Growth Energy Comments on EPA's Renewable Fuel Standard (RFS) Program: RFS Annual Rules

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INTRODUCTION

Growth Energy respectfully submits these comments on the Environmental Protection Agency's Proposed *Renewable Fuel Standard (RFS) Program: RFS Annual Rules*.[1] Growth Energy is the world's largest association of biofuel producers, representing 89 biorefineries that produce nearly 9 billion gallons annually of low-carbon renewable fuel and 95 businesses associated with the biofuel production process.

Congress established the RFS program to force the market to increase the use of renewable fuel in the nation's transportation fuel supply. Congress did so in recognition of the many benefits that increased renewable fuel use would bring: reduction in harmful greenhouse gas ("GHG") emissions, enhanced energy security and independence, and economic development. Although renewable fuels continue to promote these benefits—in fact, conventional starch ethanol achieves more than double the GHG reduction that Congress initially expected—EPA's implementation of the RFS program to date has not fully served Congress's objectives. EPA has repeatedly failed to issue timely standards, and then has set the standards after the fact to the actual level of renewable fuel use. EPA has long guarded a massive RIN bank ostensibly to provide a safety valve for an emergency, with the consequence of undermining the very incentives that Congress intended the RFS program to provide. And EPA's annual process of determining standards has often simply aimed to match the standards to what it predicted the market would do anyway, nullifying the RFS program.

Although EPA's current proposal contains several salutary features, it also again reflects these and other fundamental errors in the agency's approach to the RFS program. On the one hand, the proposal includes the conclusion that a non-advanced volume of 15 billion gallons of renewable fuel is readily achievable, a long overdue remedy of the unlawful 2016 general waiver, and a long overdue decision to bring small refinery exemption ("SRE") decisions into the sunlight. On the other hand, many aspects of the proposal would seriously damage the RFS program and violate EPA's legal duties, by, for example, substantially undervaluing the benefits of conventional ethanol for climate change, relieving obligated parties of their failure to meet their 2020 obligations (even after accounting for the actual levels of fuel use and SREs in 2020), and nullifying the program for 2021. Growth Energy, therefore, urges EPA to carefully reconsider many parts of its proposal to ensure that they accord with the goals Congress set for the RFS program and the limits Congress placed on EPA's authority.

Growth Energy also urges EPA to finalize this rulemaking expeditiously. Compliance year 2022 is well underway and market participants need clear, definite RFS signals. As this proposal shows, delay translates into lost opportunity to encourage increased renewable fuel use and fulfill the program's aims. It is imperative that EPA minimize delay in issuing standards.

More specifically, in this comment, Growth Energy argues as follows:

Part I: *EPA must adopt a framework for performing a reset that is faithful to the RFS Program's statutory structure and purpose.* In proposing standards for 2020, 2021, and 2022,

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[1] *Renewable Fuel Standard (RFS) Program: RFS Annual Rules*, Proposed Rule ("NPRM"), 86 Fed. Reg. 72,436 (Dec. 21, 2021).

EPA invokes its reset authority for the first time. Contrary to EPA's proposed approach, the reset is not a valid mechanism to re-open previously finalized standards, to override congressional directives and priorities, or to engage in an amorphous balancing of factors as it sees fit. Rather, Congress intended reset mechanism to be a targeted prospective correction for the specific conditions that triggered the reset. In conducting a reset, EPA must still establish volume requirements that, first and foremost, further Congress's market-forcing policy and objectives, to the extent that a volume of renewable fuel use is feasible and will not cause important and severe harm of the type that would trigger another waiver. Further, EPA must always take into account the best available science when performing a reset.

Part II: *EPA should prioritize climate change impacts and must incorporate the best available science in its analysis.* Reducing GHG emissions from the transportation sector is a core congressional objective of the RFS—indeed the RFS is the only Clean Air Act program explicitly aimed at reducing GHG emissions—and deserves special emphasis. Congress's intent that implementing the RFS's market-forcing policy will achieve the full measure of available GHG reductions from transportation fuel aligns with EPA's and the Administration's stated climate goals and efforts to decarbonize the transportation sector. Doing so requires EPA, in this rulemaking, to update its lifecycle GHG emissions analysis for conventional corn ethanol using the best currently available science, which is much more favorable than EPA's existing 2010 lifecycle analysis. Specifically, two expert reports on lifecycle analysis should guide EPA's update: (1) Environmental Health and Engineering, a multidisciplinary team of environmental health scientists and engineers, presents critical analysis of available credible studies deriving a central best estimate of carbon intensity, taking uncertainty into account; and (2) Stefan Unnasch of Lifecycle Associates, an independent environmental consulting firm specializing in lifecycle analysis of fuel production pathways, presents a comprehensive review of the emissions factors of the ethanol lifecycle and explains why several key elements of EPA's 2010 lifecycle analysis are demonstrably no longer valid.

Part III: *EPA must correct its overstatement of potential adverse environmental impacts associated with RFS.* There is no credible evidence that the proposed standards will adversely affect wetlands, ecosystems, species, habitat, water quality/availability, or soils. More specifically, claims that the RFS causes land use change are unsubstantiated, and EPA's environmental assessment should reflect the absence of an established causal relationship between the RFS and any adverse impacts to wildlife habitat, ecosystems, or species. There is similarly no sound science that the RFS program has caused or will cause adverse impacts to water quantity or quality. EPA must correct the record on its treatment of these issues. Moreover, EPA may, and should, make a finding under Section 7 of the Endangered Species Act that the proposed 2022 standards would have no effect on listed species or habitat, nor could the proposed 2020 and 2021 standards conceivably have such an impact because those years are entirely past. On the other hand, EPA fails to recognize the potentially significant benefits to air quality associated with ethanol-blended fuels. Finally, EPA's environmental justice analysis makes wholly unsupported statements regarding adverse impacts to soil and water that may have negative impacts on environmental justice communities. EPA should continue to recognize the important role biofuels may play in mitigating disproportionate impacts of climate change on low-income and vulnerable communities, as well as the air quality benefits of ethanol-blended fuels for these communities.

Part IV: *EPA's proposed modification of the 2020 standards undermines the RFS program, contradicts the Clean Air Act, and is irrational.* EPA proposes to retroactively reduce the 2020 volumes to those actually used in 2020. This is plainly unlawful. EPA has no power to relieve obligated parties of their noncompliance simply because they did not comply. Doing so nullifies the RFS program. Congress designed the RFS program to force the market to use increasing volumes of renewable fuel each year, and the threat of penalties for noncompliance is the mechanism by which the program implements this design. EPA's proposed retroactive absolution creates a perverse incentive: obligated parties will have no reason to bother complying with RFS standards. When they fail, EPA will absolve them, and the more they fail, the more likely EPA is to save them. Congress did not grant EPA such a counterproductive power. Certainly, the reset provision does not grant such power. The reset provision was intended to enable EPA to prospectively issue a multi-year waiver to remedy the circumstances that triggered the reset. Moreover, EPA's assessment of the appropriate reduction of the 2020 standards is flawed. The standards automatically account for lower-than-projected demand for transportation fuel in 2020. Further, EPA should not reduce the standards to account for lower-than-projected SREs. But even if those adjustments were valid, EPA's proposed reduction would still exceed them by more than half a billion RINs. None of EPA's reasons for the reduction is well-founded or rational. Having to use carryover RINs, to carry forward RIN deficits, or to incur noncompliance penalties are precisely how the RFS program provides compliance flexibility and ultimately ensures compliance; those are not adverse consequences EPA can or should alter the standards after the fact to avoid. EPA's approach to the RIN bank is particularly troubling; EPA has long said the bank would provide a cushion for a major unforeseen compliance disruption, and yet now EPA proposes *not* to draw on the bank *because* there was an unforeseen compliance disruption, namely, the Covid-19 pandemic. That is irrational and undermines the RFS program.

Part V: *EPA's proposal to set the 2021 standards to actual levels unlawfully negates the RFS Program.* EPA's proposal to set 2021 volumes at levels of actual use is also unlawful. Again, the reset authority cannot be used retroactively or to go beyond remedying the conditions that triggered the reset. EPA's proposal also negates the RFS program for 2021. Although the D.C. Circuit previously approved of an approach similar to what EPA proposes for 2021, that decision does not condone EPA's now-routine procedure of delay and negation. The Clean Air Act cannot be interpreted to grant EPA the power to cancel the program, which is the effect of EPA's proposal. In setting 2021 standards, EPA should instead—as it has in some past years—determine the volumes based on data available as of November 30, 2020, and allow obligated parties to comply through carryover RINs and deficit carryforward. That approach fulfills Congress's clear directive that EPA ensure that the volume requirements be met regardless of EPA's delay in issuing standards.

Part VI: *EPA substantially understates the reasonably feasible volume of ethanol use in 2022*. EPA's proposed 2022 standards reflect an unjustifiably low expectation of ethanol use. There is ample production-facility capacity, feedstock, distribution infrastructure, and vehicles to consume vastly more ethanol than EPA assumes—without adverse environmental or economic consequences. Indeed, projected ethanol volumes assume that only a miniscule fraction of existing infrastructure for delivering and consuming E85 and E15 will be used. The so-called E10 blendwall is not the *problem*; it is the *consequence* of market conditions that do not encourage the market to shift from E10 to higher-ethanol blends. The solution is precisely how

Congress intended the RFS program to function: higher RFS requirements would raise RIN prices, encouraging investments and discounts of higher-ethanol blends relative to E10, thereby motivating consumers to choose those blends at substantially higher volumes.

Part VII: *In setting RFS standards, EPA should backfill shortfalls with any other available qualifying renewable fuels.* The Clean Air Act and principles of reasoned decisionmaking require that EPA backfill any renewable fuel shortfall with any other types of reasonably available qualifying renewable fuel, unless doing so could trigger a waiver or otherwise cause important and severe harm. EPA's 2022 proposal ignores this by mechanically reducing the total renewable fuel standard by the same amount as the projected cellulosic shortfall. The result is to unnecessarily lower total renewable fuel volumes, thereby increasing GHG emissions from standard fossil fuels that could be replaced with other renewable fuels. This shortchanges the RFS program's ability to achieve both Congress's and the administration's environmental goals.

Part VIII: *EPA must include carryover cellulosic RINs in the available volume when reducing the cellulosic volume requirement.* The Clean Air Act's text and purpose require that, for purposes of exercising the cellulosic waiver, EPA count available carryover cellulosic RINs toward the projected volume of cellulosic fuel that is available during a calendar year.

Part IX: *The proposed RFS standards would not appreciably raise retail prices for food or gasoline*. Prices for 2020 and 2021 are already past and therefore cannot be affected by this proposal. And EPA's proposed non-advanced volume of 15 billion gallons for 2022—even if filled entirely with conventional ethanol—would not divert corn from projected non-ethanol uses and thus would not increase corn or associated food prices. Further, strong empirical data show that expected renewable fuel use will actually lower retail gasoline prices.

Part X: *EPA's proposed response to the invalidation of its 2016 general waiver on remand is necessary and appropriate.* Growth Energy appreciates EPA's proposed remedy for the unlawful general waiver of the 2016 standards on remand from the D.C. Circuit. That error has long undermined the RFS program by inflating the RIN bank, which in turn has suppressed RIN prices and dampened the RFS program's incentives to increase the use of renewable fuel. Only by remedying the unlawful error through a make-up obligation does EPA comply with the court's judgment and fulfill its statutory duty to ensure that the *legally valid* applicable volumes are met. It is imperative, though, that EPA also issue its promised second 250-million-gallon supplemental requirement for 2023.

Part XI: *EPA should retain the standard equation as revised in the 2020 rule.* Even if EPA adopts the standards and findings of its separately proposed denial of pending SRE petitions (as it should), EPA should still retain the standard equation as revised by the original 2020 rule, so that the equation adjusts for projected SREs. That would enable EPA to set future standards that are rationally and reasonably calculated to ensure that the applicable volume requirements are met, as EPA is statutorily required to do.

Part XII: *Robust RFS requirements promote rural economic health.* As Congress expected, a commitment to growth in the use of ethanol promotes meaningful economic benefits, especially in rural and agricultural areas of the country. The ethanol industry supports hundreds of thousands of jobs and creates billions of dollars of household wealth and GDP. Increasing ethanol use would help grow these benefits.

Part XIII: *EPA is obligated to adjust the 2022 RFS standards to make up for past retroactive SREs*. The massive volume of retroactive SREs that EPA has granted in the past have ballooned the RIN bank and undermined the market-forcing effect of the RFS program. To fulfill its statutory duty to ensure that the volumes are met, EPA must adjust the 2022 standards to offset the past retroactive SREs. Failing to do so also violates principles of reasoned decision by disregarding a central problem with the standard-setting task and by setting standards that EPA knows in advance will fail to serve their intended purpose. This failure also converts exemptions into atextual waiver, which EPA has no authority to do.

Part XIV: *It is imperative that renewable fuel producers have flexibility to use biointermediates in fuel production in order to lower costs and drive innovation.* EPA should ensure that the final biointermediates regulations facilitate use of biointermediates, afford needed flexibility to producers, and are not unduly burdensome on potential biointermediates or renewable fuel producers.

Part XV: *EPA should act expeditiously to approve the numerous pending registration applications for simultaneous production of starch and cellulosic ethanol from corn kernel feedstock.* Growth Energy urges EPA to expedite pathway approval for carbon capture, utilization, and storage, and to approve the pending petition to allow biodiesel and renewable diesel facilities to use corn oil produced from corn wet mills as feedstock.

Part XVI: *EPA should adopt the proposed approach to confidential business information.* Growth energy supports EPA's proposal not to treat as confidential basic information relating to SRE petitions and SRE decisions for purposes of the Freedom of Information Act. EPA thwarts essential oversight and engages in secret national lawmaking when it conceals its SRE decisions. EPA's proposal accords with recent case law, Justice Department guidance, and good government practices. EPA has made similar proposals in the past; now is the time to finally adopt this important policy change.

DISCUSSION

I. OVERVIEW OF STATUTORY FRAMEWORK: WHEN RESETTING RFS VOLUMES, EPA'S MANDATE IS TO PRIORITIZE CONGRESS'S CORE RFS OBJECTIVES TO THE EXTENT REASONABLY FEASIBLE, UNLESS DOING SO WOULD CAUSE IMPORTANT AND SEVERE HARM

A. EPA Must Implement the Reset So as to Serve the RFS Program's Core Objectives

In the Energy Policy Act of 2005 ("EPAct") and Energy Independence and Security Act of 2007 ("EISA"), Congress created the RFS and established annual renewable fuel volumes in order to achieve three principal objectives: (1) reduce GHG emissions to address climate change; (2) improve U.S. energy security; and (3) support agricultural development. These fundamental purposes are reflected in the statutory text codified at section 211(o) of the Clean Air Act;[2] well-settled by the case law[3] and legislative history;[4] and EPA's own statements (e.g., "Congress created the renewable fuel standard (RFS) program to reduce greenhouse gas emissions and expand the nation's renewable fuels sector while reducing reliance on imported oil.").[5]

Moreover, as discussed in greater detail below, Congress intended the RFS to be *market-forcing*—the statutory volumes are not mere projections of what the market could be anticipated to achieve in the absence of the program and applied in that manner they would serve no purpose. "Congress intended the Renewable Fuel Program to be a market forcing policy that would create demand pressure to increase consumption of renewable fuel."[6] The steadily increasing volumes established by the RFS are designed–by sending appropriate price signals to the market—to *incentivize* and *accelerate* the transition from petroleum-based fuels to biofuels,

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[2] 121 Stat. 1492, Energy Independence and Security Act of 2007.

[3] *American for Clean Energy v. EPA ("ACE")*, 864 F.3d 691, 696 (D.C. Cir. 2017) ("Congress intended the Renewable Fuel Program to move the United States toward greater energy independence and to reduce greenhouse gas emissions."); *Growth Energy v. EPA*, 5 F. 4th 1, 7 (D.C. Cir. 2021) ("To move the United States towards greater reliance on clean energy, the Clean Air Act's Renewable Fuel Standard Program calls for annual increases in the amount of renewable fuel introduced into the U.S. fuel supply."); *American Fuel & Petrochemical Mfrs. v. EPA*, 937 F.3d 559, 568 (D.C. Cir. 2019) ("Enacted in 2005 and amended in 2007, the Renewable Fuel Program … was designed '[t]o move the United States toward greater energy independence and security' and 'to increase the production of clean renewable fuels.'").

[4] 149 Cong. Rec. S5986, 2003, Statement of Sen. Tim Johnson, Co-Sponsor ("Simply put, adoption of the RFS amendment will help lower our dependence on foreign oil, strengthen energy security, increase farm income, provide for clean air, and create jobs throughout the United States, particularly in the rural communities."); *id.* at S5985, Statement of Tom Daschle, Co-Sponsor ("Clean air benefits cannot be understated. In 2002 alone—just last year—ethanol use in the United States reduced greenhouse gas emissions by 4.3 million tons, which is the equivalent of removing more than 636,000 vehicles from the road. That is a remarkable achievement."); *id.* at S6048, Statement of George Voinovich, Co-Sponsor ("Importantly, renewable fuels help to reduce greenhouse gases emitted from vehicles. Including carbon dioxide, methane, and other gases that contribute to global warming—another answer to the problem of carbons.").

[5] *Renewable Fuel Standard Program*, EPA, https://www.epa.gov/renewable-fuel-standard-program; s*ee also*, *e.g.*, NPRM at 72,439 (recognizing congressional "intent [behind the RFS] to support increasing production and use of renewable fuels, and the potential positive impacts of renewable fuels on several of the statutory factors such as climate change and energy security"); EPA, *Renewable Fuel Standard Program (RFS2) Summary and Analysis of Comments* 1-1 (Feb. 2010), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1007GC4.pdf ("As our analysis in support of the rulemaking demonstrates, we believe that the increase[d] use of renewable fuels in place of petroleum fuels will provide both greenhouse gas and energy benefits to our nation, as well as significant economic benefits to our agricultural sector.").

[6] *ACE*, 864 F.3d at 705 (quotation marks omitted).

in order to fully capture their societal, economic, and environmental benefits. Various statements in EPA's current proposal recognize the market-forcing intent of the RFS.[7]

The Proposed Volume Standards for 2020, 2021, and 2022 ("Proposed Rule") is significant because it marks the first time EPA has invoked its authority under Section 211(o)(2)(B)(ii) to reset the statutory volumes originally established by Congress.[8] The reset is not, however, an occasion for EPA to reconsider or refashion the purposes behind the RFS program; nor is it an authorization to retroactively reopen annual RVO rules finalized in previous years. It is, rather, the opportunity provided by Congress for EPA to conduct a midcourse correction and to recalibrate the statutory volume requirements in order to pursue full implementation of the program's market-forcing function, consistent with the unforeseen constraints that triggered the reset.

To be sure, Congress identified a set of factors for EPA to consider in establishing new volumes in the event the reset is triggered.[9] And EPA has a certain degree of discretion in the way it analyzes and applies these factors. But Congress did not intend these factors to be an excuse for EPA to write on a clean slate, to substitute its own judgment for Congress's purposes, or to engage in a free-form weighing and balancing of factors to establish new volumes however EPA sees fit in pursuit of whatever objectives EPA wishes to prioritize.[10]

In short, Congress did not intend the reset to be unmoored from the RFS program's original intent or from the conditions that triggered the reset. Correspondingly, Congress did not intend the reset mechanism to authorize a complete reworking of those parts of the RFS program that *are* functioning properly. To the contrary, Congress created the reset authority to allow EPA to make a targeted correction in the implementation of the RFS program under a narrowly circumscribed set of circumstances, and then to assess a number of factors, but only to the extent relevant to determining the best way to address the circumstances that triggered the reset in the first place and while continuing to pursue the program's purposes. Thus, the reset primarily empowers EPA to implement a multi-year waiver to spare itself and interested parties the burdens and uncertainty of annual, ad hoc waiver proceedings, and consideration of the remaining statutory factors is relevant only to the extent they help EPA improve implementation

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[7] *See*, *e.g.*, NPRM at 72,439 (noting EPA's reliance on "our assessment of the ability for the RFS program to incentivize increased production and use of renewable fuel in 2022").

[8] *See* NPRM at 72,443 n.33.

[9] 42 U.S.C. § 7545(o)(2)(B)(ii).

[10] *Cf.* NPRM at 72,443 ("While the statute requires that EPA base its determination on an analysis of these factors, it does not establish any numeric criteria, require a specific type of analysis (such as quantitative analysis), or provide guidance on how EPA should weigh the various factors.").

of the program to better realize the program's core objectives. This is evident from the basic structure of the RFS program and how the reset authority fits within that structure.[11]

B. The Statutory Structure Shows That the Reset Serves as a Prospective Multi-Year Waiver

In the EPAct and EISA, Congress established applicable volumes for various categories of renewable fuels in a statutory table. The table provides annual applicable volumes through 2022 for total, advanced, and cellulosic biofuels, and through 2012 for biomass-based diesel.[12]

Congress authorized EPA to "waive" these statutory applicable volumes but *only* in circumstances where certain expressly prescribed conditions are met. For example, EPA may invoke the "general waiver" provision under Section 211(o)(7)(A) to reduce volumes from any category of renewable fuel if either EPA determines that the statutory volume would severely harm the economy or environment of a State, a region, or the United States, or if EPA determines that there is inadequate domestic supply of renewable fuel to meet the statutorily required volume.[13] Further, EPA must invoke the "cellulosic waiver" provision under Section 211(o)(7)(D) to reduce the volume of cellulosic biofuel if EPA determines that cellulosic biofuel production is projected to be less than the statutory volume.[14]

EPA's reset authority under Section 211(o)(7)(F) is triggered only if EPA invokes these waivers to reduce the statutory volume for a given category of renewable fuel by at least 20 percent for two consecutive years or by at least 50 percent for a single year.[15] At that point, EPA must establish new applicable volumes for the waived renewable fuel category, and it must do so for all of the remaining years in the statutory table.[16]

EPA must exercise its reset authority within one year of the Agency action that triggered the waiver.[17] EPA must also finalize the reset volumes at least 14 months prior to the first year to which they are applicable.[18] EPA's reset must be based on the Agency's assessment of a set of statutory factors organized into six groups,[19] and EPA must carry out this analysis in

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[11] *See King v. Burwell*, 576 U.S. 473, 498 (2015) (holding that a statute's structure and purpose are vitally important to its interpretation since "[a] fair reading of legislation demands a fair understanding of the legislative plan").

