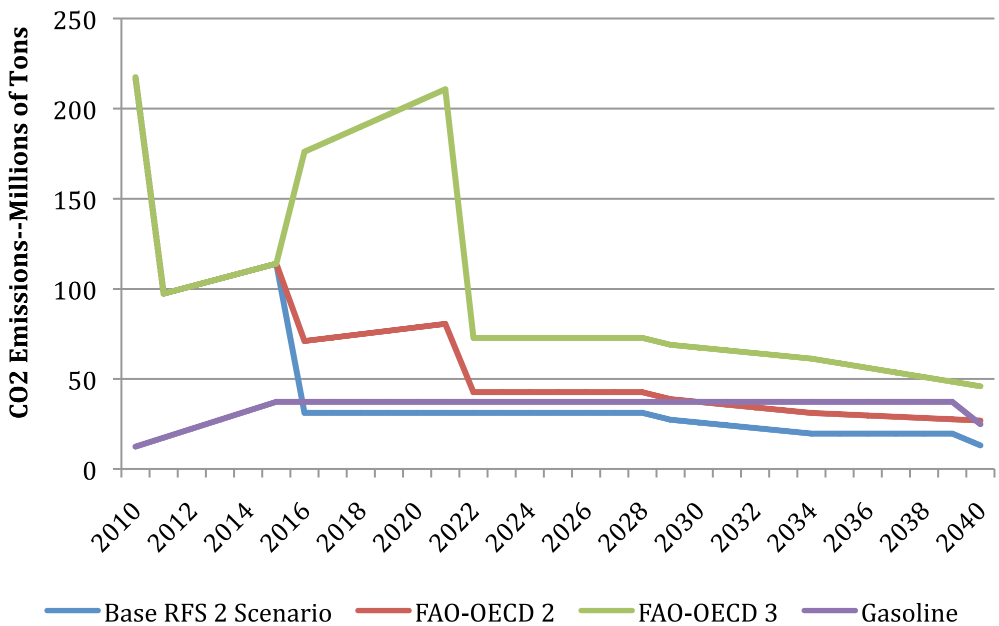


Table 4 below summarizes the CO_2 emissions consequence for each scenario and for projected gasoline consumption for the period 2010-2040:

Table 4

Scenario	Cumulative CO_2 emissions 2010-2040 (millions of tons)	Incremental Cumulative CO_2 emissions over the RFS2 baseline (millions of tons)
RFS2	1,400	
Option 2	1,880	477
Option 3	3,120	1,680
Gasoline	1,069	(-331)

Key points:

- Option 2 results in a 34% increase in CO_2 emissions relative to the RFS2 baseline;
- Option 3 more than doubles emissions, resulting in a 117% increase in CO_2 emissions relative to the RFS2 baseline.

As in CATF's 2011 analysis of RFS2 baseline (which examined emissions from the 4.5 billion gallon increase in corn ethanol production during 2010-2015), lifecycle emissions from the corn ethanol used to comply with the RFS would be higher than the emissions that would result from an energy equivalent volume of gasoline.

The following two figures are drawn from CATF's 2011 analysis. Figure 5 shows annual emissions for each of three trajectories: corn ethanol used to comply with RFS2 baseline volume requirement (referred to as "EtOH modeled"), an energy equivalent volume of gasoline, and a 20% reduction in GHG emissions from gasoline (which EISA required of non-grandfathered conventional biofuels).