[12] 42 U.S.C. § 7545(o)(2)(B)(i)(I-IV).

[13] *Id.* at § 7545(o)(7)(A).

[14] *Id.* at § 7545(o)(7)(D).

[15] *Id.* at § 7545(o)(7)(F).

[16] *Id.*

[17] *Id.*

[18] *Id.* at § 7545(o)(2)(B)(ii).

[19] *Id.*

coordination with the Secretary of the Department of Energy ("DOE") and the Secretary of the U.S. Department of Agriculture ("USDA").[20]

Once the last year in the table is reached for a given category of renewable fuel (e.g., the last year in the table for total, advanced, and cellulosic renewable fuel is 2022), it is then incumbent on EPA to establish new applicable volumes for all future years, involving the same set of statutory factors that governs the reset.[21] (The process of setting new applicable volumes for the years beyond the original statutory table is referred to as the "set" rulemaking process.) Importantly, while both the reset mechanisms rely on the same list of statutory factors that apply to the "set," their purposes and functions are distinct because of the different circumstances that trigger each mechanism, and EPA's approach to each must reflect this distinction. A set rulemaking is triggered simply by the passage of time, and EPA's role is to continue pursuing the core congressional objectives for the RFS in light of the present circumstances—which is to say, to set volumes that strive to increase the use of renewable fuel to the extent feasible unless doing so would cause important and severe harm. A reset rulemaking is similar but, importantly, has a narrower primary focus: to remedy the specific circumstances that triggered the reset in lieu of repeated annual waivers.

In the current rulemaking, the reset was triggered by repeated use of the cellulosic waiver. EPA's central focus, therefore, should be to adjust the volume requirements to account for the circumstances that are leading to consistent shortfalls in cellulosic production. EPA should use the statutory reset factors to anticipate the level of cellulosic production that can feasibly be achieved without in turn triggering another type of waiver or otherwise causing important and severe harm, and set the cellulosic volume requirement to that level. Further, because the cellulosic standard is nested, EPA should reduce the advanced and total volume requirements correspondingly, except if EPA determines that higher levels of renewable fuel use can feasibly be achieved without in turn triggering another type of waiver or otherwise causing important and severe harm. This approach best serves Congress's purpose of promoting increased renewable fuel use to reduce GHG emissions, enhance U.S. energy security, and support economic development, and best accounts for the statutory structure and context of the reset.

C. The Proper Framework for Analyzing the Statutory Reset Factors Is Spurring Increased Use of Renewable Fuels Except to the Extent That Such Use Would Be Infeasible or Would Cause Important and Severe Harm

Once the reset process is triggered, EPA must follow the analysis Congress set forth in Section 211(o)(2)(B)(ii). EPA is required, first and foremost, to engage in a backward-looking assessment of how the program has performed to date.[22] This gives EPA the opportunity to consider how program implementation may be improved to better achieve the RFS program's

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[20] *Id.*

[21] *Id.*

[22] *Id.*; acknowledged by EPA at EPA, *Draft Regulatory Impact Analysis: RFS Annual Rules* ("DRIA") 8 (Dec. 2021), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013KOG.pdf.

core congressional objectives, particularly by assessing and responding to the conditions that led to the particular waiver that triggered the reset.

EPA must then engage in a forward-looking assessment/projection of the impacts of setting volumes at certain levels in future years. This gives EPA the opportunity to consider how the objectives of the program may best be achieved, given the results of the Agency's analysis.

In both its backward-looking and forward-looking assessments, EPA must consider a variety of statutory factors loosely collected into six groups:

> I. [T]he impact of the production and use of renewable fuels on the environment, including on air quality, climate change, conversion of wetlands, ecosystems, wildlife habitat, water quality, and water supply;
> II. [T]he impact of renewable fuels on the energy security of the United States;
> III. [T]he expected annual rate of future commercial production of renewable fuels, including advanced biofuels in each category (cellulosic biofuel and biomass-based diesel);
> IV. [T]he impact of renewable fuels on the infrastructure of the United States, including deliverability of materials, goods, and products other than renewable fuel, and the sufficiency of infrastructure to deliver and use renewable fuel;
> V. [T]he impact of the use of renewable fuels on the cost to consumers of transportation fuel and on the cost to transport goods; and
> VI. [T]he impact of the use of renewable fuels on other factors, including job creation, the price and supply of agricultural commodities, rural economic development, and food prices.[23]

These factors fall roughly into three categories: (1) factors relating to core statutory objectives; (2) capacity constraints/feasibility; and (3) other potential economic and environmental harms (or benefits), largely consonant with those considered in the severe economic or environmental harm general waiver.[24] Although the statutory list itself does not provide EPA with a precise method to weigh the factors, not all factors are of equal importance or deserve equal weight; the structure and purpose of the statute demonstrate that each group of factors serves a distinct role in the analytical hierarchy.

First, certain key factors directly correspond to the core congressional objectives behind the RFS program: *i.e.*, the impact of renewable fuels on climate change (para. I); energy security (para. II); and job creation and rural economic development (para. VI).[25] These are the

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[23] 42 U.S.C. § 7545(o)(2)(B)(ii).

[24] *Id.* § 7545(o)(7)(A)(i).

[25] *See, e.g.*, NPRM at 72,439 (recognizing "the potential positive impacts of renewable fuels on several of the statutory factors such as climate change and energy security.").

environmental, economic, and societal benefits of increasing renewable fuel use that Congress expressly sought to promote in enacting the RFS. Under the market-forcing structure of the RFS, EPA must prioritize achievement of these goals through increased renewable fuel usage to the extent feasible without causing severe negative harm.[26]

Second, certain factors relate to the feasibility of achieving a level of renewable fuel use: the expected rate of commercial production (para. II) and the sufficiency of infrastructure to deliver and use renewable fuel (para. IV). These factors reflect Congress's intention that, although EPA should use the volume requirements to increase the use of renewable fuel, that effort is limited by how much renewable fuel can feasibly be produced, delivered, and consumed. These feasibility factors provide the practical cap beyond which the market cannot be forced.

Third, the remaining factors represent other potential negative (or positive) effects of increased renewable fuel use: additional environmental impacts other than the key congressional objective of addressing climate change, including air quality, conversion of wetlands, ecosystems, wildlife habitat, water quality, water supply (para. I); the deliverability of products other than renewable fuel (para. IV); fuel prices (para. V); and the prices of other goods and foods (para. VI).[27] Congress recognized the possibility that increasing the use of renewable fuel beyond a certain point could have other adverse environmental or economic effects, and directed EPA to account for them. But Congress did not intend for EPA to weigh these effects equally with the primary goals of the program—that would frustrate the purpose of the RFS and involve a far greater, and suspect, delegation of policymaking authority to EPA. Rather, the standard Congress established for the general waiver—"severe" harm[28]—provides the guidepost for weighting these additional factors. As the purpose of the reset is to address—and, moving forward, to avoid—the conditions that result in annual waivers, Congress understandably intended EPA to consider this third group of reset factors so as to avoid the future need for a severe environmental or severe economic harm waiver.[29] EPA may reduce volume requirements

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[26] And again, as noted above, EPA is permitted to *reduce* the volumes in the statutory table only with respect to the category of renewable fuel that triggered the reset, and only so far as necessary to address the underlying problem that caused it.

[27] As noted elsewhere in these comments, several of these factors illustrate the beneficial impacts of biofuel use. For example, use of biofuels improves air quality (with respect a number of conventional and hazardous pollutants) and lowers the cost of gasoline to consumers. *See, e.g.*, DRIA at 266.

[28] 42 U.S.C. § 7545(o)(7)(i).

[29] If EPA were to reduce otherwise feasible renewable fuel volumes based on environmental or economic impacts that are speculative or that fall well below the "severe" threshold, such an approach would be contrary to law and arbitrary and capricious.

below their feasible level only if necessary to avoid *severe* harms to the considerations Congress specified.[30]

D. EPA's Proposed Approach to the Statutory Factors Is Flawed Because It Disregards the Proper Framework for Conducting a Reset

EPA's proposed approach to analyzing and applying the statutory reset factors is flawed, in that the Agency seems to believe it has discretion to balance the factors as it sees fit, or to offset important concrete benefits with speculative or minor harms.[31] EPA, for example, notes that the reset "does not establish any numeric criteria" or mathematical formulae that directly translate into volumes.[32] That is true, in part, but is also beside the point. Certain of the reset factors, like GHG emissions and job creation, *are* susceptible to quantitative analysis and should be addressed as such. Other factors may be less quantitative in nature, like energy security, but are no less capable of being analyzed objectively. And while Congress did not dictate a specific numeric formula for resetting volumes, it is not true, as EPA asserts, that the statute "does not … provide guidance on how EPA should weigh the various factors."[33]

To the contrary, as discussed above, the text, structure, and purposes of the statute provide EPA with a simple, coherent framework with which to analyze and apply the factors together. Again, the ultimate goal of the reset analysis is clear: establish volume requirements that promote increased use of renewable fuel to the extent feasible without causing important and severe harm. The factors that relate to these benefits should be analyzed within this framework.

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[30] While the purpose of these factors in the reset analysis is to prevent severe harm, several of these factors show beneficial impacts of biofuel use. For example, use of biofuels improves air quality (with respect a number of conventional and hazardous pollutants) and lowers the cost of gasoline to consumers. *See, e.g.*, DRIA at 266.

[31] NPRM at 72,447 ("[S]ome of the statutory factors assessed for conventional renewable fuel favor the implied statutory volume (15 billion gallons) or higher volumes, while other factors favor lower volumes."); NPRM at 72,443 (stating that neither the statute nor legislative history "provide[s] guidance on how EPA should weigh the various factors"); RFS Volume Rule Overview for Interagency Review (Aug 27, 2021) (Docket #EPA-HQ-OAR-2021-0324-0315) (relegating statutory factors to an appendix and making no reference to the factors when describing the basis for annual volumes).

[32] NPRM at 72,443.

[33] *Id.*

II. THE CENTRAL ROLE OF CLIMATE CHANGE TO THE RFS PROGRAM AND TO THE RESET ANALYSIS

A. Consistent with the Overarching Reset Framework, This Reset Presents EPA with an Opportunity to Further the Administration's Climate Goals Through Full and Effective Implementation of the RFS Program

1. The President has prioritized climate action and set ambitious GHG reduction goals

The President has repeatedly recognized that climate change poses an "existential threat."[34] As EPA has explained, "[t]he impacts of climate change are affecting people in every region of the country, threatening lives and livelihoods and damaging infrastructure, ecosystems, and social systems in communities across the nation."[35] For that reason, failure to utilize all available pathways of reducing carbon emissions increases the likelihood of "climate disaster" with "devastating" impacts, particularly on the most vulnerable communities.[36]

The Administration has therefore made combatting climate change one of its highest priorities. Among other commitments, it has adopted the Intergovernmental Panel on Climate Change's (IPCC's) goal of limiting global temperature increases to 1.5 degrees Celsius.[37] And the Administration has adopted highly ambitious national goals to address climate change by slashing GHG emissions, including a 50-52% reduction in GHG emissions by 2030 and a net-

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[34] *Remarks by President Biden Before Signing Executive Actions on Tackling Climate Change, Creating Jobs, and Restoring Scientific Integrity*, White House Briefing Room (Jan 27, 2021), https://www.whitehouse.gov/briefing-room/speeches-remarks/2021/01/27/remarks-by-president-biden-before-signing-executive-actions-on-tackling-climate-change-creating-jobs-and-restoring-scientific-integrity/ ("I'm signing today an executive order to supercharge our administration ambitious plan to confront the existential threat of climate change. And it is an existential threat.").

[35] *U.S. Environmental Protection Agency Policy Statement on Climate Change Adaptation* (May 26, 2021), *in* U.S. ENVIRONMENTAL PROTECTION AGENCY CLIMATE ADAPTATION ACTION PLAN (Oct. 2021), https://www.epa.gov/system/files/documents/2021-09/epa-climate-adaptation-plan-pdf-version.pdf.

[36] U.S. Dep't of State, *The Long-Term Strategy of the United States* (Nov. 2021), https://unfccc.int/sites/default/files/resource/US_accessibleLTS2021.pdf.

[37] *See generally* IPCC, *Climate Change 2021: The Physical Science Basis* (Aug. 2021); *Fact Sheet: President Biden Sets 2030 Greenhouse Gas Pollution Reduction Target Aimed at Creating Good-Paying Union Jobs and Securing U.S. Leadership on Clean Energy Technologies*, White House Briefing Room (Apr. 22, 2021) (referring to "the President's goal of achieving net-zero greenhouse gas emissions by no later than 2050 and of limiting global warming to 1.5 degrees Celsius, as the science demands."), https://www.whitehouse.gov/briefing-room/statements-releases/2021/04/22/fact-sheet-president-biden-sets-2030-greenhouse-gas-pollution-reduction-target-aimed-at-creating-good-paying-union-jobs-and-securing-u-s-leadership-on-clean-energy-technologies/.

zero economy by 2050.[38] The Administration has adopted a whole-of-government approach to addressing this problem, with all three of the federal agencies involved in the reset analysis and in renewable fuels policy generally—EPA, DOE, and USDA—playing prominent roles.[39]

2. The Administration's climate goals are not attainable without significant and immediate GHG reductions in the transportation sector, and these reductions are not feasible without biofuels

"The transportation sector is the biggest contributor to greenhouse gases in our economy– which means it can and must be a big part of the climate solution."[40] Indeed, as the White House recently acknowledged, "we must reduce" greenhouse emissions from the transportation sector "to ensure we meet President Biden's goals to create a net-zero economy by 2050."[41]

Within the transportation sector, an essential tool for reducing GHGs and combating climate change is transitioning from petroleum-based fuels to renewable fuels to the greatest extent feasible and continuing to lower the carbon intensity of the renewable fuels that displace petroleum.[42] Indeed, the RFS program is the *only* Clean Air Act regulatory program aimed

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[38] *Id.*; Exec. Order 14008, *Tackling the Climate Crisis at Home and Abroad* (Jan. 27, 2021).

[39] *Fact Sheet: President Biden Takes Executive Actions to Tackle the Climate Crisis at Home and Abroad, Create Jobs, and Restore Scientific Integrity Across Federal Government*, White House Briefing Room (Jan 27, 2021), https://www.whitehouse.gov/briefing-room/statements-releases/2021/01/27/fact-sheet-president-biden-takes-executive-actions-to-tackle-the-climate-crisis-at-home-and-abroad-create-jobs-and-restore-scientific-integrity-across-federal-government; *About the Bioenergy Technologies Office*, DOE, https://www.energy.gov/eere/bioenergy/about-bioenergy-technologies-office ("[B]ioenergy technologies will help decarbonize the transportation sector, while mitigating greenhouse gas emissions to combat climate change."); *Bioenergy in a Changing Climate*, USDA, https://www.climatehubs.usda.gov/bioenergy-changing-climate ("Bioenergy can reduce dependence on fossil fuel, reduce reliance on foreign oil, lower emissions of greenhouse gases and bring business to rural economies.").

[40] *NHTSA Advances Biden-Harris Administration's Climate & Jobs Goals*, Nat'l Highway Traffic Safety Admin. (Apr. 22, 2021), https://www.nhtsa.gov/press-releases/nhtsa-advances-biden-harris-administrations-climate-jobs-goals; *see also Carbon Pollution from Transportation*, EPA, https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation ("Greenhouse gas (GHG) emissions from transportation account for about 29 percent of total U.S. greenhouse gas emissions, making it the largest contributor of U.S. GHG emissions.").

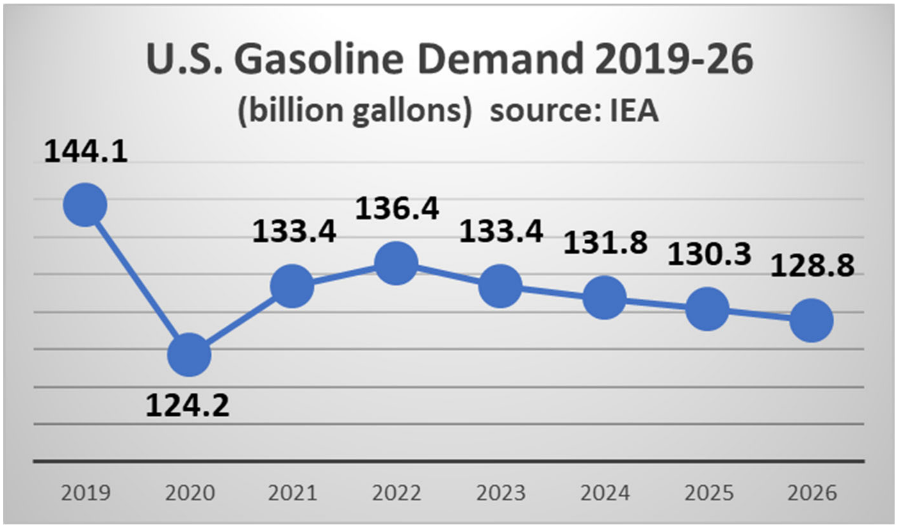
[41] *Fact Sheet: The Bipartisan Infrastructure Investment and Jobs Act Advances President Biden's Climate Agenda*, White House Briefing Room (Aug. 5, 2021) https://www.whitehouse.gov/briefing-room/statements-releases/2021/08/05/fact-sheet-the-bipartisan-infrastructure-investment-and-jobs-act-advances-president-bidens-climate-agenda/.

[42] *See* Int'l Energy Agency, *Net Zero by 2050: A Roadmap for the Global Energy Sector* 78 (2021) (projecting that to reach net zero by 2050, global liquid biofuel consumption rises from 1.6 mboe/d to 6 mboe/d in 2030, before levelling off around 7mboe/d in 2050).

explicitly at reducing GHG emissions. While the Administration is pursuing initiatives to improve the fuel efficiency of gasoline and diesel-powered vehicles and to increase the number of electric vehicles on the road, those policies can only go so far toward countering the pace of climate change; they face political, economic, and structural challenges, and may be on a long and slow path to implementation. The fact is that liquid fuels will be needed to keep the American transportation system running for the foreseeable future. And, given that fact, the Administration will not be able to realize its climate goals unless it harnesses the full potential of biofuels to substitute for the petroleum that will otherwise dominate the liquid fuels market for years to come.

3. Demand for liquid fuels will persist for the foreseeable future

Even if demand for gasoline and diesel decreases due to increases in fuel efficiency and electrification, the downward trend is projected to be slow and occur over several decades. The International Energy Agency's most recent medium-term projections for gasoline demand in the United States, for example, show a steep recovery from pandemic levels in 2020,[43] followed by only a mild decrease in gasoline demand over the next four years.[44]



Longer-term projections similarly show that demand for liquid fuels as a source of energy will continue to be substantial. Bloomberg's economic transition scenario, which projects global gasoline demand out to 2050 while incorporating increases in electric vehicle usage from technological advances and market trends, predicts that demand for gasoline and diesel will not

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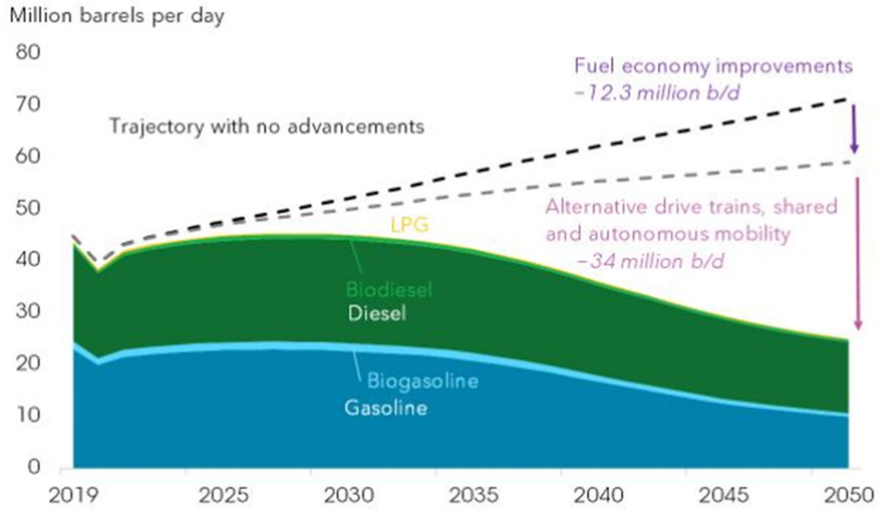
[43] The U.S. Energy Information Agency's short-term projections also show U.S. liquid fuel consumption increasing through 2023. *Short-Term Energy Outlook: U.S. Liquid Fuels*, U.S. Energy Info. Admin. (Jan. 11, 2022), https://www.eia.gov/outlooks/steo/report/us_oil.php.

[44] Int'l Energy Agency, *Oil 2021: Analysis and Forecast to 2026* (Mar. 2021), https://iea.blob.core.windows.net/assets/1fa45234-bac5-4d89-a532-768960f99d07/Oil_2021-PDF.pdf (data converted from million barrels per day).

significantly decrease until the 2030's, and will retain a major share of transportation sector energy consumption through 2050.[45]

Road fuel demand - Economic Transition Scenario



Source: BloombergNEF, IEA

Moreover, the U.S. Energy Information Administration projects liquid fuel consumption in the U.S. transportation sector to stay nearly constant through 2050, with gradual declines in motor gasoline offset by gradual increases in renewable jet fuel.[46]

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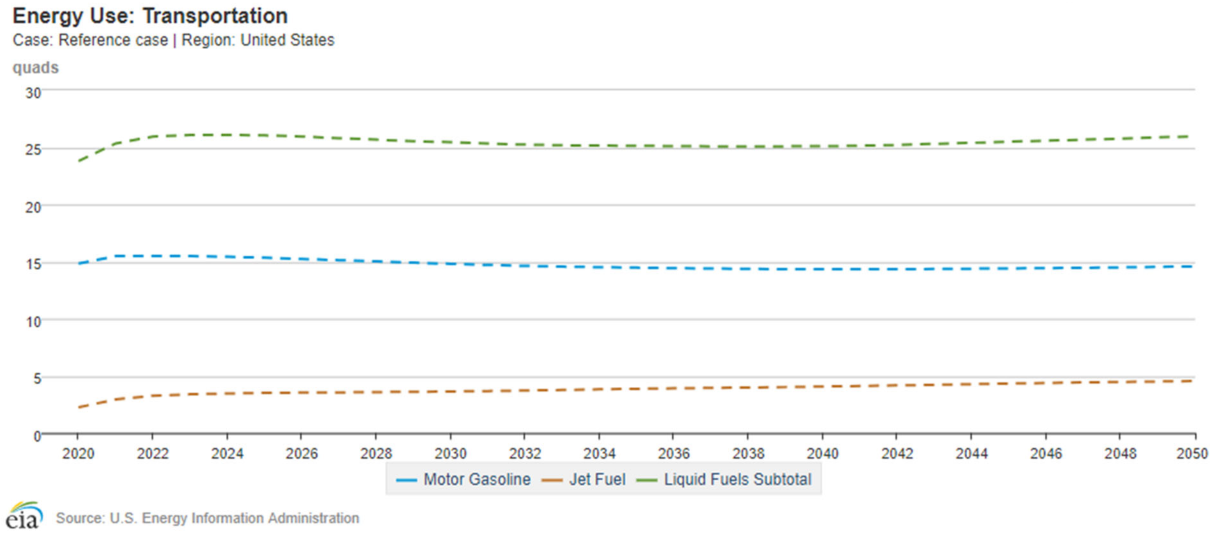
[45] *Electric Vehicle Outlook 2021*, BloombergNEF (Aug. 2021), https://bnef.turtl.co/story/evo-2021/page/1.

[46] *Annual Energy Outlook 2021, Total Energy Use: Liquid Fuels*, U.S. Energy Info. Admin., https://www.eia.gov/outlooks/aeo/data/browser/#/?id=1-AEO2021&region=0-0&cases=ref2021&start=2019&end=2050&f=A&linechart=~~~~ref2021-d113020a.30-1-AEO2021&ctype=linechart&sourcekey=0.



These projections demonstrate that even as the light duty vehicles market transitions to electrification, liquid fuels will remain a substantial component of transportation sector energy usage for a long time. The concentration of renewable fuels as a portion of the liquid fuels supply must steadily increase if climate goals are to be realized, especially if overall demand for liquid fuels declines over the long term.

4. EPA and the Administration have repeatedly recognized the necessity of biofuels to decarbonize the transportation fuel supply in the United States

As EPA has repeatedly stated, "[t]he fundamental objective of the RFS provisions under the Clean Air Act is clear: To increase the use of renewable fuels in the U.S. transportation system every year through at least 2022 in order to reduce greenhouse gases (GHGs) and increase energy security."[47] Moreover, EPA recognizes that "[r]enewable fuels represent an opportunity for the U.S. to move away from fossil fuels towards a set of lower GHG transportation fuels, and a chance for a still-developing low GHG technology sector to grow," and that "[t]hese lower GHG renewable fuels include corn starch ethanol."[48]

In the Administration's "Long-Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050," released in advance of the Glasgow Climate Conference,

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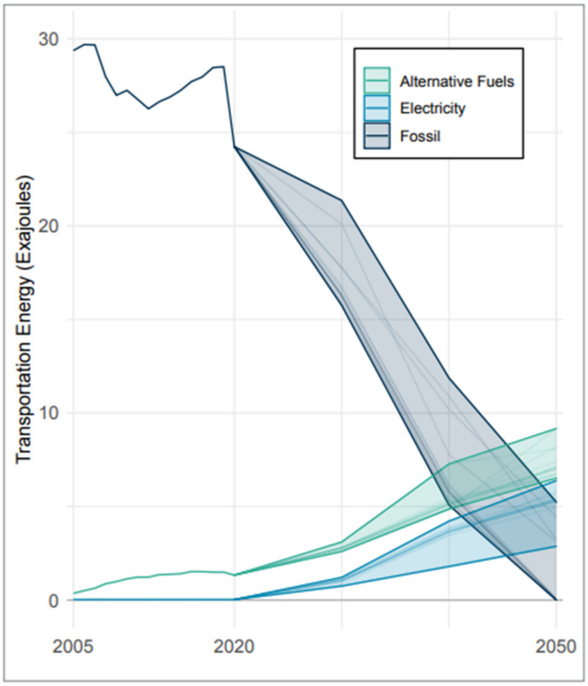
[47] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017, 80 Fed. Reg. 77,420 (Dec. 14, 2015) (to be codified at 40 C.F.R. pt. 80).

[48] NPRM at 77,421; *see also ACE*, 864 F.3d at 696 ("By mandating the replacement—at least to a certain degree—of fossil fuel with renewable fuel, Congress intended the [RFS] Program to move the United States toward greater energy independence and to reduce greenhouse gas emissions."); *Am. Petroleum Inst. v. E.P.A.*, 706 F.3d 474, 476 (D.C. Cir. 2013) ("In establishing the RFS program, Congress made commercial production of cellulosic biofuel, an advanced biofuel derived from sources of lignocellulose such as switchgrass and agricultural wastes, central to the program's objective of reducing greenhouse gas emissions.").

for example, alternative fuels including biofuels play a necessary role in the transition away from fossil fuels in the transportation sector. Recognizing that "[o]ver time, electricity, carbon beneficial biofuels, and hydrogen will become increasingly clean," the Long-Term Strategy emphasizes that use of these energy sources must be accelerated in order to decrease carbon emissions in the face of a projected increase to transportation sector demand.[49] Indeed, the Long-Term Strategy projects that net-zero in the transportation sector will be achieved by accelerating the use of both alternative fuels and electricity to power a transition away from fossil fuel consumption:



Across multiple net-zero scenarios, increased use of alternative fuel, including biofuel, and electricity will be needed to offset decreases in fossil fuel usage.[50]

To accomplish these goals the President has, among other things, called upon the agricultural sector to maximize its carbon reduction potential, noting that "America's farmers, ranchers, and forest landowners have an important role to play in combating the climate crisis and reducing greenhouse gas emissions, by sequestering carbon in soils, grasses, trees, and other vegetation and *sourcing sustainable bioproducts and fuels*."[51]

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[49] U.S. Dep't of State, *The Long-Term Strategy of the United States* 42 (Nov. 2021), https://unfccc.int/sites/default/files/resource/US_accessibleLTS2021.pdf.

[50] *Id.* Figure 8.

[51] Exec. Order 14008, *Tackling the Climate Crisis at Home and Abroad* (Jan. 27, 2021) (emphasis added).

5. EPA has undervalued the GHG reduction potential of biofuels

As discussed in greater detail below, EPA's failure to update its methodology for assessing the lifecycle GHG emission benefits of ethanol causes EPA to substantially undervalue those GHG benefits, contrary to the best science available.[52] This undervaluation can lead the Agency to falter in its administration of the RFS program, implementing the program in a way that shortchanges (or eliminates) its market-forcing potential, and undermining the program's ability to incentivize increasingly higher renewable fuel volumes as compared to what would have occurred without the program.

In the reset and in its implementation of the RFS program generally, EPA should seek to advance the RFS program's unique climate objectives and better align the RFS with the Administration's climate policies. Among other things, as part of the Agency's backward-looking review of the implementation of the RFS program, EPA should fully and accurately account for the role of ethanol in reducing GHG emissions on a lifecycle basis. While shortfalls in cellulosic biofuels have resulted in an inability to meet the ambitious statutory goal of 36 billion gallons by 2022, U.S. ethanol production has nonetheless quadrupled between 2005 and 2019, and ethanol has substantially exceeded the threshold expectations for GHG reductions.[53] As a result, studies have shown that roughly 544 million metric tons of CO_2e emissions have been avoided[54]—the equivalent of taking 8.5 million passenger vehicles off the road each year.[55] EPA's proposal and DRIA give short shrift to the GHG accomplishments of biofuels under the RFS, noting generally that renewable fuels "have the potential to reduce GHGs and influence climate change if their use displaces petroleum derived fuels," but failing to acknowledge studies showing how they have proven their value as a tool in the fight against climate change.[56]

B. Updating the GHG LCA for Ethanol Should Be a Top Priority for EPA

As EPA and the courts have long recognized, where EPA is engaged in rulemaking to protect the environment and public health, EPA must rest its decisions on the best available

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[52] *See infra* Part II.B.

[53] *U.S. Bioenergy Statistics*, USDA (Jan. 21, 2022), https://www.ers.usda.gov/data-products/u-s-bioenergy-statistics.

[54] Usung Lee et. al *Retrospective Analysis of the U.S. Corn EthanolIndustry for 2005–2019: Implications for Greenhouse Gas Emission Reductions* (May 4, 2021), https://doi.org/10.1002/bbb.2225.

[55] *Greenhouse Gas Equivalencies Calculator*, EPA (Mar. 2021), https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

[56] DRIA at 63.

science.[57] For that reason, Growth Energy applauds EPA's announcement to hold a workshop later this year "to incorporate the *best available science* into an update of our lifecycle analysis (LCA) of biofuels."[58] Nevertheless, in light of this fundamental principle, EPA's failure over the last decade to incorporate best available science in its LCA methodology for corn ethanol–and its failure to do so in the current proposal–is perplexing and if continued in the final rule would be arbitrary and capricious. Instead, EPA disregards evidence in the record and continues to employ an admittedly outdated and inaccurate LCA for ethanol. While EPA attempts to justify this failure on "uncertainty" regarding ethanol's LCA, EPA neglects to use available scientific methods commonly used in other contexts to address any uncertainty here.

To accurately quantify the GHG impacts of EPA's reset rulemaking–both in terms of the GHG increase resulting from EPA's proposed reduction of the 2020 volumes and resetting 2021 volumes to reflect actual production, as well as the benefits to be realized by setting ambitious but feasible 2022 volumes–EPA must update its corn ethanol LCA.[59] EPA in 2010 projected that lifecycle GHG emissions from corn ethanol would be 21% less than the representative 2005 petroleum baseline, and still relies on this value in the current rulemaking.[60] In contrast, the best available and most recent science–including studies published by the DOE's Argonne National Lab and USDA, the two agencies that EPA is required by law to consult with in conducting the reset analysis–place the lifecycle GHG reductions from corn ethanol in the range of 39-46% below the petroleum baseline. These results are bolstered by other studies, including the expert analyses of Environmental Health & Engineering, Inc. (EH&E) and Life Cycle Associates, LLC attached to this comment letter and described briefly below.[61] EPA cannot disregard this

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[57] *Physicians for Social Resp'y v. Wheeler*, 956 F.3d 634 (D.C. Cir. 2020); Our Mission and What We Do, https://www.epa.gov/aboutepa/our-mission-and-what-we-do (EPA must ensure that national "efforts to reduce environmental risks are based on the best available scientific information."); Exec. Order No. 13990 (Jan. 20, 2021) ("the Federal Government must be guided by the best science").

[58] Notice of Workshop on Biofuel Greenhouse Gas Modelling, 86 Fed. Reg. 73757 ("Through this workshop, we will initiate a public process for getting input on (i) how to incorporate the best available science into an update of our lifecycle analysis (LCA) of biofuels.") (emphasis added).

[59] Growth Energy is encouraged by EPA's announcement of a February Workshop on Biofuel Greenhouse Gas Modelling, but it is crucial that EPA follow through with the efforts necessary to promulgate an accurate and updated lifecycle analysis based on the best available science as soon as possible.

[60] *2010 Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis*, US Envt'l Prot. Agency, Report No.: EPA-420-R–10–006 ("2010 RIA").

[61] *See* Scully, et. al., *Carbon intensity of corn ethanol in the United States: state of the science* (2021) (showing reduction of 46%); Lee, et. al., *Retrospective analysis of the U.S. corn ethanol industry for 2005–2019: implications for greenhouse gas emission reductions* (2021) (showing reduction of 44%%); Rosenfeld, et. al. *A Life-Cycle Analysis of the Greenhouse Gas Emissions from Corn-Based Ethanol* (Sept. 5, 2018) (showing reduction of 39%).

information in its current rulemaking, regardless of its laudable commitment to initiate a process outside of this rulemaking to consider this information for other, future purposes.

To be sure, the importance of updating EPA's LCA for corn ethanol extends beyond the current rulemaking; it will also be relevant to a range of agency decisions, including, for example, the forthcoming set rulemaking and any future rulemakings designed to facilitate the use of E15, flex fuel vehicles, and use of higher-level ethanol blends like E85, and will be critical to the development of sound policy related to sustainable aviation fuel (SAF). With respect to SAF, a memorandum of understanding between DOE, USDA and DOT adopted ambitious targets, calling for production of 3 billion gallons by 2030 and 35 billion gallons by 2050.[62] Accomplishing these volume goals will not be feasible without harnessing the potential of the U.S. ethanol industry, which produces 86% of the nation's biofuels.[63] However, EPA's current LCA for ethanol poses a regulatory barrier to SAF produced from ethanol because it would be unlikely to generate RINs under the RFS program[64] and would be unlikely to qualify for an SAF tax credit as currently proposed in Congress.[65]

Consistent with Administration policy, the current proposed RFS rule, as well as other new policies EPA may pursue to achieve the Administration's climate goals, will rely on the social cost of carbon (SCC) in combination with ethanol's lifecycle analysis to monetize the benefits of anticipated GHG emission reductions in the Agency's regulatory cost-benefit analyses.[66] (And we note that EPA has emphasized the efforts taken to ensure that the SCC is developed in accordance with "best available science."[67]) But use of a flawed ethanol LCA as an

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[62] Sustainable Aviation Fuel Grand Challenge, DOE, https://www.energy.gov/eere/bioenergy/sustainable-aviation-fuel-grand-challenge

[63] *EIA Expands Data Coverage of Biofuels in our Monthly Energy Review*, U.S. Energy Info. Admin. (Nov. 19, 2021) ("Fuel ethanol accounted for 86% of total U.S. biofuels production in July 2021, biodiesel for 9%, renewable diesel fuel for 5%, and other biofuels for less than 1%.").

[64] 42 U.S.C. § 7545 (o)(2)(A)(i) (requiring renewable fuel to achieve a 20% reduction in lifecycle GHG emissions)

[65] Build Back Better Bill Act, H.R. 5376, 117th Cong. § 136203 (2021) (requiring SAF to achieve a 50% reduction in lifecycle GHG emissions).

[66] Exec. Order No.13990, *Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis* (Jan. 20, 2021).

[67] DRIA at 77 ("Specifically, in 2009, an interagency working group (IWG) that included the EPA and other executive branch agencies and offices was established to ensure that agencies were using the *best available science* and to promote consistency in the SC-CO2 values used across agencies."); *id.* at 78 ("IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies.") (emphasis added); *id.* ("On January 20, 2021, President Biden issued Executive Order 13990, which reestablished the IWG and directed it to ensure that the U.S. Government's estimates of the social cost of carbon and other greenhouse gases reflect the *best available science* and the recommendations of the National Academies.") (emphasis added).

input into SCC cost-benefit calculations skews the resulting monetized benefits, and undermines EPA's efforts to ensure scientific integrity in its analyses of the costs and benefits of policies to mitigate GHGs and address climate change. EPA cannot justify such self-contradiction in this rulemaking on the grounds that it has not gotten around to updating its LCA yet; the information has been available, is presented in these comments and part of the record, and ignoring it for another day in another context would be arbitrary.

Moreover, utilizing the best available science on corn ethanol's carbon intensity has a substantial impact on cost-benefit analyses. For example, using the interim SCC, a calculation of the monetized societal benefits of GHG reductions from actual and projected corn starch ethanol consumption in 2020-2022, relying on EPA's 2010 carbon intensity ("CI") score of 73.2 gCO2e/MJ, would show benefits of about *$3.6 billion*. However, if using EH&E's central estimate of 51.4 gCO2e/MJ[68] and keeping all other factors equal, the calculation would show more than twice the benefits, *i.e.*, about *$7.6 billion*. This *$4 billion gap* should then have a substantial effect on regulatory decision-making.[69] EPA must adopt the best available science in its LCA to ensure that the most currently well-founded GHG benefits of biofuels are disclosed to the public and relied on by policymakers.

1. The best available science indicates corn ethanol has more than double the GHG emissions reductions of EPA's outdated estimate, putting it roughly on par with advanced biofuels

It has been over a decade since EPA modeled the lifecycle GHG impacts of corn ethanol in the original 2010 RFS rule. In the intervening years, the models used in EPA's original analysis have been substantially updated with respect to the models' methodologies, designs, data, and parameters. Most significantly, modeled emissions associated with indirect land use change ("iLUC") are dramatically lower than previously understood. Because iLUC is a substantial component of EPA's estimated GHG emissions for corn starch ethanol, it is critical that EPA address the latest science that coalesces around a substantially-reduced iLUC estimate.[70] Indeed, in 2010, EPA acknowledged that land use change modeling, which was relatively new science at the time, would need to be reassessed as modeling techniques

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[68] Environmental Health & Engineering, Inc., *Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards* 5 (Figure 1) (Feb. 3, 2022) ("EH&E Report") (attached as Ex. 1).

[69] If the final social cost of carbon increases from than the interim value, the gap between results using EPA's 2010 CI score and EH&E's central best estimate would widen even further. *See* DRIA at 83 (noting that "the SC-GHG estimates used in this proposed rule likely underestimate the damages from GHG emissions").

[70] DRIA at 66. EPA might also consider that reputable models used in other jurisdictions, such as the GHGenius model used in Canada, that do not include indirect LUC given the speculative nature of iLUC emissions.

improved.[71] The early stage of this modeling is demonstrated by EPA’s own reduction in its LUC estimate by more than 50% from the proposed rule in 2009 to the final in 2010.[72] LUC models did not suddenly stop improving in 2010, and the Agency’s 2010 estimate is now an outlier from the most recent and best available science:

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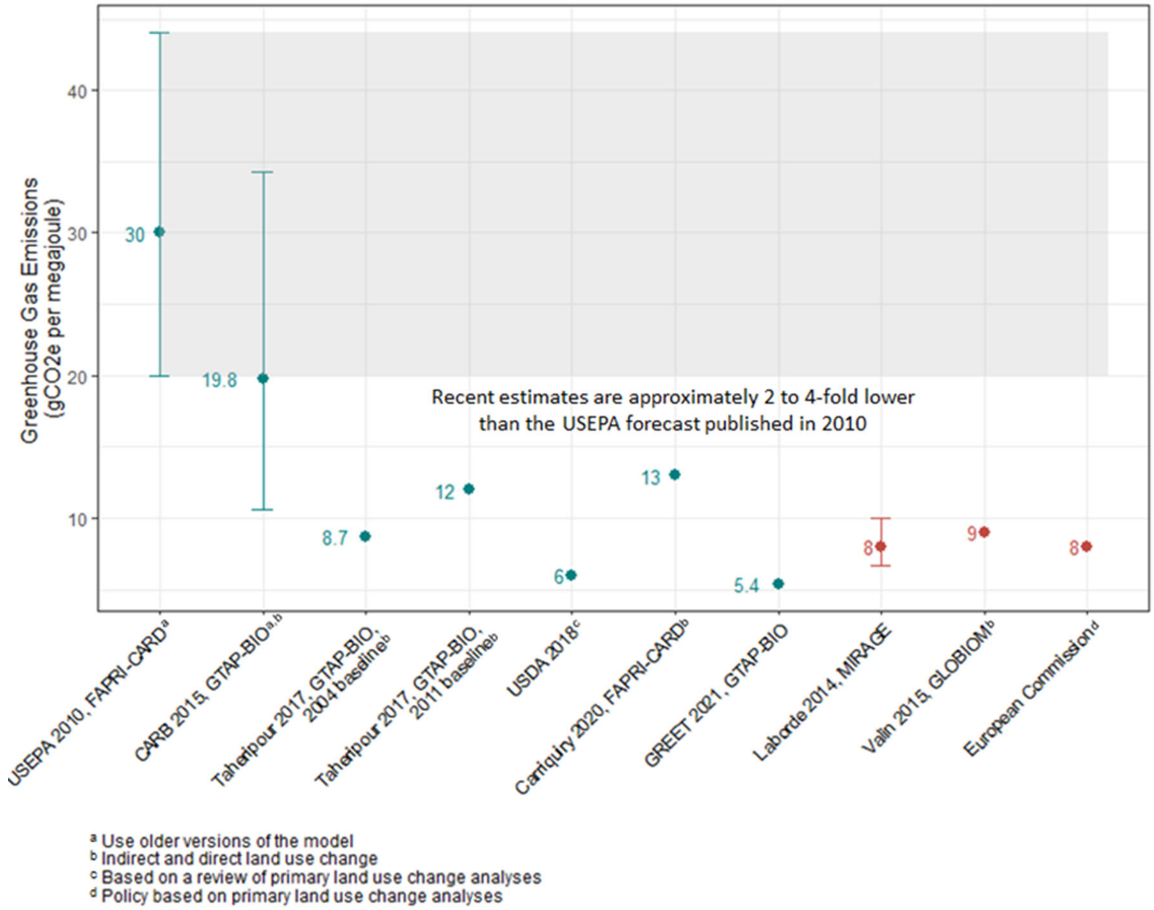
[71] Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program, 75 Fed. Reg. 14,670, 14,678 (Mar. 26, 2010) (to be codified at 40 C.F.R. pt. 80) (“the Agency is also committing to further reassess these determinations and lifecycle estimates “); Cong. Rsch. Serv., *Calculation of Lifecycle Greenhouse Gas Emissions for the Renewable Fuel Standard (RFS)* 13 (“EPA acknowledged that a transparent and scientific analysis of the GHG emission impact of renewable fuels going forward will be further refined as additional data sources and models become available.”); EPA Off. of Inspector Gen., *EPA Has Not Met Certain Statutory Requirements to Identify Environmental Impacts of Renewable Fuel Standard* pdf p. 3 (Aug. 18, 2016) (“[T]he EPA committed to update this analysis as lifecycle science evolves, but does not have a process for initiating an update.”).