Figure 5: Annual Corn Ethanol CO_2 Emissions

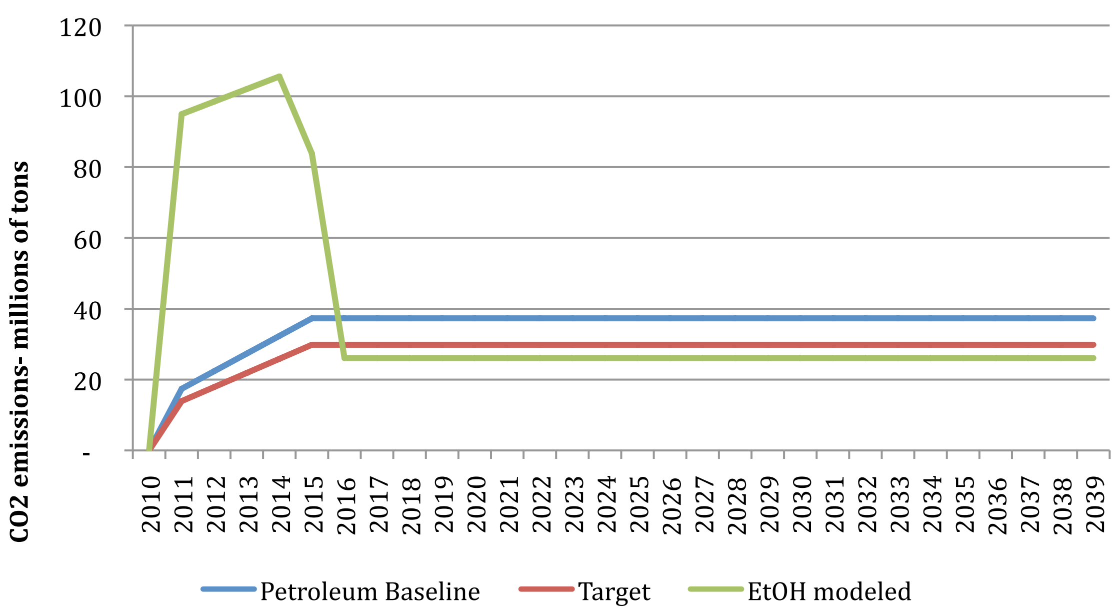
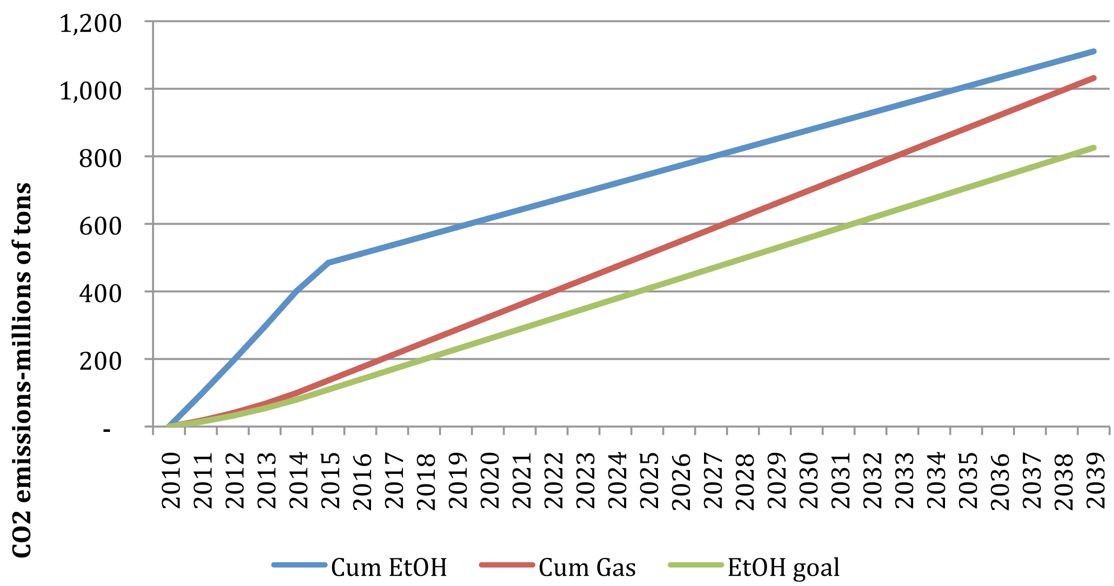


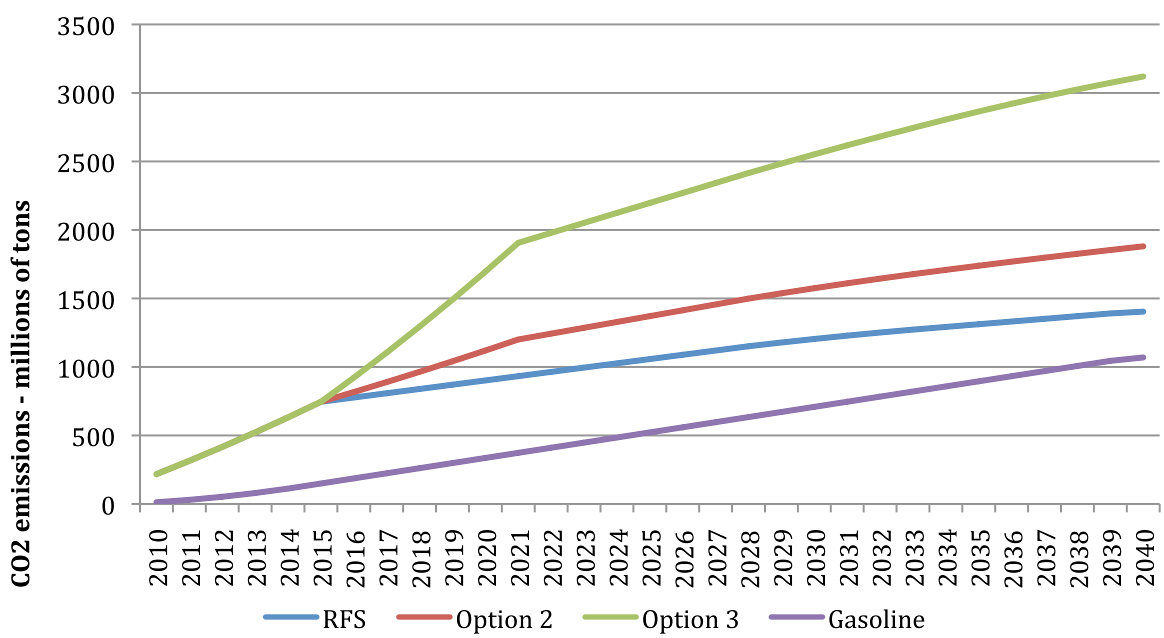
Figure 6 shows the cumulative emissions for the same three.

Figure 6



The following graph, Figure 7, presents cumulative emissions for RFS2 baseline, OECD Options 2 and 3, and gasoline:

Figure 7



It should be clear that both OECD Options 2 and 3 are significantly worse from a climate perspective than the RFS as originally modeled. Indeed, for the period considered, all three biofuel scenarios have significantly higher emissions than gasoline.

Steve Brick
Jonathan Lewis