[72] EPA, *Lifecycle Greenhouse Gas (GHG) Emissions Results Spreadsheets* (Oct. 30 2008), Docket ID EPA-HQ-OAR-2005-0161, https://www.regulations.gov/document/EPA-HQ-OAR-2005-0161-0938; EPA, *Renewable Fuel Standard Program (RFS2) Regulatory Impact Analysis* (Feb. 2010), https://19january2017snapshot.epa.gov/sites/production/files/2015-08/documents/420r10006.pdf

Comparison of USEPA's iLUC estimates with relevant most recent studies from the U.S. and Europe[73]



iLUC estimates have decreased over time because both modeling techniques and data inputs have improved. Specifically, over the past 12 years, iLUC models have improved by (1) addition of new modules that allow for more accurate simulation of real-world agricultural practices; (2) addition of more spatially resolved information on land cover; and (3) tuning of parameters that describe rates of land conversion and land.[74]

The attached report by EH&E, "Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards," (Exhibit 1) addresses these improvements in greater detail. EH&E is a multi-disciplinary team of environmental health scientists and engineers with expertise in measurements, models, data science, LCA, and public health, who recently published a study titled "Carbon intensity of corn ethanol in the United States: state of the science."[75] This study concluded that the carbon intensity corn starch ethanol has decreased

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[73] EH&E Report at 5 (Figure 1).

[74] EH&E Report at 5-8.

[75] Scully, et. al.

by approximately 50% over the past 30 years to a current central estimate of 51gCO_2e/MJ, or 46% below the 2005 petroleum baseline.[76]

As explained in more detail in EH&E's expert report (attached), updates to two models in particular, GTAP-BIO and FAPRI, warrant EPA's close attention as EPA previously relied on these models for its 2010 analysis and enhanced data inputs yield substantially different results a decade on.[77] Taking these updates into account, most credible studies using these models reflect an iLUC estimate for corn ethanol of 1.3 to 11 gCO_2e/MJ.[78] Analyses by European investigators of iLUC using different models similarly arrive at a substantially-reduced iLUC estimate of 8 to 9 gCO_2e MJ^{-1}.[79] EPA cannot disregard this information in the current rulemaking for which it is highly relevant.

In addition, the attached expert report by Life Cycle Associates, LLC, "Review of GHG Emissions of Corn Ethanol under the EPA RFS2" (Exhibit 2), similarly concludes that, using a methodology similar to EPA's in the 2010 RIA with updates for best available data and modeling choice, parameters, and inputs, an appropriate corn ethanol CI is in the range of 40 to 55 g CO_2e/MJ, or approximately 45 to 55% lower than a representative 2005 gasoline baseline.[80] As addressed extensively in the report, the key factors that result in a substantially lower CI than EPA projected in 2010 include:

- Adjustments for iLUC, taking into account modeling that better reflects real-world observations regarding reduced rates of deforestation;
- Ethanol plants' reduced energy consumption and the lower GHG intensity of the electric grid;
- Increased corn oil extraction and substantial use of corn oil in BBD production;
- Displacement of iLUC and nitrogen emissions associated with soybeans;
- A higher baseline CI for 2005 petroleum fuels.

EPA must take this analysis, along with the substantial scientific literature on ethanol's GHG LCA, into account in this rulemaking.

2. Uncertainty in LCA modeling can be managed by comparing existing credible studies

EPA's DRIA repeatedly references "considerable" uncertainty in LCA modeling.[81] It was true in 2009 and 2010 that there was uncertainty with respect to GHG lifecycle assessments of

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[76] *Id.*

[77] EH&E Report at 5-8.

[78] Scully, et. al. at 7.

[79] EH&E Report at 5.

[80] Life Cycle Associates, LLC, *Review of GHG Emissions of Corn Ethanol under the EPA RFS2* 48 (Feb. 4, 2022) (attached as Ex. 2).

[81] DRIA at 65.

fuels, especially as the models were less mature, but that was no impediment to EPA then. Nor should it be now. Reliance on uncertainty is not a substitute for grappling with the best currently available information, especially where EPA recognizes that such information is available but would defer engaging with it. And even then, after undertaking thorough consideration of the best available information, remaining uncertainty is a justifiable rationale for an agency to withhold action only if the uncertainty is so "unusually profound" at that juncture that the agency "could not form" a reasoned judgment about the evidence.[82] Here, the uncertainty is neither unusually profound nor prevents EPA from forming reasoned judgment on the LCA of ethanol.

More specifically, analyses of iLUC confront four main categories of uncertainty: (1) methodology, (2) model design, (3) data, and (4) parameters.[83] EPA can manage these uncertainties by relying upon the existing literature to derive an updated central estimate of iLUC emissions from available estimates in the numerous credible studies using generally accepted or commonly used models.[84] This approach addresses and narrows each category of uncertainty by comparing estimates that are the product of models with different methods, designs, data, and parameter values. Examples of this approach exist, for example, in Scully *et al.*[85] and Lewandrowski et al.,[86] and EPA should build upon these methodologies and the existing literature to incorporate the best available science in an updated GHG LCA for ethanol.

An analogous example of this approach exists in the social cost of carbon (SCC) metric. In developing the SCC, the interagency working group had to address an issue with significant scientific uncertainty by utilizing central estimates, embracing the principle of best available science, and adopting an interim approach to provide the best available values without causing undue delay.[87] EPA is legally obligated to adopt similar techniques in the context of updating the LCA for corn ethanol for purposes of this rulemaking, taking into account the best current information, and only then addressing remaining uncertainties using established methods such as central estimates.

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[82] *Murray Energy Corp. v. EPA*, 936 F.3d 597, 620 (D.C. Cir. 2019); *see also Motor Vehicle Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 52 (1983).

[83] ICAO. CORSIA Supporting Document: CORSIA Eligible Fuels – Life Cycle Assessment Methodology, (June 2019).

[84] EH&E Report at 8-11.

[85] Scully *et al* 2021.

[86] Jan Lewandrowski, et. al. *The Greenhouse Gas Benefits of Corn Ethanol –Assessing Recent Evidence*, 11 Biofuels 361, (2019).

[87] DRIA at 77 ("As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, the EPA agrees that the interim SC-GHG estimates represent the most appropriate estimate of the SC-GHG until revised estimates have been developed reflecting the latest, peer-reviewed science.").

3. EPA's "illustrative" scenario of GHG impacts of the proposed rule is flawed and misleading

In its proposal, EPA both relies upon an outdated approach to lifecycle assessment, and applies that outdated LCA in a faulty manner. Specifically, in the "illustrative GHG scenario" EPA uses the volume of renewable fuel consumed in 2020 (which was depressed due to the pandemic and associated economic downturn) as the baseline against which to measure the proposed 2021 and 2022 volumes.[88] Using this lens, increases in renewable fuels volumes in 2021 and 2022 are portrayed as a demand shock that induces land use change in the "illustrative" scenario. However, use of the most currently accurate baseline (e.g., 2019 actual or proposed volumes or a no RFS scenario) would show that increases in conventional volumes in 2021 and 2022 are merely returning to 2019 levels after an anomalous gasoline demand collapse in 2020 caused by the COVID-19 pandemic.[89] Thus, the purported GHG emissions increases in 2021 and 2022 associated with the land use change are illusory, and a product of the depressed baseline volumes in 2020, rather than reflective of real-world conditions. EPA itself notes that "once the cost of clearing and converting land is incurred, it seems likely that land will continue to be used for agricultural purposes in the future."[90] Yet EPA contradicts this assertion by concluding that returning to 2019 renewable fuel volumes will result in the conversion of new land. In reality, as addressed below, even when EPA has increased renewable fuel volumes in the past, there have not been concomitant conversion of land for agricultural uses. EPA must correct the illustrative scenario to remove GHG emissions increases associated with the misleadingly assumed "pulse "of land use change in 2021 and 2022.

III. EPA OVERESTIMATES OTHER ENVIRONMENTAL IMPACTS

A. There Is No Credible Evidence That the Proposed Rule Will Cause Adverse Impacts to Wetlands, Ecosystems, Species, Habitat, Water Quality/Availability, or Soils

Under the proper framework for evaluating the statutory factors in Section 211(o)(2)(B)(ii), EPA should "reset" volumes so as to maximize achievement of the core congressional objectives behind the RFS (including reducing GHG emissions), tempered only by capacity constraints and the need to avoid unacceptable negative effects, i.e., those that would produce severe environmental or economic consequences. One of the main areas in which EPA must consider the possibility of indirect costs (and/or benefits) from the RFS program is the

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[88] DRIA at 68-69.

[89] Robert Rapier, *Gasoline Demand Collapses to a 50-Year Low*, Forbes (Apr. 9, 2020) (noting that the COVID-19 pandemic resulted in the lowest gasoline demand levels in over half a century); EH&E Report at 11-14.

[90] DRIA at 67.

potential for indirect impacts to land and water, including to wetlands, ecosystems, species, habitat, water quality/availability, and soils.[91]

On this score, the Proposed Rule and DRIA contain a number of vague, conclusory, and unsupported statements suggesting that the proposed 2022 renewable fuel volumes (and the implied conventional biofuels volumes in particular) could result in adverse indirect environmental impacts. For example, EPA suggests that the Proposed Rule would result in "increased corn production in the U.S.," which in turn "could result in greater conversion of wetlands, adverse impacts on ecosystems and wildlife habitat, adverse impacts negative impacts on water quality and supply, and increased prices for agricultural commodities and food prices."[92] However, as explained below, a wide body of scientific literature demonstrates that there is no established causal connection between the RFS and adverse impacts to the environment, a fact which EPA has acknowledged in other contexts but overlooks here. No studies discussed in the DRIA, or any other studies to date, have definitively established a causal link between the RFS and impacts to land or water. In fact, the existing data indicate that the RFS *does not* result in land use change or adverse water availability/quality impacts. This is not news to EPA as it has reached the same conclusions in other contexts. For the reasons described in greater detail below, EPA should find that the record evidence fails to establish indirect environmental impacts to land or water as a reason to depart downward from the renewable fuel volumes proposed for 2020, 2021, or 2022, including the implied conventional volume of 15 billion gallons proposed for 2022. Indeed, EPA should acknowledge that there is room for volumes to be set at even higher levels without triggering any unacceptable adverse environmental effects.

1. Claims that the RFS causes land use change are unsubstantiated, as EPA has previously acknowledged and must incorporate into its analysis here

EPA's analysis of the potential for indirect impacts to wetlands, ecosystems, habitat, water quality and supply, and soils—indirect impacts that would result from additional lands being converted to agricultural purposes—fails to adequately address the critical threshold question of whether the RFS program *causes* land use conversion in the first place. EPA relies on its 2018 Second Triennial Report in asserting that "[e]vidence from observations of land use change suggests that some of [the] increase in acreage and crop use is a consequence of increased biofuel production."[93] But EPA also asserts that these effects cannot reasonably be estimated or quantified.[94] Further, it is unclear how these particular "observations" of land use change shed light on whether there has been an increase in total acreage and crop use, or whether biofuel production is the *cause* of any such increase. Unable to take the analysis beyond speculation that "some" increase in acreage and crop use is attributable to biofuel production,

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[91] *See* 42 U.S.C. § 7545(o)(2)(B)(ii)(I). Impacts on climate change and air quality, which are also listed in section 211(o)(2)(B)(ii)(I), are addressed separately in Parts II and III of these comments.

[92] NPRM at 72,447.

[93] DRIA at 88.

[94] *Id*. at 88, 127–28.

EPA does *not* identify potential impacts to land or water as a reason to adjust downward the volumes it proposes for 2020, 2021, or 2022. Indeed, at the end of the day, EPA insists that in devising its proposed total renewable fuel volumes, it has "take[n] into consideration the potential negative impacts of renewable fuels produced from crops such as corn or soybeans on environmental factors such as the conversion of wetlands, ecosystems, and wildlife habitat."[95] A closer examination of the record evidence, however, would allow EPA to bolster the support for its proposal and to be less equivocal in analyzing the land and water-related factors in Section 211(o)(2)(B)(ii)(I).

Rather than creating the impression that some unquantifiable amount of negative environmental impacts exists, EPA should acknowledge that there is simply no credible evidence for the proposition that the RFS program has caused, or that the Proposed Rule will cause, land conversion notwithstanding EPA's vague hypothesizing to the contrary. Because EPA fails to address the complex chain and multiple variables relevant to addressing the question of causality, much of its analysis of environmental impacts are rooted in suppositions and inapposite. Further, the DRIA's reliance on studies cited in the Second Triennial Report for evidence of causation is perplexing as EPA has acknowledged in other contexts, including certain sections of the DRIA, that "a causal connection [between the RFS and land use change] is difficult to make with confidence."[96] Below we first explain the significance of understanding causality with respect to the RFS and land use change before turning to EPA's assessment of impacts to wetlands, wildlife, habitat, soil, and water.

a. Understanding the causal chain

The relationship between the RFS and impacts to land and water involves a complex causal chain comprised of the following significant links, each of which have multiple interrelated variables:[97]

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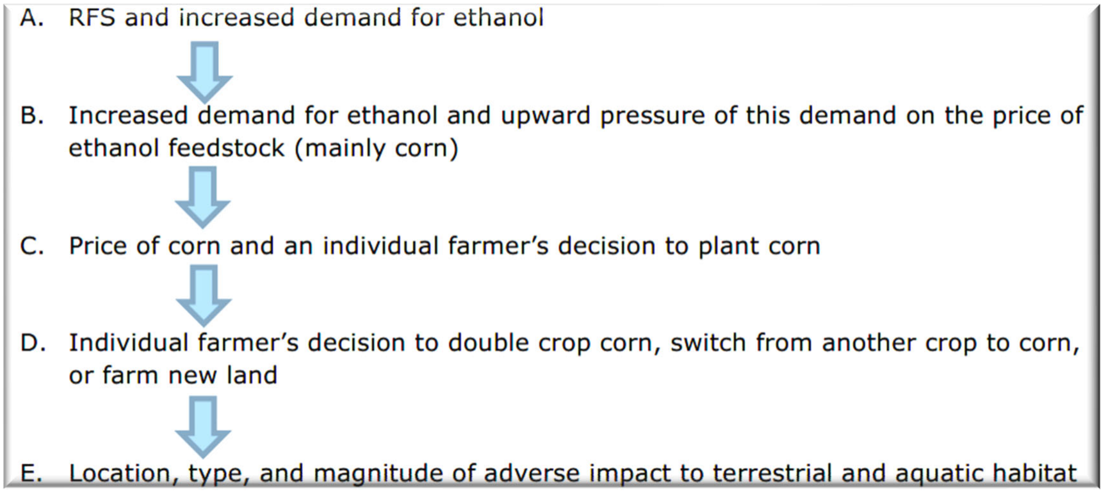
[95] NPRM at 72,451.

[96] DRIA at 88.

[97] Ramboll, *Supplemental Analysis Regarding Allegations of Potential Impacts of the RFS on Species Listed Under the Endangered Species Act* at 2 (Nov. 29, 2019) ("Nov. 2019 Ramboll Supplemental Report").



A. RFS and increased demand for ethanol

B. Increased demand for ethanol and upward pressure of this demand on the price of ethanol feedstock (mainly corn)

C. Price of corn and an individual farmer's decision to plant corn

D. Individual farmer's decision to double crop corn, switch from another crop to corn, or farm new land

E. Location, type, and magnitude of adverse impact to terrestrial and aquatic habitat

Take, for example, the third and fourth links in the chain. Farmers' decisions about whether to plant more corn, and whether to convert more land for that purpose, are driven by many factors having nothing to do with the RFS Program. These include including fluctuating food prices, other government policies, existing equipment and infrastructure, and improvements in crop yields, pests and disease, and the costs of energy and fuel.[98] Future prices of different crops relative to each other also help farmers determine the crop planting mix; however, there are limitations on farmers' ability to switch between crops (e.g., crop rotation schedules, limitations on machinery needed for particular crops).[99] Thus, the RFS is only one of many variables that drive planting decisions.

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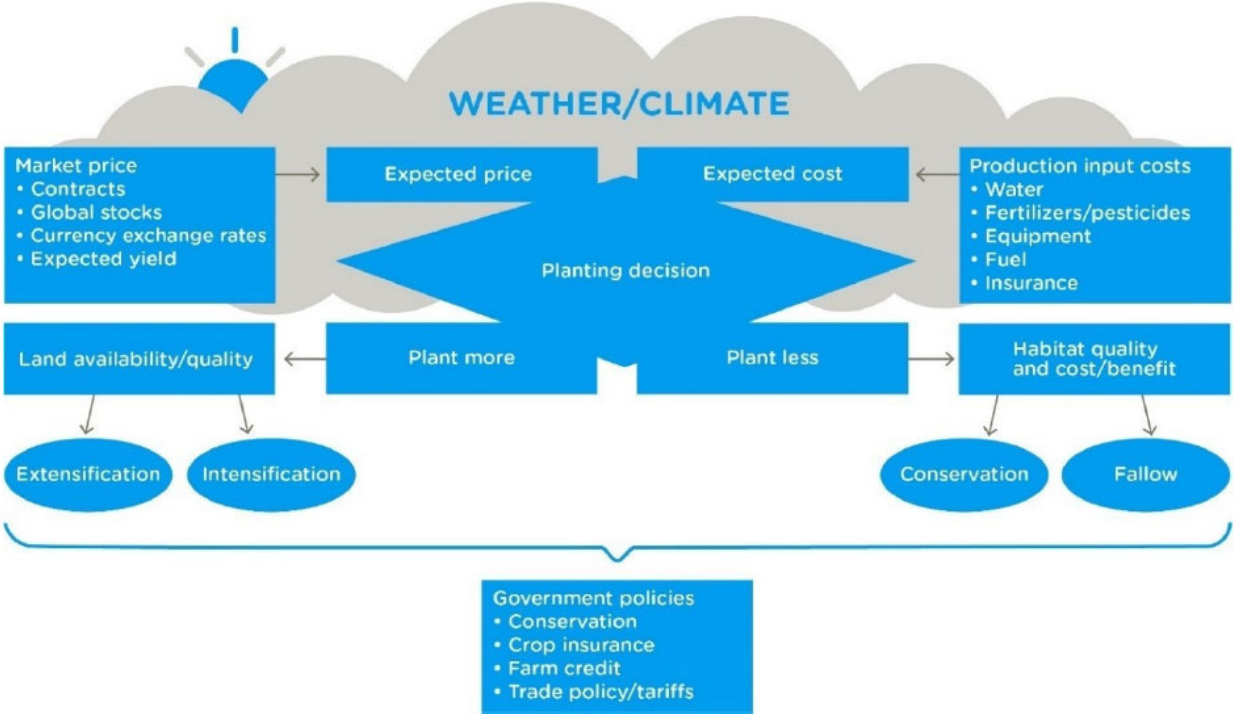
[98] Ramboll, *The RFS and Ethanol Production: Lack of Proven Impacts to Land and Water* at 5 (Aug. 18, 2019) ("Aug. 2019 Ramboll Report").

[99] Nov. 2019 Ramboll Supplemental Report at 4.



Further, even to the extent farmers' decisions are driven in part by corn prices, there is no direct causal connection between the RFS program and corn prices. The complex economic and policy factors that determine corn prices include oil prices, currency exchange rates, economic growth (and demand for food) in developing countries, market speculation, U.S. agricultural policies, trade restrictions, and macroeconomic shocks.[100] In addition, most of the increase in the price of corn (as well as other crops like soy and wheat) since 2005 has been attributed to higher oil prices, rather than any other factor.[101] A recent study that analyzed food price inflation and land use classification concluded that food inflation since 1973 was actually the *lowest* during biofuel increases in the years 1991–2016, and was most highly correlated with the price of oil.[102]

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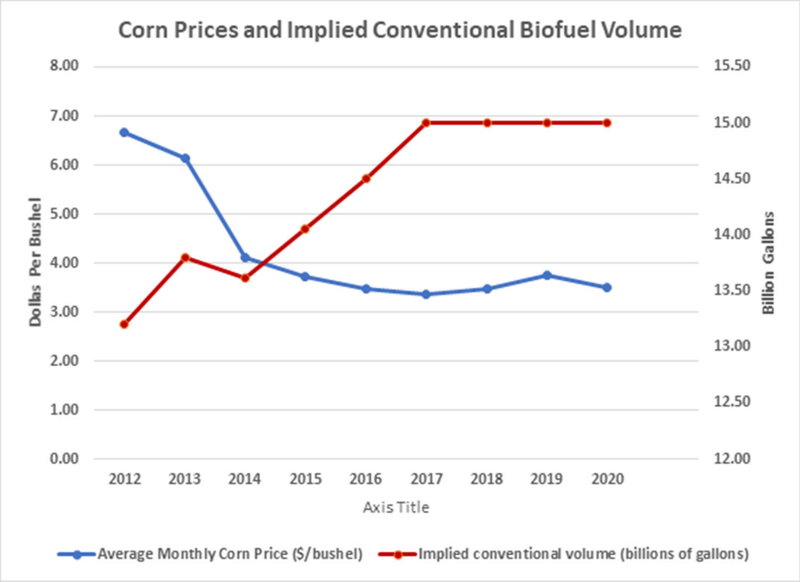
[100] *Id*. at 6.

[101] *Id*. In recent years the strongest correlation to corn prices has been oil prices because costs of producing corn include costs for fuel, lubricants, electricity, and fertilizer. *See* D.S. Shrestha et al., *Biofuel Impact on Food Prices Index and Land Use Change*, 124 Biomass & Bioenergy 43 (2019), https://ethanolrfa.org/file/1829/Shreshtha-et-al-Biofuel-impact-on-food-prices-index-and-land-use-change-03-2019.pdf; *Energy for Growing and Harvesting Crops Is a Large Component of Farm Operating Costs*, U.S. Energy Info. Admin. (Oct. 17, 2014), https://www.eia.gov/todayinenergy/detail.php?id=18431.

[102] Net Gain, *Analysis of EPA's Proposed Rulemaking for 2020, 2021, and 2022 RVOs, Regarding Land Use Change, Wetlands, Ecosystems, Wildlife Habitat, Water Resource Availability, and Water Quality* at 7 (Feb. 3, 2022) ("Net Gain Report") (attached as Ex. 3).

Indeed, the most recent data available demonstrate that there is no predictable effect between recent RFS obligations and corn prices.[103]



Moreover, even if a farmer does decide to plant corn, there is no reason to assume that he or she would alter land from non-agricultural use to agricultural use to do it. If a farmer decides to increase production of a certain crop, this can be accomplished by either producing more of the crop on existing land (intensification) or putting new land into production (extensification, which could result in land use change).[104] All else being equal, extensification is the least preferred option as it is the option most likely to involve additional expenditures such as land clearing and other preparation.[105] This decision is also driven by a variety of factors unrelated to ethanol demand which include weather conditions, soil quality, crop output, and input prices, innovations in equipment, crop insurance, disaster insurance, and marketing loans.[106]

Further, as a factual matter, nearly a century of USDA data illustrates that corn yields per acre have steadily increased while total corn acreage has plateaued.[107]

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[103] *See Prices Received by Month*, USDA (2019) https://www.nass.usda.gov/Charts_and_Maps/graphics/data/pricecn.txt.

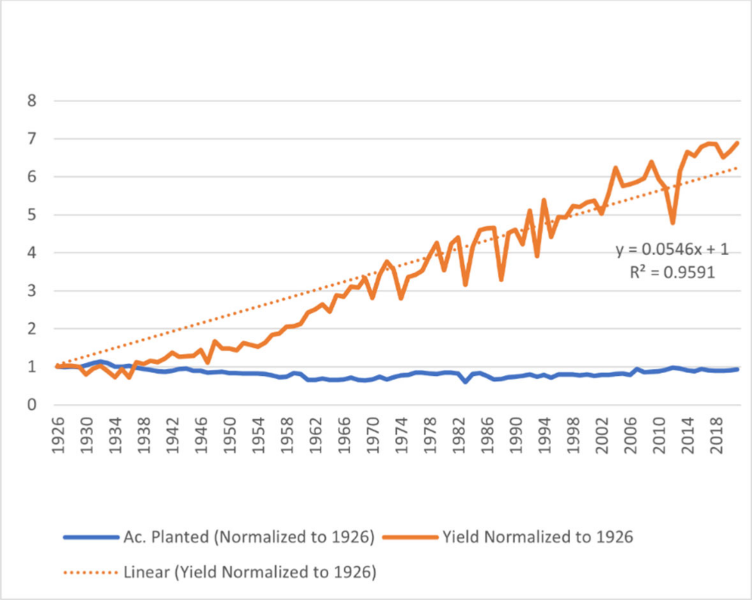
[104] Aug. 2019 Ramboll Report at 4.

[105] *Id*.

[106] Nov. 2019 Ramboll Supplemental Report at 4, 23.

[107] Net Gain Report at 9; Stillwater Associates LLC, *The RFS Reset: A Look at Corn Land Use and Conventional Ethanol Production* at 4, 7–10 (Aug. 30, 2019) ("2019 Stillwater Report").

Relative Change in Acres of Corn Planted and Yield (1926-2021)[108]



The increase in demand has largely been met by an approximately 7-fold increase in yield in bushels per acre.[109] In other words, increased production of corn is driven by intensification—the production of more corn on the same acreage of land—which does not result in land conversion.[110] The USDA further anticipates changes in corn production to result in an increase of approximately 16.1 more bushels per acre by 2028 without a substantial increase in farmed acres (and with a corresponding reduction in the use of water resources and fertilizer).[111]

Finally, critical to understanding the issue of whether the RFS causes land use change is the basic question of whether the RFS drives demand for ethanol (the first link in the chain above). As EPA itself has noted, ethanol demand in the United States has been driven by factors wholly unrelated to the RFS, such as the ubiquity of E10 in the domestic gasoline market and the demand for ethanol for export markets.[112] Because ethanol is less expensive than gasoline to produce and enhances the octane of fuel at lower cost to the consumer, "[w]ith or without the

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[108] Net Gain Report at 9.

[109] *Id*.

[110] *Id*.

[111] Aug. 2019 Ramboll Report at 29.

[112] *Id*. at 15; 2019 Stillwater Report at 3-4, 9; Initial Br. for Respondent U.S. EPA at 95–96, *Growth Energy v. U.S. EPA* (No. 19-1023) (Jan. 9, 2020) ("EPA Br."); EPA, *Endangered Species Act No Effect Finding for the 2020 Final Rule* at 7 (Dec. 2019) ("2020 No Effect Memo").

RFS, the industry will continue to produce E10 in substantial quantities."[113] EPA has thus previously reasonably concluded in the context of the 2019 Renewable Volume Obligation (RVO) that the RFS program "is not driving corn ethanol production or corn cultivation (much less farmers' decisions on when, where, and how to plant crops in 2019)," and therefore could not be driving LUC or impacts to habitat, wildlife, and ecosystems, as discussed below.[114]

In sum, careful analysis and consideration of the causal chain makes clear that the RFS program is not driving conversion of land for production of corn crop for ethanol for the RFS program. Nor will the 2022 proposed volumes have this effect as the implied conventional renewable fuel volumes are the *same* as three years ago in the 2019 RVO, e.g., 15 billion gallons. There is no evidence that *new*, previously uncultivated land would be put into corn production as a result of EPA reverting back to the 2019 implied conventional volumes in the 2022 RVO. Indeed, the analysis above suggests that this is a wholly unrealistic outcome because (1) even in 2020, when gasoline demand dropped precipitously due to the pandemic-related economic downturn and ethanol production was idled, there is no evidence that this shock caused farmers to change planting behaviors for 2021 to allow corn fields in rotation to fallow;[115] (2) even if farmers had reduced corn plantings in 2021 as a result of the economic downturn, increased corn demand has been met for decades through intensification, not extensification, meaning it is highly unlikely there would be LUC as a result of 2022 volumes returning to 2019 levels; (3) the RFS is only one of myriad factors impacting farmers' planting decisions; and (4) in any event, the Proposed Rule likely will not be finalized in time to impact crop planting decisions where planning decisions are made well in advance of the spring planting season.[116] Further, EPA should apply these real-world understandings to its "illustrative" GHG scenario that alleges there will be an "initial pulse of land use change emissions" in 2021 and 2022 due to use of a misleading 2020 baseline, as addressed in Part II above.[117]

b. Studies that have asserted that the RFS causes land use change are flawed

Recent literature has uncovered serious flaws in studies cited by the DRIA that attempt to implicate the RFS in land use change, ecosystem impacts, grassland losses, or adverse impacts to water quality tied to land use change.[118] This is mainly because previous analyses (such as Lark et al, 2015, and Wright et al., 2017) were based on the Crop Data Layer (CDL) data set, which has been found to be inaccurate. Recent studies note that reliance on CDL data results in

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[113] EPA Br. at 96.

[114] *Id.*

[115] Stillwater Associates LLC, *Comments to EPA on 2020-2022 RFS Rule* at 3 (Feb. 4, 2022) ("2022 Stillwater Report").

[116] *See* Nov. 2019 Ramboll Supplemental Report at 5–6.

[117] DRIA at 73.

[118] Net Gain Report at 4–6.

misleading levels of land use change by a wide margin and even contradicts USDA data.[119] EPA has previously acknowledged the methodological and analytical flaws in these studies and should do so here.[120] Moreover, many studies addressing LUC and the RFS fail to recognize (1) the extent to which cropping practices contribute substantially to meeting increased demand for corn, and (2) that production of dried distillers grains (DDGS) has offset substantial demand for corn as livestock feed.[121] EPA should also acknowledge a recent study with countervailing findings that assessed the local impact of ethanol plants on cropland transitions and concluded that ethanol plant expansions actually *reduce* the probability of cropland conversion by 0.5% on average. It found further that fields near ethanol plants are 10% less likely to be converted from non-agricultural land into cropland than fields farther away.[122]

c. EPA should acknowledge, as it has in other contexts, that there is no established causal link between the RFS and land use change

EPA's discussion of environmental impacts in the DRIA is fundamentally flawed in that it fails to adequately address the causal issues described above. As discussed further below with respect to specific environmental media, throughout the DRIA, EPA refers to potential environmental impacts associated with biofuels production rather than direct causal impacts of the RFS program or the Proposed Rule. The Second Triennial Report suffered from these same analytical shortcomings, which EPA has taken pains in the years since the report's release to clarify its analysis, but it is unfortunately repeating the same errors here. Specifically, EPA explained that:

> The [Second Triennial] Report explored *general associations* between biofuel production *(much of which has no relation to RFS rules)*, crop cultivation, and environmental impacts. Although the Report also inferred some land-use impacts related to biofuel production were linked to the RFS program, *it did not causally link specific RFS annual rules with land-use impacts. The Report instead emphasized the difficulties in making such a causal attribution*. And, critically, the Report did not attempt an analysis of impacts caused by the later released 2019 Rule.[123]

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[119] *See* Jennifer B. Dunn. et al, *Measured Extent of Agricultural Expansion Depends on Analysis Technique*, 11 Biofuels, Bioproducts & Biorefining 247 (2017); Joshua Pristola & Randall Pearson, *Critical Review of Supporting Literature on Land Use Change in the EPA's Second Triennial Report to Congress* (2019); 2019 Stillwater Report; Nov. 2019 Ramboll Supplemental Memo; Net Gain Report at 4–5.

[120] *See* 2020 No Effect Memo at 15–16; EPA Br. at 92.

[121] *See* Aug. 2019 Ramboll at 23–24.

[122] Net Gain Report at 4–5 (citing Pates and Hendricks, *Estimating the Local Impact of Ethanol Plants on Cropland Transitions*, Selected Poster prepared for Presentation at the 2019 Agricultural & Applied Economics Association Annual Meeting, Atlanta, GA (2019)).

[123] EPA Br. at 101 (internal citations omitted) (emphasis added).

Further, EPA's 2020 No Effect Memo clarified the findings in the 2018 Triennial Report suggesting that biofuels grown for the RFS program have an impact on land use change or water quality and quantity:

> This report did not specifically address the impacts of the 2020 RFS standards…. [and] while the report did discuss literature that generally relates biofuels to crop cultivation, such statements are of limited relevance to the 2020 RFS standards as they did not purport to establish any causal link between the 2020 RFS standards and increased crop cultivation…. *[T]he report did not purport to establish a causal connection between the 2020 RFS standards or any other RFS annual rule and land use changes*…. Thus, the report is of limited utility in assessing the environmental impacts of the 2020 RFS standards.[124]

The 2020 No Effect Memo further explains that the Second Triennial Report did not consider necessary factors including complex regulatory and market factors that are relevant to evaluating a causal relationship, which results in an analysis that "is not accurate and leads to incorrect attribution of land use change and biofuels."[125] EPA has similarly concluded that "[e]vidence shows that recent RFS rules, like the 2019 Rule [which establishes the same conventional volumes as the Proposed 2022 Rule] are not associated with increased corn and soybean demand or cultivation in the United States."[126] However, EPA does not discuss in the DRIA the substantial evidence that supported this conclusion with respect to the prior RVO rulemakings and applies equally to its analysis of environmental impacts of the Proposed Rule.

The DRIA also overlooks EPA's *own* critiques of Lark and others that assert a causal connection between the RFS and land use change based on flawed methodologies, assumptions, and data sets. For example, EPA previously criticized Lark's failure to establish the necessary causal links to support an assertion that the RFS causes LUC, or to make a defensible link

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[124] 2020 No Effect Memo at 14 (emphasis added).

[125] *Id*. at 15.

[126] *Id*. at 87.

between any particular planting or land conversion decisions that may impact habitat or species and the RFS program.[127]

2. The RFS program has not caused adverse impacts to wetlands, wildlife, ecosystems; nor will the Proposed Rule

With the necessary background and context set forth above, we now turn to EPA's discussion of environmental impacts to wetlands, wildlife, and ecosystems in the DRIA. As an initial matter, the introductory discussion to this section of the DRIA makes numerous specious claims that must be corrected. First, it reiterates the Triennial Report's claim that there is "an observed increase in acreage planted with soybeans and corn between the decade leading up to the enactment of EISA and the decade following enactment. Evidence from observations of land use change suggests that some of this increase in acreage and crop use is a consequence of increased biofuel production."[128] These statements ignore the data that total acreage planted in corn has actually remained stable over time despite substantial increases in corn yields and ethanol production.[129] It implies that EISA and the RFS *cause* increased corn plantings while failing to take into account other factors that influence each link in the causal chain described above, such as ethanol demand external to the RFS (i.e., use in E10 to boost octane and the rise in foreign ethanol exports) and the complex variables that impact individual farmers' decisions regarding what to plant, where, and how much.

EPA then asserts without support that "[i]t is likely that the environmental and natural resource impacts associated with land use change are, at least in part, due to increased biofuel production and use."[130] To what land use change is EPA referring that is relevant here? Acres planted in corn have been stable for over a decade. Further, biofuels production is driven by many factors, of which the RFS program is only one, and EPA has previously established that the program, as implemented, is not driving demand.[131] EPA should acknowledge that the best available science supports that there is *no* causal connection between the RFS and LUC, and

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[127] *See* EPA Br. at 91–92 ("Dr. Lark generalizes that, across the United States, only 27% of uncultivated lands that unregulated farmers converted to croplands were planted to corn. This means most of the lands are converted for other reasons. Even when farmers plant corn on converted land, most of this corn is grown for non-biofuel uses. Even for corn that is ultimately used for biofuel production, Environmental Petitioners present no evidence that such biofuels are ultimately used for RFS compliance (as opposed to being exported). And assuming some corn grown on some undisclosed plot of converted land was used to produce biofuels satisfying the RFS volumes, Environmental Petitioners present no evidence that the unregulated farmer would not have converted the specific parcel or planted corn but for the 2019 Rule.") (internal citation omitted).

[128] DRIA at 88.

[129] *See* Net Gain Report at 9; 2019 Stillwater Report at 7–10; 2022 Stillwater Report at 2.

[130] DRIA at 88.

[131] 2020 No Effect Memo at 6; EPA Br. at 96.

therefore there are no established impacts to wetlands, wildlife, and ecosystems caused by the RFS program in general or the Proposed Rule in particular.[132]

In particular with respect to wetlands, EPA's discussion of losses of wetlands cite to studies that do not even attempt to link wetlands losses to the RFS or even to biofuels production in general.[133] Rather, the reports explore wetlands losses on cropland and rangeland without any particular nexus to biofuels, ethanol, or the RFS. EPA's conclusion is that it cannot "determine the *portion* of wetlands acres lost in order to grow feedstocks for biofuels," but there is no reason to link the loss of wetlands to biofuels in the first instance.[134] EPA's discussion thus misleads the reader into thinking there is some established connection between wetlands loss and biofuels production *when there is not*.[135] EPA later suggests that simply because there has been wetlands loss since 2007 it is possible the 2022 volumes will exacerbate those losses without the necessary causal nuances described in detail above.[136] These conclusions are unfounded and misleading, especially when offered in the context of the Draft *Regulatory Impact Analysis* that is supposed to explore the regulatory impacts of the RFS historically and the Proposed Rule's potential future effects.

Similarly, with respect to ecosystems, EPA acknowledges at the outset that "attributing the fraction of these changes [to ecosystems] to biofuels is not currently possible with any degree of confidence" and therefore attributing changes to the RFS program and the Proposed Rule are not possible.[137] EPA nonetheless discusses at-length studies and data exploring reductions in rangeland and grassland that have no identifiable link to the RFS program or the Proposed Rule, without devoting any attention to explaining the many complex reasons why attribution is not possible and is not supported by the scientific literature.

With respect to wildlife, on the one hand, EPA acknowledges that "[w]hile the impacts of land use and management on wildlife have been studied, the impacts of biofuels generally and the annual volume requirements under the RFS program specifically have not."[138] But it also asserts that biofuels production is driving conversion of grasslands to cropland with potential risks for grassland species including birds and insects.[139] The DRIA then summarizes a variety of scientific literature on losses of bird species and insect pollinators such as bees.[140] Consistent with its conclusion on wildlife, EPA asserts that it cannot "confidently estimate the fraction of wildlife habitat loss or of corn or soy production that is attributable to biofuel production or use,"

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[132] Net Gain Report at 12–13.

[133] DRIA at 89.

[134] *Id*. (emphasis added).

[135] *See* Net Gain Report at 12–13.

[136] DRIA at 91.

[137] *Id*. at 92.

[138] *Id*. at 97.

[139] *Id*. at 96.

[140] *Id*.

much less to the RFS program or a particular RVO rulemaking.[141] EPA should acknowledge that the scientific literature does not support that there is *any* relationship between the RFS program and adverse wildlife impacts, rather than leaving readers with the distinct impression that there are impacts of bird species and bees tied to the program, but they are not quantifiable or "confidently" estimable.

Further, claims by parties (e.g., Lark) that have sought to tie the RFS to impacts to wildlife have been thoroughly disproven. For example:

- There is no evidence that the whooping crane is affected by annual RFS rules. The population has been increasing over time and has grown at an accelerated rate after the RFS was implemented.
- There is no evidence that the Black-footed ferret is affected by annual RFS rules. Populations have been rapidly increasing since 2000, with no dip apparent in the years after the RFS was implemented.
- There is no evidence that annual RFS rules are impacting Gulf Sturgeon by exacerbating the Gulf of Mexico dead zone. The Gulf Sturgeon's critical habitat is located east of the Mississippi River delta, while the Gulf of Mexico hypoxic zone is exclusively to the west. Moreover, as addressed below, there is no evidence that land use tied to the RFS has impacted nutrient loading in the Gulf of Mexico because nutrient loading has remained relatively constant from 1980 through present day.[142]

3. The RFS Program has not caused adverse impacts to soil and water quality; nor will the Proposed Rule

In the section of the DRIA titled "Drivers" in the soil and water quality section, EPA asserts that because corn-grain ethanol and soy biodiesel account for most biofuels "produced to date[,] … the majority of soil and water quality impacts from biofuels thus far have come from the production of corn and soybeans."[143] EPA then extensively discusses adverse soil and water quality effects that are tied to agricultural activities in general and alleged, but unquantified, extensification of corn and soybean plantings, in particular.[144] EPA concludes that "[a]ssumed increases in biofuel production associated with higher RFS volumes would likely lead to an increase in land for agriculture …. [and] an increase in cropland acreage would generally be expected to lead to more negative soil and water quality impacts."[145] This discussion is incorrect and misleading for a number of reasons. First, nowhere does EPA explain that there is *no* evidence linking adverse soil and water quality impacts to the RFS program, as the latest scientific literature confirms.[146] Second, EPA simply assumes any increase in biofuel production

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[141] *Id.* at 98.

[142] Nov. 2019 Ramboll Supplemental Report at 7–12.

[143] DRIA at 100.

[144] *Id.* at 101–12.

[145] *Id.* at 113–14.

[146] Net Gain Report at 14, 16–17.

would drive extensification when there is no support for this claim, as addressed extensively above. Increases in ethanol production have occurred for the entire duration of the RFS program without need for new cropland for corn plantings given efficiency and yield improvements.[147]

Further, EPA reliance on the Second Triennial Report to suggest that corn grown for ethanol is a contributor to eutrophication in downstream water bodies is misplaced.[148] The Second Triennial Report fails to consider that these watersheds are composed of a complex mix of urban and rural uses, where agriculture runoff may be only one component—and where there is still no attempt to link corn grown for ethanol to the RFS.[149] Significantly, nutrient loading into the Gulf of Mexico has remained relatively stable in the last 40 years, despite corn yield increasing dramatically during this time frame.[150] Furthermore, the data demonstrates that regional hypoxic conditions in Western Lake Erie and the Gulf of Mexico were increasing in frequency and severity long before ethanol production in the United States increased.[151] In addition, there has been a reduction in total nitrogen concentrations in surface water bodies in Iowa, which is the highest corn producing state, a fact which further refutes that there is a link between expanded corn production for any reason and increased nutrient loading.[152] Though more progress can always be made on nutrient efficiency and minimizing runoff, the data shows that eutrophication is not worsening, even with higher levels of corn production, and that increased production of corn does not result in increased usage of nutrients—in fact, the most recent data show that there has been a downward trend in nutrients required on a per-bushel basis. In other words, even an increased production of corn does not result in increased usage of nutrients and has actually resulted in a reduction in nutrient requirements on a per gallon of ethanol basis.[153]

EPA also does not address recent farming technologies and techniques that reduce the use of fertilizers and nutrients. For example, fertilizers have been reduced through the use of precision agriculture, variable-rate application, and GPS- and sensor-based mapping which restrict the addition of fertilizer to the area immediately around the plant.[154] Seed improvements have also produced plants with increased efficiency at utilizing available nitrogen, thus further lowering fertilizer application requirements.[155] Advances in sustainable farm management, including substantial improvements in nutrient formulation and use, and technological improvements in pesticide and fertilizer application, will continue to reduce the potential for

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[147] *Id*. at 9.

[148] DRIA at 100, 108.

[149] Net Gain Report at 18–19.

[150] *Id*.

[151] *Id*. at 18, Figure 6 (using data from the U.S. Geological Survey, *Nutrient Loading for the Mississippi River and Subbasins*, https://nrtwq.usgs.gov/mississippi_loads/#/).

[152] Aug. 2019 Ramboll Report at 14.

[153] 2019 Stillwater Report at 29.

[154] *Id*.

[155] *Id*.

impacts to water quality in regional watersheds near corn growing areas regardless of the cause of historical water quality impacts.[156]

4. The RFS Program has not caused adverse impacts to water quantity and availability; nor will the Proposed Rule

EPA's discussion of water quantity and availability suffers from the same flaws as its analysis of the environmental media discussed above. Specifically, EPA fails to meaningfully distinguish between potential impacts to water availability that are tied to the RFS and the Proposed Rule and potential impacts associated with biofuel production at *any* volumes and due to any number of drivers (e.g., export demand, demand for ethanol for E10 blending). The wide body of scientific literature on water quantity does not support a causal nexus between the RFS and strained water resources.[157] Further, in the Proposed Rule and DRIA, EPA ignores that advances in farming practices and technology have reduced the potential impacts of biofuel production on water resource availability. EPA states that "the primary driver of impacts to water quantity is the water used for irrigation of the biofuel feedstocks."[158] Yet, today, most of the corn grown in the United States is non-irrigated. There has been an increased use of precision agriculture methods and best practices to retain soil moisture and reduce tilling, all of which mitigate any impacts to water resource availability.[159] In addition, technological advancements such as genetic engineering for improved drought tolerant corn cultivars result in corn that is able to tolerate reductions in water without affecting yield.[160] The chart below clearly demonstrates a decreasing trend in water used for growing corn over the past few decades, in part as a result of these practices.[161]

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[156] Aug. 2019 Ramboll Report at 7.

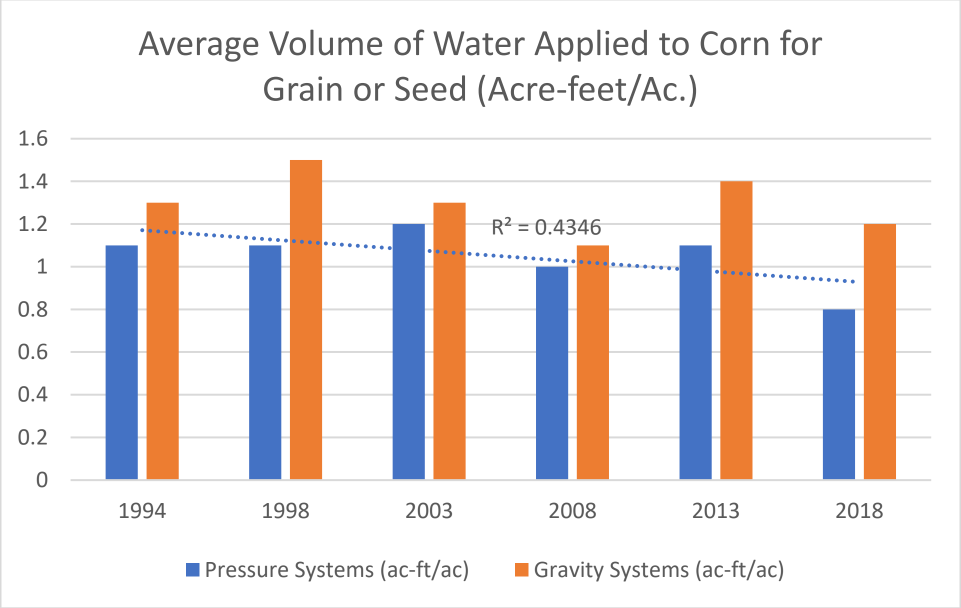
[157] Net Gain Report at 14–17.

[158] DRIA at 115.

[159] Nov. 2019 Ramboll Supplemental Report at 30.

[160] Net Gain Report at 16–17.

[161] *Id*. at 17, Figure 5.



Moreover, EPA places too little emphasis on the reduction in water use accomplished by ethanol refineries in recent years. Ethanol refineries have made great strides to reduce water consumption by employing practices such as process optimization, capture of water vapor from dryers, and boiler condensate recycling.[162] EPA should correct its discussion of water quantity and availability to, at a minimum, make clear that the scientific literature does not suggest that the RFS program causes any adverse impacts.

5. EPA does not adequately assess the environmental impacts associated with petroleum-based fuels

Any possible effects of biofuel production and refining on the environment should not be viewed in a vacuum, but should be viewed with respect to the alternative—production of gasoline and diesel fuel. Although EPA acknowledges that a comparison between the effects of biofuel and petroleum production should be undertaken, it states that "such an assessment would be expansive and could not be performed on the timeline of this rulemaking."[163] However, there is a wealth of readily-available scientific literature that addresses petroleum impacts, which clearly document direct adverse effects on land use change, water quality, ecosystems (including wetlands), and wildlife.[164] Instead EPA presents an incomplete assessment of water-related impacts of petroleum, without consideration of petroleum production's impact on land use change, habitat, wildlife, and ecosystems. In short, in assessing the factors in Section 211(o)(2)(B)(ii)(I), EPA needs to consider the potential for indirect environmental impacts biofuels *as compared to* the potential for such impacts from the petroleum-based fuels that the biofuels are displacing. This comparative analysis is at the heart of lifecycle GHG analysis, which assesses the lifecycle GHG emissions from a gallon of renewable fuel compared with the

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[162] *Id*. at 15; Aug. 2019 Ramboll Report at 33.

[163] DRIA at 112.

[164] *See* Aug. 2019 Ramboll Report at 37–43.

equivalent gallon of petroleum fuel. Logically, the same comparative analysis should be undertaken with respect to all of the environmental factors in Section 211(o)(2)(B)(ii)(I).

B. EPA Should Finalize a "No Effects" Finding Under Section 7 of the Endangered Species Act

The Proposed Rule suggests that EPA is considering U.S. Fish and Wildlife Service ("USFWS") consultation pursuant to Section 7(a)(2) of the Endangered Species Act (ESA) for the Proposed Rule based on two D.C. Circuit cases.[165] Specifically, the Proposed Rule states that based on the D.C. Circuit's decisions finding that EPA failed to make an adequate effects determination under Section 7 of the ESA for the 2018 and 2019 RFS rules, EPA would consider initiating consultation "as appropriate" for the Proposed Rule.[166] Here, consultation is not appropriate for a number of reasons. At a minimum, to the extent that EPA does engage in informal consultation with the wildlife services (USFWS and/or the National Marine Fisheries Service), these agencies should easily conclude that the Proposed Rule is not "likely" to adversely affect listed species or habitat and thus determine that a formal consultation process is not required.[167]

As a preliminary matter, the 2020 and 2021 proposed volumes will be entirely retroactive; therefore, EPA is amply supported in finding that the proposed volumes for those years have no effect on listed species or habitat. In addition, EPA may, and should, make a finding that the 2022 RVO volumes would have no effect on listed species or habitat. EPA need not consult with USFWS because it can make a reasoned showing that there is no evidence of any impact. First, there is no evidence that the RFS incentivizes ethanol production at the implied conventional volumes proposed, which are the same as the 2019 and 2020 RVOs. As EPA corrected concluded in the 2020 No Effect Memo, even if EPA were "to waive all of the RFS requirements for 2020, [it] would expect domestic use of ethanol in the U.S. to only decrease slightly" due to the ubiquity of E10 blending.[168] Nor is there evidence that demonstrates land use change or water impacts as a result of crops grown for renewable fuel for the RFS program, either in past years or at the volumes proposed for 2022. Even further removed, without impacts on land and/or water, there can be no impact on listed species or habitat. And as EPA concluded in the DRIA, "it is not possible to …. confidently estimate the impacts to … wildlife … generally nor from the annual volume requirements, specifically."[169]

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[165] *See Am. Fuel & Petrochemical Mfrs. v. EPA*, 937 F.3d 559 (D.C. Cir. 2019); *Growth Energy v. EPA*, 5 F. 4th 1 (D.C. Cir. 2021).

[166] NPRM at 72,442.

[167] *See* 50 C.F.R. 402.13(c).

[168] 2020 No Effect Memo at 6.

[169] DRIA at 98–99.

This is because there is no evidence of such a causal relationship. To be sure, none of the studies cited in EPA's DRIA demonstrates any link.[170]

As further explained below, EPA may explain and support a no effect finding with ample evidence in the record, including the Ramboll Report and Supplemental Memo and the Net Gain Report (and literature cited therein), all of which undertake an exhaustive effort to address what evidence exists regarding corn grown and ethanol produced for the RFS and impacts to the environment and wildlife, and find none.

In any event, if EPA still determines that the Proposed Rule *may* affect listed species or habitat, all that is required is informal consultation with USFWS to determine whether the action "is not likely to adversely affect" a listed species or critical habitat.[171] The record clearly supports a finding that the RFS is not likely to adversely affect listed species or habitat. As set forth in Ramboll's November 2019 Supplemental Memo and Net Gain's Expert Report, there is no evidence of any causal relationship between corn grown for the RFS and impacts to endangered or threatened species or habitat.

Specifically, there is no evidence that (1) the RFS increases the demand for ethanol or the volumes in the Proposed Rule would increase demand for biofuels in a market-forcing manner; (2) the increased demand for ethanol determines the prices of corn; (3) the price of corn determines a farmer's decision to plant corn; (4) the farmer would clear previously uncultivated land to plant corn, resulting in land use change; (5) this increased corn production would cause nutrient loading and worsen hypoxia in downstream water bodies (whether due to intensification or extensification); and (6) the geographic locations at which land use change or intensification may occur and/or impacts to water quantity or quality affect any particular listed species or habitat. Consistent with EPA's determination in the original 2020 RVO, "[g]iven the highly attenuated causal chain between the [Proposed Rule] and potential impacts on listed species and critical habitat, any such impacts would be 'only reached through a lengthy causal chain that involves so many steps as to make the consequence not reasonably certain to occur.'"[172]

As EPA further correctly explained in the original 2020 No Effect Memo and is equally applicable here:

> [The Proposed Rule] do[es] not require, authorize, fund, or carry out the production of any specific biofuel or crop, the use of any land that is critical habitat, or the taking of any listed species or other activity that may affect any listed species. Decisions on what type of feedstock to use for biofuel production, where such feedstocks are grown, the types and volumes of agricultural inputs such as fertilizer or pesticide to use in growing the feedstocks, and what types of renewable fuel will ultimately be produced, are made by

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[170] *See id*. §§ 3.3.3, 3.4.2.3 (citing various studies on terrestrial and aquatic species, none of which connect impacts to corn grown for the RFS to adverse impacts).

[171] 50 C.F.R. 402.13(c).

[172] 2020 No Effect Memo at 4 (quoting 50 C.F.R. 402.17(b)(3)).

> third parties, and any on-the-ground activities to implement and carry out those decisions are undertaken by such third parties. Moreover, some third parties, notably farmers who decide how much and where they plant crops, are not regulated by the RFS program at all.[173]

In addition, EPA has previously comprehensively addressed that the 2018 Second Triennial Report "did not purport to establish a causal connection between the 2020 RFS standards or any other RFS annual rule and land use changes," and is therefore of "limited utility in assessing the environmental impacts of the … RFS standards."[174] That finding is equally applicable to EPA's fulfillment of its obligations under the ESA here.

Moreover, the declaration of Tyler Lark, which was relied upon in both of the D.C. Circuit decisions referenced above, does not serve as a foundation for a finding that the Proposed Rule is "likely to adversely affect" a listed species or critical habitat. This declaration has subsequently been widely critiqued, with much of the evidence cited in the declaration actually *refuting* the declaration's own assertions. As just a few examples, an analysis of several of the Lark Declaration's claims of land conversion in specific areas (which allegedly affected species such as the whooping crane, Powesheik skipperling, and yellow-billed cuckoo), found that those areas had been converted long before the inception of the RFS, therefore negating any causal connection.[175] Similarly, the Declaration summarily concluded that corn and soy production worsened the Gulf of Mexico dead zone thus impacting the Gulf Sturgeon; however, the dead zone does not overlap temporally or geographically with habitat for the Gulf Sturgeon.[176]

EPA has previously acknowledged the limitations of the Lark Declaration. Specifically, EPA considered the evidence discussed in the Lark Declaration and found shortcomings, including that the underlying studies were based on inconclusive temporal and spatial associations using satellite imagery.[177] As EPA explained, "there is no way to determine if the crops grown on a particular parcel were used for biofuel production versus some other use …. [the studies cited in the Lark Declaration] remain probabilistic and limited in scope, and [insufficient to] identify impacts on particular parcels of land."[178] In sum, in the context of an informal consultation with USFWS for this rulemaking, EPA should carefully review and

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[173] *Id*. at 3.

[174] *Id*. at 14.

[175] Nov. 2019 Ramboll Supplemental Report at 7–12.

[176] *Id*. at 15 (concluding that "the presumption in the Lark Declaration that the RFS has resulted in impacts to Gulf sturgeon is unsubstantiated").

[177] *See* 2020 No Effect Memo at 15.

[178] *Id*. at 8.

consider the body of literature that found the Lark Declaration to rely on unsupported assumptions and speculation, used faulty data sets, and is otherwise unreliable.[179]

Thus, EPA may explain and support a no effect finding with ample evidence in the record, but at a minimum, EPA, in informal consultation with USFWS, should conclude that the RFS "is not likely to adversely affect" listed species or habitat.

C. Air Quality Impacts of Proposed Rule

EPA's brief analysis of air quality impacts in the Proposed Rule, relying in part on the Anti-Backsliding Study, concludes that the overall impacts to air quality of the biofuels volumes in the Proposed Rule will be minor and therefore do not favor higher or lower volumes.[180] EPA finds that the overall concentration of ethanol in gasoline is likely to remain constant at approximately 10% as a result of the rulemaking, rather than the rule spurring increased production and use of higher-level ethanol blends.[181] EPA's analysis in the DRIA overlooks the air quality benefits of ethanol-blended fuels.

In particular, EPA should acknowledge the benefits of ethanol-blended fuel in reducing emissions of potent air toxics such as benzene and 1,3 butadiene, as well as particulate matter (PM) and carbon monoxide.[182] Specifically with respect to primary $PM_{2.5}$, a new study finds substantial cold start emissions reductions associated with increased ethanol blending and the dilution of aromatics in the final blend. The attached report from Drs. Kazemiparkouhi, MacIntosh, and Suh summarizes the study's findings and its implications, namely that ethanol-blended fuels can drive air quality improvements in communities with environmental justice concerns that, due to proximity to congested roadways, are more adversely impacted by tailpipe emissions from mobile sources, including primary $PM_{2.5}$.[183] In sum, EPA should consider the potential emissions and air quality benefits of ethanol-blended fuels in setting volumes of renewable fuels under its reset authority and in future RFS rulemakings.

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[179] *See* Joshua Pristola & Randall Pearson, *Critical Review of Supporting Literature on Land Use Change in the EPA's Second Triennial Report to Congress* (2019); 2019 Stillwater Report; Nov. 2019 Ramboll Supplemental Report; Net Gain Report.

[180] *See* DRIA at 58.

[181] *Id.* at 58, 61.

[182] *See* Growth Energy Comments on Proposed Anti-Backsliding Determination for Renewable Fuels and Air Quality, Docket ID No. EPA-HQ-OAR-2020-0240 (July 1, 2020), https://www.regulations.gov/comment/EPA-HQ-OAR-2020-0240-0012.

[183] *Comments of Drs. Fatemeh Kazemiparkouhi, David MacIntosh, Helen Suh*, EPA-HQ-OAR-2021-0324 (Feb. 3, 2022) (attached as Ex. 4).

D. Increasing Renewable Fuel Volumes Benefits Communities with Environmental Justice Concerns

1. Environmental justice and climate change

Growth Energy strongly agrees with EPA that the proposed increases in the renewable fuel volumes in 2022 will reduce GHG emissions and therefore may mitigate disproportionate impacts of climate change on low income and vulnerable communities.[184] As addressed above, biofuels such as corn ethanol contribute substantially to reducing GHG emissions in the transportation sector. For example, recent analysis finds that nationwide use of E15 in lieu of E10 could reduce U.S. GHG emissions by over 17 million tons per year, the equivalent of removing 3.85 million vehicles from the roads.[185] Although it may be difficult to quantify with precision the benefits to vulnerable communities associated with reductions in GHG emissions, EPA is correct to take these known benefits into account in a qualitative manner.

2. Environmental justice and air quality

EPA's discussion of potential air quality impacts of the Proposed Rule on communities with environmental justice concerns overlooks the extent to which these communities may experience improvements in local air quality associated with combustion of gasoline-ethanol blends, especially at higher concentrations. Combustion of the fossil fuel component of gasoline and diesel results in harmful primary particulates and toxic aromatics like benzene and toluene. As EPA notes, low income, minority, and vulnerable communities are often proximate to major roadways where these pollutants are more concentrated.[186] Increased biofuel-blending can mitigate these emissions. In particular, a recent study conducted by the University of California, Riverside found that greater use of ethanol-blended fuels can reduce carbon monoxide, ozone, and primary particulate matter levels relative to the use of gasoline-only fuels.[187] In addition, as discussed above, primary $PM_{2.5}$ emissions from gasoline-ethanol blends are lower than non-blended fuels. Primary $PM_{2.5}$ emissions have substantial human health impacts as discussed above and in Exhibit 4. Because communities of concern face disproportionate impacts of such emissions, we encourage EPA's environmental justice analysis to take into account the ability of increased biofuel-blending to ease the pollution burdens these communities bear, including through reductions in primary particulates and the toxic constituents in gasoline.

3. Environmental justice and water/soil impacts

EPA suggests in the DRIA that the proposed 2022 volumes may "have disproportionately severe negative impacts on environmental justice communities within

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[184] *See* DRIA at 221.

[185] Air Improvement Resources, Inc., *GHG Benefits of 15% Ethanol (E15) Use in the United States* 2 (Nov. 30, 2020), http://www.airimprovement.com/reports/national-e15-analysis-final.pdf.

[186] DRIA at 222.

[187] University of California, Riverside, Center for Environmental Research and Technology ("CE-CERT") Study.

American Indian tribes and other low income populations that rely on local fisheries as a source of food or income or that may not be able to afford costly water filtration systems to address nitrate contamination in their drinking water."[188] This sweeping statement is wholly unsupported by EPA's analysis of past and potential environmental impacts of the RFS program in general and the 2022 proposed volumes in particular. First, as addressed extensively above, the scientific and economic literature on these issues does not indicate that the RFS drives farmers' choices to plant particular crops and raises corn prices.[189] There are many complex and interrelated variables that impact planting decisions and commodity decisions. Further, even if the RFS may drive more demand for corn or soybeans, the literature does not support that demand would be met in a manner that entails negative impacts to water quality, e.g., by greater application of fertilizers that may cause additional agricultural runoff, nutrient leaching, and algae blooms.

EPA's conclusory and alarmist statements regarding endangerment to human populations that rely on fisheries entirely overlook that over the last four decades as demand for biofuels has increased substantially, fertilizer use has gone *down* as farming technologies have improved over time.[190] Further, nutrient loading to the Gulf of Mexico has remained stable since the 1980s,[191] and as EPA acknowledged in the Second Triennial Report, total nitrogen concentrations in surface water bodies in Iowa (where corn growth has intensified) has gone down.[192] Moreover, EPA does not geographically associate hypothesized adverse impacts to water quality to environmental justice communities that may rely on local fisheries as a food source or communities that cannot afford water filtration. There is no evidence to support that proposed 2022 volumes may adversely impact such communities.

IV. EPA'S PROPOSED MODIFICATION OF THE 2020 STANDARDS UNDERMINES THE RFS PROGRAM, CONTRADICTS THE CLEAN AIR ACT, AND IS IRRATIONAL

"Congress intended the Renewable Fuel Program to be a 'market forcing policy' that would create 'demand pressure' to increase consumption of renewable fuel."[193] EPA's proposal to retroactively lower previously set standards to the point of actual use—and thereby relieve obligated parties of their failure to comply with their legal obligations under those standards—nullifies Congress's RFS policy. EPA's proposed retroactive absolution creates perverse incentives for future compliance: no longer will there be any reason for obligated parties to

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[188] DRIA at 224.

[189] As addressed in Part VI, our analysis supports that the Proposed Rule will not have adverse impacts on food prices. However, to the extent the proposed volumes do have an impact on prices, we agree with EPA that such impacts will be minimal and will not adversely impact low income and vulnerable communities. *See* DRIA at 225.

[190] *See* Net Gain Report.

[191] Aug. 2019 Ramboll Report at 27.

[192] EPA, *Biofuels and the Environment: Second Triennial Report to Congress* 69 (June 2018), https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=542063&Lab=IO.

[193] *ACE*, 864 F.3d at 705.

bother trying to comply with RFS standards; if they fail, they can count on EPA to bail them out. And the worse they fail, the more likely EPA will be to save them. Obviously, Congress did not authorize EPA to do this. The reset provision invoked by EPA certainly does not; that provision permits only prospective adjustments, and requires that any adjustments be focused on addressing the circumstances that triggered the reset. Moreover, contrary to EPA's assertions, the 2020 volumes *do* affect future use of renewable fuel through the carryover RIN mechanism (as EPA acknowledges elsewhere in its proposal). At most, EPA could reduce the 2020 standards to account for the actual level of SREs and cellulosic production but no further.

A. EPA's Proposal to Retroactively Lower Previously Set Standards to the Level of Actual Use Negates the RFS and Therefore Is Impermissible

EPA proposes "to retroactively reduce the 2020 volumes to those actually used."[194] Although EPA admits that "retroactively adjusting the 2020 standards will disrupt market expectations created by the prior final rule, for instance on the part of biofuel producers," it states that it is "relieving burdens on obligated parties, and in some cases, the potentially onerous burden of noncompliance with the RFS program and the possibility of penalty payments."[195]

EPA's reasoning is baffling. For one thing, EPA admits that its proposal will harm renewable fuels producers—the entities that Congress expected to benefit economically from the RFS program—for the benefit of obligated parties—the entities on whom Congress placed the burden of compliance. EPA provides no explanation—nor could it—for why it is permissible or appropriate to choose to transfer the cost of obligated parties' noncompliance onto renewable fuels producers.

More fundamentally, Congress designed the RFS program "to force the market to create ways to produce and use greater and greater volumes of renewable fuel each year."[196] The threat of penalties for noncompliance is precisely how the program implements this market-forcing policy.[197] If compliance was to be required only when compliance is not burdensome, there would have been no point in requiring compliance.

EPA's proposed approach will teach obligated parties that they need not bother trying to comply with their congressionally mandated obligations in the future because if they fail to, EPA will relieve them of those obligations—and the worse they fail, the more likely EPA will be to do so, creating an insidious incentive.[198] This time, EPA invokes the Covid-19 pandemic; next time, it might invoke some other unusual circumstance. This approach conflicts with Congress's

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[194] NPRM at 72,449.

[195] *Id.*

[196] *ACE*, 864 F.3d at 710.

[197] *Id.* at 704-705 (noting that Congress "place[d] any compliance burdens" on obligated parties to "ensur[e] that the renewable fuel volume requirements are met"); *see Duquesne Light Co. v. EPA*, 791 F.2d 959, 960 (D.C. Cir. 1986) (Clean Air Act's penalties are "designed to alter … economic behavior by changing the costs of" noncompliance (quotation marks omitted).

[198] NPRM at 72,449.

intent and is an irrational way to manage the RFS program. Indeed, the Supreme Court recently rejected it, explaining that interpreting the RFS statute such that "the least compliant refineries [w]ould be the most favored" would have "the strange"—and impermissible—"effect of disincentivizing … refineries from ever trying to comply."[199]

EPA asserts that "this rulemaking has no ability to affect actual production, imports, and use of renewable fuel in 2020," since "2020 has already passed."[200] EPA's reliance on this truism disregards how the RFS program functions, as EPA itself admits elsewhere in its proposal. The 2020 standards *will* have such effects in *future* years through the mechanisms of the carryover RIN bank and deficit carryforwards. As EPA correctly says, the original "higher volumes for 2020 … would cause some combination of a drawdown of the carryover RIN bank [and] carryforward deficits."[201] And EPA correctly explains that the carryover RIN bank and carryforward deficits "operate such that … any RIN deficits [in one year] can impact the market for RINs and renewable fuels in the next year. As such, compliance with the RFS standards for one year is inherently intertwined with compliance for the prior year."[202] In other words, as EPA says, the "actual market effects" of one year's RFS standards are "mediated through the carryover RIN bank" from the prior year's compliance performance.[203] EPA's disregard of this obvious reality when crafting its modification of the 2020 standards therefore renders its proposal internally incoherent and irrational.

EPA insists on taking an expansive, atextual view of its statutory authority—a view that allows it to nullify the very statutory program it was charged with administering. This is not how agencies are supposed to interpret their authority. EPA cannot disregard the fundamental nature of the RFS program as a binding, market-forcing policy that operates through enforced compliance obligations, or the reality that enforcement of the obligations for past years affect the course of the program. As the Supreme Court has held, it is fundamental to the constitutional separation of powers and the constitutional process of bicameralism and presentment that the Executive Branch cannot nullify a duly enacted statute—even if the statute expressly says it can.[204] Even an agency's power to cancel a specific statutory program can exist only where Congress has clearly granted that power and the cancellation "execut[es] the policy that Congress had embodied in the statute."[205] That standard is not met here. Again, the statute does not authorize cancellation, and it makes no sense to think that Congress implicitly intended EPA to be able to use the reset provision to cancel the program when that would defeat the central congressional purpose of the RFS program: forcing the market to increase its use of renewable

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[199] *HollyFrontier Cheyenne Ref., LLC v. Renewable Fuels Ass'n*, 141 S. Ct. 2172, 2182 (2021).

[200] NPRM at 72,448.

[201] *Id.* at 72,457.

[202] *Id.* at 72,454.

[203] *Id.* at 72,456.

[204] *Clinton v. City of New York*, 524 U.S. 417, 443 (1998) (invalidating Line Item Veto Act); *Ethyl Corp. v. EPA*, 51 F.3d 1053, 1060 (D.C. Cir. 1995) ("We refuse, once again, to presume a delegation of power merely because Congress has not expressly withheld such power.").

[205] *Clinton*, 524 U.S. at 444.

fuel through binding RFS obligations. As the Supreme Court has said, "Congress … does not alter the fundamental details of a regulatory scheme in vague terms or ancillary provisions—it does not, one might say, hide elephants in mouseholes."[206]

That is doubly true for an interpretation that would give the agency the power to nullify a congressional program "of vast economic and political significance," like the RFS.[207] When it comes to "authorizing an agency to exercise [such] powers," courts "expect Congress to speak clearly."[208] Congress has not clearly given EPA the power to cancel the RFS standards, and therefore EPA does not have that power. On the contrary, Congress imposed on EPA "a statutory mandate to 'ensure[]' that [the volume] requirements are met."[209]

B. The Reset Power Is Not Available to Reduce Already-Set Standards for a Past Year or to Reduce Volume Requirements More Than Needed to Address the Circumstances That Triggered the Reset

The Clean Air Act provides that if EPA "waives" an "applicable volume requirement set forth in [the statutory] table" by "at least 20 percent … for 2 consecutive years" or by "at least 50 percent … for a single year," EPA "shall promulgate a rule … that modifies the applicable volumes set forth in the [statutory] table … for all years following the final year to which the waiver applies."[210] Because EPA used a cellulosic waiver to reduce the total and advanced volume requirements by more than 20 percent in consecutive years, EPA triggered its authority to reset the total and advanced volume requirements.[211] EPA now proposes to use this power to reduce the standards it set for 2020 far beyond the level needed to offset the cellulosic shortfall that materialized in 2020.

EPA lacks the authority to use the reset to alter previously set standards for a past year, to reduce volume requirements by more than needed to address the circumstances that triggered the reset, and certainly to do both together. EPA asserts that the reset provision "provides EPA broad discretion to modify the renewable fuel volumes and to establish biofuel volume requirements at the volumes actually consumed."[212] In particular, EPA says that the reset provision "give[s] EPA considerable discretion to weigh and balance the various factors required by statute" and "implied authority to consider factors that inform our analysis of the statutory

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[206] *Whitman v. American Trucking Ass'n*, 531 U.S. 457, 468 (2001).

[207] *Alabama Ass'n of Realtors v. HHS*, 141 S. Ct. 2485, 2489 (2021) (quotation marks omitted); *see, e.g.*, *Massachusetts v. EPA*, 549 U.S. 497, 532-534 (2007); *Whitman*, 531 U.S. at 485; *North Carolina v. EPA*, 531 F.3d 896, 910-911 (D.C. Cir. 2008).

[208] *Alabama Ass'n of Realtors*, 141 S. Ct. at 2489.

[209] *ACE*, 864 F.3d at 698-699 (quotation marks omitted); *see* 42 U.S.C. § 7545(*o*)(2)(A)(i), (3)(B)(i).

[210] 42 U.S.C. § 7545(*o*)(7)(F).

[211] NPRM at 72,443.

[212] *Id.* at 72,449.

factors."[213] EPA's expansive view of its discretion is substantially overstated. EPA has mistakenly read the list of reset factors in isolation, divorced from the rest of the statute. The reset power is in fact a narrow one whose scope reflects its triggering circumstances: it enables EPA to adjust the volume requirements to account for a systemic supply shortage or severe harm relative to Congress's original expectations, and to do so prospectively across multiple years, for the purpose of relieving EPA and interested parties of the burdens and uncertainties of relying on ad hoc annual waivers. In other words, the reset provides EPA the power to anticipatorily issue a multi-year waiver.

1. EPA cannot use the reset power to retroactively reduce past standards

EPA proposes to use the "reset" power to retroactively reduce the previously set 2020 standards. Those standards instructed market participants how to structure their conduct during 2020 and that afforded obligated parties ample time to comply. EPA may not unwind them now. Courts are "reluctant to find … authority [for retroactive rulemaking] absent an express statutory grant."[214] Here, there is nothing close to an express grant to use the reset power retroactively. On the contrary, interpreting the statute that way would, as explained, allow EPA to nullify the RFS program—something Congress did not permit. The reset provision in the statute can only be read to permit prospective modifications.

The statute prescribes *prospective* sequencing: EPA is statutorily required to issue a reset "rule []within 1 year after issuing [the triggering] waiver"[215] and "no later than 14 months before the first year for which [the reset] applicable volume will apply."[216] When using the reset power, EPA is to "modif[y] the applicable volumes … for *all years following* the final year to which the [triggering] waiver applies."[217] And the statute directs EPA to consider factors that are expressly forward-looking and make sense only that way. For example, EPA must consider "the *expected* annual rate of *future* commercial production of renewable fuels."[218] All these provisions convey Congress's intent that the reset be performed before the compliance years for any standards that are reset.

Moreover, the statute specifies that EPA may use the reset to modify only "the applicable volumes set forth in the [statutory] table."[219] That precludes using the reset to modify standards that have already been modified through a waiver, as EPA proposes here, since the 2020 standards already reflect EPA's prior cellulosic waivers.

EPA invokes judicial decisions (reluctantly) interpreting the Clean Air Act to permit EPA

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[213] *Id.* at 72,443.

[214] *Bowen v. Georgetown Univ. Hosp.*, 488 U.S. 204, 208-209 (1988).

[215] 42 U.S.C. § 7545(*o*)(7)(F).

[216] *Id.* § 7545(*o*)(7)(F); *id.* § 7545(*o*)(2)(B)(ii).

[217] *Id.* § 7545(*o*)(7)(F) (emphasis added).

[218] *Id.* § 7545(*o*)(2)(B)(ii)(III) (emphasis added).

[219] *Id.* § 7545(*o*)(7)(F); *id.* § 7545(*o*)(2)(B)(ii).

to promulgate RFS standards after a statutory deadline.[220] That authority does not support EPA's proposed retroactive reset of the 2020 standards. For one thing, the issue here is not whether EPA can set volume requirements after the statutory deadline but whether it can alter ones it has already set after the compliance year. The issue in EPA's cited cases was whether, by missing the statutory deadline to issue percentage standards, EPA "forfeited its authority" to do so.[221] Only because that result would have undermined the entire RFS program did the D.C. Circuit find that the strong presumption against retroactive rulemaking was overcome. Emphasizing "Congress' focus on ensuring the annual volume requirement was met regardless of EPA delay," the D.C. Circuit reasoned that denying EPA the ability to issue RFS standards after it has missed the statutory deadline would "lead to the drastic and somewhat incongruous result of precluding EPA from fulfilling its statutory mandate" to ensure that the requirements are met,[222] which would thus be "flatly contrary to Congress' intent and would turn agency delay into a windfall for" obligated parties.[223]

Nothing remotely like that is at stake from missing the statutory deadline for a reset. In fact, the circumstances here are the reverse. The reset power is not essential to EPA's implementation of the program or, specifically, its fulfillment of its duty to ensure that the volume requirements are met. Even without a reset, there would be volume requirements and EPA could use them to set percentage standards—exactly as EPA did in the original 2020 rulemaking. Rather, the reset is merely a convenience to relieve interested parties and EPA of the burdens and uncertainties of having to use the ad hoc waiver process serially. This is evident from the facts that the reset is triggered only by large or repeated waivers, and that the reset provision directs EPA to reset the volume requirements for *all* subsequent years once triggered.[224] Thus, the reset provision reflects Congress's recognition that if its original volume expectations were too far off the market, it would be more convenient administratively and provide more long-term certainty to the market to allow EPA to adjust the statutory volumes for all remaining years in one fell swoop than to go through an inevitable waiver process each year. In short, the reset power provides EPA the ability to issue an advance multi-year waiver.

To be clear, even if EPA can exercise its reset authority after the statutory deadline, it can do so only for *future* years, not for a past year. Like the statutory interpretation rejected by the D.C. Circuit in EPA's cited cases, allowing EPA to reset already-set standards for past years would interfere with EPA's overarching statutory duty to ensure that the volume obligations are met and would afford obligated parties a windfall, relieving them of apparently legally binding obligations they already had ample opportunity to comply with. EPA's view here would also pervert the reset: instead of using the reset to increase market certainty by averting the need for ad hoc waivers, EPA's proposal *undermines* market certainty by unsettling already-finalized

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[220] NPRM at 72,438 & n.5.

[221] *Monroe Energy, LLC v. EPA*, 750 F.3d 909, 919 (D.C. Cir. 2014).

[222] *Id.* at 920 (quotation cleaned).

[223] *National Petrochemical & Refiners Ass'n v. EPA ("NPRA")*, 630 F.3d 145, 157 (D.C. Cir. 2010) (quotation marks omitted).

[224] 42 U.S.C. § 7545(*o*)(7)(F).

standards and altering the effect of actions taken in reliance on those standards.

EPA's general authority to reconsider finalized RFS standards is no answer.[225] An agency's power of reconsideration is not unfettered; it must still be exercised pursuant to and within the bounds of the agency's statutory authority. And as explained, EPA lacks statutory authority to reset already-set standards for a past year.

2. EPA has no statutory authority to use the reset to reduce volumes further than needed to address the cellulosic production issues triggering the reset

As just explained, the reset is intended to function as an anticipatory, multi-year waiver. Accordingly, the circumstances that lead to the triggering waiver also constrain the scope of the reset authority: EPA may use its reset authority only to adjust the applicable volumes to account for the conditions that led to the triggering waivers and, but for a reset, would continue to do so. As it turned out, the reset was triggered by cellulosic waivers due to shortfalls in cellulosic biofuel production, and therefore EPA may use the reset to reduce the cellulosic, advanced, and total volume requirements only to the extent needed to account for future shortfalls in cellulosic production. Insofar as EPA's proposal would use the reset to reduce the 2020 volumes below that level, it exceeds EPA's authority and is unlawful.

The statute ties the scope of the reset to the triggering conditions. The reset power is triggered only by a "waive[r],"[226] and a waiver is available "only in limited circumstances"[227]: if "implementation" of an RFS volume requirements "would severely harm the economy or environment of a State, a region, or the United States"; if "there is an inadequate domestic supply" of renewable fuel to meet a requirement; if "the projected volume of cellulosic biofuel production is less than the minimum applicable volume"; or if "there is a significant renewable feedstock disruption or other market circumstances that would make the price of biomass-based diesel fuel increase significantly."[228] Further, the reset provision—which is presented in the statutory subsection defining the "waivers"—is triggered only by significant waivers in consecutive years or a large waiver in one year.[229] And the reset provision directs EPA to modify the volumes "for *all years following* the final year to which the [triggering] waiver applies."[230] All this together shows that the reset serves as an alternative to the ordinary annual waiver process; when it becomes evident that repeated waivers will be inevitable because Congress's initial expectations were substantially incorrect, instead of going through the waiver process each subsequent year, EPA can effect a multi-year waiver, modifying the volume requirements for all subsequent years in fell swoop, simplifying the process for EPA and all interested parties and providing the market with greater certainty about future RFS obligations.

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[225] NPRM at 72,444.

[226] 42 U.S.C. § 7545(*o*)(7)(F).

[227] *NPRA*, 630 F.3d at 149.

[228] 42 U.S.C. § 7545(*o*)(7)(A), (D), (E).

[229] *Id.* § 7545(*o*)(7)(F).

[230] *Id.* (emphasis added).

Accordingly, the purpose of the reset is to remedy the circumstances that led to the triggering waivers and that would continue to lead to future waivers but for a reset, and that is the extent of EPA's power. EPA's view, in contrast, is that once there is a triggering waiver for the reset, EPA can rewrite the relevant applicable volume to any degree it wants, as long as it considers the statutorily specified factors.[231] But there is no reason to suppose—in fact, it is absurd to suppose—that Congress intended the reset provision to grant EPA more power than necessary to address the condition that triggers the reset authority in the first place. "'Modify,'" the D.C. Circuit has held, "connotes moderate change."[232] And neither the power to modify nor the duty to consider various statutorily specified factors in conducting the reset requires greater authority. Rather, EPA is to assess those factors for the purpose of determining the expected extent of the triggering condition in the future and the appropriate future volume, accounting for what is feasible and potential important and severe adverse consequences. That is, as explained above, EPA is to consider the statutory reset factors for the purpose of determining how to set new volume requirements that address the reset-triggering conditions while trying to avoid causing conditions for other waivers in the future. That is it; again, Congress does not sneak major powers into obscure technical provisions.

Finally, the reset provision's use of the word "any" has no bearing on this issue. The statute states, "[f]or any of the tables in paragraph (2)(B)," if EPA "waives" a requirement "in any such table" by the requisite amount, it may reset.[233] Thus, "any" merely refers to the applicable volumes whose waiver can trigger a reset: any of them—cellulosic, BBD, advanced, or total—not just one or a subset of them. The word "any" does nothing to define the scope of the modification that EPA may make to the volume requirement.

C. EPA's Proposed Rationale for Reducing the 2020 Standards Is Irrational and Contrary to the Statute

EPA proposes to reduce the 2020 standards in response to two "significant and unanticipated events": (1) "The COVID–19 pandemic and the ensuing fall in transportation fuel demand, especially the disproportionate fall in gasoline demand relative to diesel demand, which significantly reduced the production and use of biofuels in 2020 below the volumes we anticipated could be achieved"; and (2) "The potential that the volume of gasoline and diesel exempted from 2020 RFS obligations through small refinery exemption (SREs) will be far lower than projected in the 2020 final rule."[234] EPA says that if it were "to simply leave the original volumes from the 2020 final rule in place, we would expect some combination of potentially disruptive outcomes: (1) A reduction in the quantity of carryover RINs; (2) obligated parties carrying deficits into 2021; and/or (3) obligated parties being out of compliance with their RFS obligations."[235]

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[231] *See* NPRM at 72,442-72,443.

[232] *MCI Telecomms. Corp. v. American Tel. & Tel. Co.*, 512 U.S. 218, 228 (1994).

[233] 42 U.S.C. § 7545(*o*)(7)(F).

[234] NPRM at 72,438.

[235] *Id.* at 72,448.

At every turn, this analysis is unreasonable and contrary to the Clean Air Act. At most, EPA could lower the 2020 standards to account for the actual level of SREs and the actual level of cellulosic production, but no further.

1. Pandemic-related demand destruction does not justify reducing the 2020 percentage standards

As EPA acknowledges, RFS obligations are "self-adjusting" to the actual level of demand for transportation fuel because the obligations "are applied as a percentage to an obligated party's gasoline and diesel fuel production; the obligation to acquire RINs for compliance rises and falls along with gasoline and diesel fuel production volume."[236] In other words, the percentage standards automatically reduce the volume of renewable fuel required to be used proportionally to the reduction in demand for transportation fuel. Accordingly, lower-than-projected demand for transportation fuel cannot generate compliance difficulties, and retroactively reducing the original volume requirements proportionally to the subsequent reduction in demand serves no purpose because the percentage standards already do that automatically. And reducing the original volume requirements *beyond* the proportional reduction already accounted for by the percentage standards to account for lower-than-projected demand for transportation fuel is obviously unjustified. In sum, the only permissible adjustment for lower actual fuel use is pointless one.

Yet, EPA proposes to reduce the 2020 standards by a disproportionately large amount. This is evident in its proposed revised percentage standards. For example, EPA would reduce the total standard from 11.56% to between 10.78% and 11.36%.[237] If EPA were proposing to reduce the volume requirements proportionally to the lost demand, the percentage standards would remain unchanged.

Although EPA acknowledges that the percentage standards "self-adjust[]" for "a shortfall in gasoline and diesel fuel consumption relative to the projected volumes results," EPA insists that 2020 is "different" from prior years when that happened because "the shortfalls in 2020 were … significantly larger than in any previous year."[238] This is irrelevant and irrational. The function of a percentage standard is that it self-adjusts in perfect proportionality regardless of how much the fuel use changes. Indeed, EPA admits that "the decrease in transportation fuel demand in 2020 proportionally decreased the required renewable fuel volume."[239]

2. EPA's apparent over-projection of SREs and the shortfall in production of cellulosic biofuel could justify at most only some of the proposed reduction of the 2020 standards

EPA points to the possibility that SREs will be lower than the projection on which the 2020 standards were based. Adjusting RFS standards retroactively to account for inaccurate

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[236] *Id.*

[237] *Id.* at 72,465.

[238] *Id.* at 72,448.

[239] *Id.*

SRE projections is a bad policy because it promotes market uncertainty. Producers and obligated parties knew well in advance what the RFS requirements were for 2020 and were able to conform their conduct to those requirements. Producers held up their end of the bargain: there was ample renewable fuel to meet the 2020 standards. Obligated parties did not. Relieving them now for the SRE shortfall disrupts the planning and investments that producers have made. It is distressing, as well as arbitrary and capricious, for EPA to consider only the benefits to obligated parties and disregard the cost to producers when considering a retroactive action. EPA must "consider[] the benefits *and the burdens* attendant to its approach."[240] In any event, if EPA will reduce standards retroactively when actual SREs are lower than projected, its policy will be irrational and therefore unlawful unless it also commits to raising standards retroactively when actual SREs are higher than projected.

Assuming EPA can adjust the standards to account for actual SREs, then *if* no SREs are granted for 2020—as EPA rightly proposes—the SRE shortfall would account for some but not all of the projected 2020 RIN shortfall. The appropriate way to adjust the standards to retroactively account for actual SREs and actual transportation fuel use is to recompute the percentage standards using these actual figures instead of their projections, along with the original volume requirements. Setting G and D to their actual figures (123.25 and 50.49) and setting GE and DE to zero, while keeping RFV-rf set to 20.09, yields a Total percentage standard of 11.09%—well below the original requirements of 11.56%—and a total volume requirement of 17.64 billion RINs.[241] The most recent EMTS data (rather than the August 2021 data EPA used for its proposal) indicate that 17.06 billion RINs were separated in 2020.[242] Therefore, accounting for lower transportation fuel demand and zero SREs still leaves a RIN shortfall of 0.58 billion (17.64 minus 17.06).

Additionally, EPA points to the shortfall in cellulosic production, and invokes the cellulosic waiver authority to reduce the 2020 cellulosic standard.[243] Even putting aside the fact that EPA could issue cellulosic waiver credits to cover this shortfall, this shortfall could justify only an extremely small reduction to the 2020 cellulosic standard. The percentage standards' self-adjustment already accounts for some of this shortfall. The *additional* shortfall in cellulosic production beyond the amount accounted for automatically by the percentage standards is only 0.02 billion RINs. Using the method for recomputing the percentage standards just described—which maintains the original volume requirement but uses actual fuel use and zero SREs—yields a revised cellulosic standard of 0.33%, or 0.52 billion RINs.[244] The latest EMTS data show that

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[240] *ACE,* 864 F.3d at 718 (quotation cleaned; emphasis added).

[241] *See* Stillwater Associates LLC, *Comments to EPA on 2020-2022 RFS Rule, Prepared for Growth Energy* 18-19 (Feb. 4, 2022) ("2022 Stillwater Report") (attached as Ex. 5).

[242] *See id.* at 19.

[243] NPRM at 72,438 n.4.

[244] *See* 2022 Stillwater Report at 18-19.

0.50 billion cellulosic RINs were separated in 2020.[245] Therefore, the additional cellulosic shortfall that could be the subject of a cellulosic waiver is only 0.02 billion (0.52 minus 0.50).

In sum, adjusting the standards to account for actual transportation fuel use, for zero SREs, and actual cellulosic production leaves a 2020 RIN shortfall of 0.56 billion (0.58 minus 0.02). EPA's proposal to set the 2020 standards to actual levels would erase that shortfall. But as explained in the next sections, EPA's reasons for doing that contradict the statute and the duty of reasoned decisionmaking.

3. The disproportionate decline in gasoline use relative to diesel use does not justify further retroactive reduction of the 2020 standards

EPA says that the decline in fuel demand "disproportionately affected gasoline more than diesel fuel."[246] "This is important," EPA states, "because on average finished gasoline contains more renewable content than finished diesel."[247] That does not matter. A disproportionate decline in demand for gasoline and diesel can happen in any year; it is an inherent risk of the program. Demand for gasoline and demand for diesel are affected by different factors, so there is no reason to expect that they will necessarily move together. If such a divergence justified adjustment for 2020, it could equally justify adjustment for any compliance year. But EPA has never even considered making such adjustments, and they are unwarranted: Obligated parties can manage their compliance performance daily, and many do, and the RIN market is liquid. Therefore, obligated parties have ample opportunity to ensure that they meet their compliance obligations even as demand for gasoline and demand for diesel diverge.

Even if this disproportionate demand loss provided a theoretically valid justification for retroactively reducing the 2020 percentage standards, it would not suffice to lower the 2020 standards because EPA has not adequately explained and justified its specific proposal. EPA has not quantified the extent of this disproportionate loss or tied that to the extent of its proposed reduction in the standards. In other words, EPA needs to determine how much of the 0.56 billion RIN shortfall is attributable to this disproportionate decline in gasoline use. Such an analysis would need, at a minimum, to account for the fact that the actual volume of BBD *exceeded* the amounts required for compliance and thus can offset at least some of the disproportionately large loss of gasoline demand. Specifically, if the standards are recomputed as described here—using the original volume requirements, the actual transportation fuel used, and zero SREs—the BBD standard would be 2.06 billion (2.10%).[248] But according to the most recent EMTS data, 2.48 billion BBD RINs were separated, leaving an excess of 0.42 billion BBD RINs.[249] The most direct and appropriate way to account for this excess is simply to ignore the disproportionate

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[245] *See id.* at 19.

[246] NPRM at 72,448.

[247] *Id.*

[248] 2022 Stillwater Report at 18-19.

[249] *Id.*

decline in demand for gasoline relative to diesel, allowing all the excess BBD RINs to offset the shortfall in RINs associated with gasoline (particularly D6 RINs).

(EPA states that "the projections in the 2020 final rule overestimated the use of biodiesel and renewable diesel, even if we adjust those projections by the shortfall in diesel demand."[250] That assessment does not reflect an adjustment for the over-projection of SREs. But even without that adjustment, EPA's statement would still be incorrect in light of the most recent EMTS data. Without an adjustment for the over-projection of SREs, the actual BBD obligation according to the original percentage standard is 2.15 billion RINs, but again 2.48 billion BBD RINs were separated.[251])

Finally, EPA could rationally adopt its proposed position to reduce the standards given the disproportionately larger decline in demand for gasoline only if it committed to also *raising* the standards to account for a disproportionately larger decline in demand for *diesel* in a future year.

4. EPA's refusal to allow supposedly "disruptive outcomes" violates the statute and undermines the RFS program

Obligated parties could close the RIN gap and achieve compliance by using carryover RINs or carrying their RIN deficits into 2021 (or both). Or they could elect to incur the penalties for noncompliance. EPA deems these "disruptive outcomes."[252] But the idea that such outcomes could justify a reduction in the standards is nonsense. They are simply the natural consequences of obligated parties' failure to stay on top of their legally binding RFS obligations. If they "disrupt" anything, it is only to disrupt the preference of some obligated parties—many of which are integrated with or closely tied to petroleum producers—not to increase their use of renewable fuel as required. Such disruption is precisely what Congress intended the RFS program to cause—it is a "market forcing policy."[253] Carryover RINs allow obligated parties to make up their deficiency in the same compliance year, deficit carrying gives obligated parties extra time to make up their deficiency, and the imposition of penalties is the backstop to ensure that obligated parties do not simply disregard their program obligations.[254]

If EPA could reduce the RFS standards retroactively to avoid these outcomes, there would be no point in having binding RFS obligations at all and the program would be worthless. Congress could not possibly have intended EPA to manage the program this way. In fact, Congress was clear that EPA could not reduce the requirements merely to avoid these outcomes. Congress expected that compliance with the RFS would sometimes be challenging or unpleasant for obligated parties, but expressly decided to allow EPA to reduce the nationwide volume

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[250] NPRM at 72,448.

[251] 2022 Stillwater Report at 18.

[252] NPRM at 72,448.

[253] *ACE*, 864 F.3d at 705.

[254] 42 U.S.C. §§ 7545(d)(1), (*o*)(5)(D).

requirements "only in *limited* circumstances"[255]: in particular, if "there is an inadequate domestic supply" of renewable fuel or if implementation "would severely harm the economy or environment of a State, a region, or the United States."[256] EPA's proposal in effect would grant a nationwide waiver based on less serious difficulties—difficulties that EPA does not suggest would meet the statutory waiver requirements. The D.C. Circuit has already rejected this approach, explaining that there is no reason to think "Congress would have established the severe-harm waiver standard only to allow waiver" under another provision "based on lesser degrees of economic harm."[257] As explained above, this principle constrains even the reset power, which is properly viewed as a power to issue an anticipatory, multi-year waiver.

5. EPA's management of the RIN bank is incoherent and exposes EPA's mistaken belief that its role is to manage the fuel market

EPA's refusal now to intentionally maintain standards that could lead to a drawdown of carryover RINs exposes EPA's management of the bank as irrational, counterproductive, and beyond its authority under the Clean Air Act. Specifically, EPA's proposal reveals that EPA actually views its role as managing the fuels market by maintaining RIN prices within a narrow band that EPA, in its inscrutable judgment, deems appropriate.

According to EPA, having a "bank of carryover RINs is extremely important in providing a liquid and well-functioning RIN market upon which success of the entire program depends, and in providing obligated parties compliance flexibility in the face of substantial uncertainties in the transportation fuel marketplace."[258] Neither of these functions, however, supports EPA's proposal for 2020.

With respect to maintaining liquidity and a well-functioning RIN market, EPA explains that "[c]arryover RINs enable parties 'long' on RINs to trade them to those 'short' on RINs instead of forcing all obligated parties to comply through physical blending."[259] That is true, but it explains only the role of tradeable credits; it does not justify maintaining a large bank of RINs carried over from a past year for compliance in a *future* year. The tradability of RINs enables obligated parties to shuffle their RINs for a given year as that year's compliance demonstration deadline approaches, enabling efficient compliance with obligations that apply to the year in which the credits were generated. For example, if one obligated party separated 10 million fewer RINs than needed to meet its 2020 obligations, and another obligated party separated 14 million more RINs than needed to meet its 2020 obligation, the short party could buy 10 million RINs from the long party, and both could meet their 2020 obligations. That is sufficient for the RIN market to provide the flexibility needed to facilitate compliance. It allows all obligated parties to achieve compliance in the most efficient way possible: more-efficient parties can separate excess

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[255] *NPRA*, 630 F.3d at 149 (emphasis added).

[256] 42 U.S.C. § 7545(*o*)(7)(A), (D), (E).

[257] *ACE*, 864 F.3d at 712.

[258] NPRM at 72,454.

[259] *Id*.

RINs, which less-efficient parties can purchase for less than the marginal cost of increasing their own separation of RINs directly.

But even if there can be a perpetual RIN bank, it is not justified by a desire for RIN liquidity. And certainly, liquidity does not justify the massive RIN bank that EPA insists on maintaining. Maintaining a RIN bank into a future year does not help create a well-functioning RIN market—again, that already exists without a perpetual bank. What it actually does is suppress RIN prices, lowering the marginal cost of compliance and thereby deterring the market from making the very investments that Congress intended to the RFS program to incentivize. As the D.C. Circuit has recognized, "higher RIN prices" are how the RFS program achieves its market-forcing policy of promoting increased renewable-fuel use: they "incentivize precisely the sorts of technology and infrastructure investments and fuel supply diversification that the RFS program was intended to promote."[260]

As for using the bank to provide compliance flexibility in the face of substantial uncertainties in the transportation fuel market, EPA's proposed modification belies that purpose. EPA proposes that, because of the Covid-19 pandemic and associated economic disruptions—an "unforeseeable circumstance[] that [supposedly] could limit the availability of RINs"—EPA should reduce the 2020 obligations so that obligated parties do *not* need to use the RIN bank for compliance.[261] In a nutshell, EPA's position is: the bank provides RINs that obligated parties can use in an emergency, but in an emergency, the obligations should be reduced so that obligated parties do not need to use the bank of RINs. That is facially irrational. The message EPA's conduct sends is that it wants to maintain the bank to suppress RIN prices. Indeed, D6 RINs have never exceeded $2 and have rarely exceeded $1.[262] But again, as the D.C. Circuit has recognized, *higher* RIN prices are the essential mechanism by which the RFS program was designed to achieve its goal of forcing the market to use rapidly escalating volumes of renewable fuel.[263] By taking actions to suppress RIN prices, EPA undermines Congress's intent.

Moreover, EPA offers no explanation for why the RIN bank needs to be so big to accomplish its purported goals. EPA says that there will be about 1.85 billion carryover RINs in the bank for 2020.[264] If obligated parties used some of those carryover RINs to satisfy the 0.56 billion RIN shortfall in 2020 (computed above), there would still be 1.29 billion carryover RINs for 2021 and thereafter. Under EPA's proposal, no drawdown will be needed for 2021—because EPA would set those standards to the actual levels of renewable use—or for 2022—because EPA would set those standards to levels EPA believes could be achieved entirely through physical blending in 2022.[265] Even if carryover RINs are needed to meet the 250-

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[260] *Monroe Energy*, 750 F.3d at 919.

[261] NPRM at 72,454.

[262] EPA, *RIN Trades and Price Information*, https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rin-trades-and-price-information.

[263] *Monroe Energy*, 750 F.3d at 919.

[264] NPRM at 72,455.

[265] *Id.* at 72,451, 72,455.

million supplemental obligation that EPA will set for 2022 to begin remedying the unlawful 2016 general waiver, there would still be 1.04 billion carryover RINs for compliance in 2023 and beyond, with ample opportunity for obligated parties to build the bank back up with more excess renewable-fuel use in 2022 and subsequent years.[266] And even if obligated parties relied exclusively on carryover RINs to meet the second 250-million supplemental obligation imposed in 2023 to remedy the unlawful 2016 general waiver, that would still leave at least 0.79 billion carryover RINs. That would provide a sizeable cushion for 2022, in the event that physical blending falls short of the 2022 requirements, or for future standards.

EPA must—but fails to—"articulate a satisfactory explanation" as to why obligated parties need more carryover RINs than that.[267] EPA mentions "the uneven holding of carryover RINs among obligated parties," but that makes no sense. Because RINs are highly tradeable, any "uneven" holdings can be evened out so that all obligated parties can comply with their obligations.[268] Again, as EPA itself notes, parties short in RINs can readily buy from parties that are long. Beyond that, EPA's only remark on the subject is the vague speculation that, "were market disruptions to occur with an insufficient carryover RIN bank, it could force the need for a new waiver of the standards, undermining the market certainty so."[269] But EPA does not explain why any particular amount of carryover RINs less than 1.85 billion would be "insufficient." Moreover, by proposing to retroactively reduce the 2020 standards, especially when there *are* sufficient RINs to comply with them, EPA introduces a more fundamental uncertainty: when and to what extent finalized RFS standards will be binding in the future or will be negated by an agency that mistakenly views its role as managing the RIN market rather than simply setting standards sufficient to "ensure" that the applicable volumes are met year after year.[270]

V. EPA'S PROPOSAL TO SET THE 2021 STANDARDS TO ACTUAL LEVELS UNLAWFULLY NEGATES THE RFS PROGRAM

EPA proposes to set the 2021 standards equal to the volumes of renewable fuel actually used in 2021.[271] EPA claims this is justified because, due to its own delay, the 2021 standards cannot affect renewable fuel production in 2021, which will have already passed by the time standards are finalized.[272] EPA adds that setting 2021 standards to actual use will "mitigat[e] burdens on obligated parties" by ensuring they "have sufficient RINs to comply."[273] These concerns are misplaced and dangerous to the RFS program, and EPA lacks authority to set the

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[266] *Id.*

[267] *Motor Vehicle Mfrs. Ass'n of U.S., Inc. v. State Farm Mut. Auto. Ins. Co.*, 463 U.S. 29, 43 (1983).

[268] NPRM at 72,455.

[269] *Id.* at 72,454.

[270] 42 U.S.C. § 7545(*o*)(2)(A)(i), (3)(B)(i); *ACE*, 864 F.3d at 698-699, 710.

[271] NPRM at 72,450.

[272] *Id.*

[273] *Id.*

2021 standards on that basis. EPA's "concerns" reflect a failure to grasp the implications of how the RFS program functions, which EPA recognizes in other contexts, revealing the irrationality of its analysis for 2021. More fundamentally, other than lowering the cellulosic standard to the actual level, EPA's proposed approach for 2021 reflects a power to cancel the RFS program. But as discussed above, EPA has no authority to do that. Certainly, that is not what the reset provision authorizes; as explained above, the reset can be used only prospectively, consistent with its purpose as a multi-year waiver. There is no benefit from using that power for a past year. Notably, again, the reset power is not essential to EPA's implementation of the program or, specifically, its fulfillment of its duty to ensure that the volume requirements are met, so there is no special need to be able to use the reset retroactively.

Even if EPA could use the reset to determine a past year's standards, EPA's proposal would exceed its reset authority. As explained above, EPA's focus in using the reset must be confined to modifying the standards to address the conditions that triggered the reset. Thus, at most EPA could use the reset to adjust the 2021 cellulosic, advanced, and total standards to account for the shortfall in cellulosic production. Similarly, even if EPA can use its cellulosic waiver power on a past year, that power is limited to reducing the volume requirements to account for the shortfall in cellulosic production. And as explained later, EPA cannot and should not reflexively reduce the advanced and total requirements by amounts equal to the cellulosic shortfall. Rather, EPA must backfill any shortfalls with other types of available qualifying renewable fuel.

EPA has the technical ability to set appropriate standards for 2021 other than by simply matching the actual levels. For example, it could do so using relevant data that was available as of November 30, 2020, as it would have done had it issued the 2021 standards on time, limited only by the volume of carryover RINs and a manageable level of carryforward RIN deficits. Although setting the standards that way now could not cause greater use of renewable fuel *in 2021*, compliance could be achieved in several ways and thereby could promote increased use of renewable fuel in future years. EPA could directly set higher 2021 requirements; EPA could combine the higher 2021 volumes with the *2022* volumes to create a combined standard for 2022; or EPA could issue a 2021 standard equal to actual use and add a supplemental obligation to the 2022 standards equal to the difference between the actual 2021 volumes and what it would have set the 2021 standards to had it acted timely. The first approach would likely lead obligated parties to draw down the RIN bank, and the latter two approaches would allow obligated parties to choose between drawing down the bank and increasing actual use of renewable fuel in 2022. Any of these approaches would increase renewable fuel use over the course of the RFS program—as EPA acknowledges elsewhere and as discussed above, the "market effects" of RFS standards are "mediated" across years "through the carryover RIN bank" (drawing down the bank in one-year increases the need for actual use in future years because obligated parties cannot turn to those retired carryover RINs for compliance)—consistent with Congress's intent.[274] And as explained above, setting standards to intentionally draw down the bank is entirely appropriate.

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[274] *Id.* at 72,456.

This is, in fact, exactly what EPA did in prior years when it missed the deadline for issuing RFS standards, and the D.C. Circuit approved of those actions as furthering Congress's intent. For instance, EPA did not issue the 2009 BBD standard until well into 2010. Yet, instead of writing off that year by retroactively setting the 2009 BBD standard to the actual level, EPA "combined" the 2009 and 2010 volumes "into a single requirement" to "ensure that these two year[s'] worth of [fuel] will be used."[275] This combined approach, EPA said, best fulfilled what "Congress expected and intended."[276] The D.C. Circuit sustained EPA's "combined" approach, concluding that it fulfilled Congress's intent, and EPA's statutory duty, of "ensuring the annual volume requirement[s are] met regardless of EPA delay."[277] "EPA could not ignore the 2009 mandate" due to its own delay.[278] Not maintaining the statutory requirements for both past and current years, the Court said, would thus have been "'flatly contrary to Congress' intent and would turn agency delay into a windfall for the regulated entities.'"[279] Similarly attending to "Congress' focus on ensuring the annual volume requirement was met regardless of EPA delay," EPA issued the 2013 standards at the statutory levels, and the D.C. Circuit affirmed.[280]

Although EPA then set the late 2014 and 2015 RFS standards to reflect actual levels, and the D.C. Circuit affirmed that action in *ACE*, the court's decision is flawed and does not support EPA's proposal for 2021. *ACE* declared that in issuing late RFS requirements, EPA must "consider[] the benefits and the burdens attendant to its approach."[281] Yet, the court did not adhere to that in reviewing EPA's 2014 and 2015 standards. *ACE* failed to consider that EPA could have mitigated any burdens in other ways, such as through carryover RINs or by adding the late standards to a future year's requirements. *ACE* also mistakenly ignored the overwhelming cost of setting standards equal to actual use: that doing so nullifies the RFS program for the late year. A proper analysis that accounted for these additional dimensions of the situation yields the conclusion that setting late standards to the level of actual use is irrational and contrary to the statute.

Moreover, even if *ACE*'s approval of EPA's approach for 2014-2015 were reasonable at the time, EPA's subsequent delay in proposing the 2021 standards—and the 2022 standards, which EPA says will not be finalized before June 2022, almost halfway through the year—shows that delay and late standards set to actual levels have become EPA's modus operandi, and thus that *ACE*'s approval cannot be extended beyond the 2015 standards. EPA's now-routine invocation of this approach displays the very concern *ACE* assured was not yet present in 2015:

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[275] Regulations of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program ("2010 Rule"), 75 Fed. Reg. 14,670, 14,718 (Mar. 26, 2010).

[276] Renewable Fuel Standard Program (RFS2) Summary and Analysis of Comments 3-186-188, EPA (Feb. 2010), https://nepis.epa.gov/Exe/ZyPDF.cgi/P1007GC4.PDF?Dockey=P1007GC4.PDF.

[277] *NPRA*, 630 F.3d at 163.

[278] *Id.* at 157.

[279] *Id.* at 156-157 (quoting EPA brief).

[280] *Monroe Energy*, 750 F.3d at 919-921.

[281] 864 F.3d at 718 (quotation cleaned).

that EPA could "us[e] its delay as an excuse to shirk its statutory duties."[282] If EPA can simply wait until a year is over to set standards and then set them at actual use, an Administrator who wishes to nullify the program need only do that year after year. And EPA's pattern of behavior shows that this is happening and will continue to happen. That is clearly not what *ACE* envisioned or approved. Nor is it what the reset provision envisions or permits. Again, Congress could not have intended to implicitly grant EPA the discretion to cancel a major statutory program. There is no reason why EPA could not have issued the 2021 standards on time. Its delay suggests a disregard for the RFS program's effects. And correspondingly, EPA's late proposal suggests a desire to prop up the RIN bank at the expense of Congress's market-forcing aims, as well as a commitment by EPA to protect obligated parties from binding RFS obligations to use more renewable fuel than they otherwise would without the RFS and the compliance consequences of failing to do so. Nothing in the Clean Air Act or *ACE* purports to afford EPA that authority.

VI. EPA SUBSTANTIALLY UNDERSTATES THE REASONABLY FEASIBLE VOLUME OF ETHANOL USE IN 2022

EPA projects that 13.788 billion gallons of ethanol will be used in 2022.[283] This is *far* below the country's capacity to produce, distribute, and consume ethanol. EPA primarily blames the so-called E10 blendwall, declaring that it is "a deciding factor in limiting growth in domestic consumption of ethanol."[284] That is incorrect. The blendwall is the result, not the cause, or the gap between actual and potential ethanol use. The cause is economic incentives—at bottom, consumers are not widely incentivized to select higher-ethanol blends over E10. The design of the RFS, however, is to provide incentives to increase the use of renewable fuel. Higher RFS requirements increase RIN values, which in turn lower the price of transportation fuel in inverse proportion to the concentration of renewable fuel. Thus, EPA can and should, consistent with Congress's intent, strive to encourage increased use of ethanol above the blendwall by increasing the RFS requirements, and especially the implied non-advanced requirement.

Instead, however, EPA proposes to set the 2022 standard based on "the projection of ethanol concentration derived from EIA reports for 2022 as a reasonable estimate of what level can be achieved in 2022."[285] In other words, EPA appears to view its task as predicting how the market will behave independently and then to match the volume requirements to that prediction. That approach contradicts Congress's clear intent that the RFS standards would be market forcing.

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[282] *ACE*, 864 F.3d at 719.

[283] DRIA at 51.

[284] *Id.* at 35.

[285] DRIA at 184.

A. More Than 15 Billion Gallons of Ethanol Could Easily Be Produced Domestically

Domestic producers of ethanol could easily meet demand of more than 15 billion gallons of ethanol in 2022. Existing facilities have the nameplate capacity to produce about 17.38 billion gallons per year, according to EIA.[286] To date, actual domestic ethanol production peaked in 2018, when 16.061 billion gallons were produced domestically.[287] Although it appears that only about 14.87 billion gallons of ethanol were produced domestically in 2021, that output reflected the lower demand for transportation fuel caused by the Covid-19 pandemic and is not indicative of feasible capacity in 2022.[288] In any event, it is still substantially more than the 13.788 billion gallons that EPA assumes will be used in 2022.

Moreover, a fairly conservative assessment of the domestic production capacity in light of feedstock supply and non-ethanol demand for feedstock shows that about 15.565 billion gallons could be produced. For this assessment, Stillwater Associates assumed that the number of planted corn acres would remain at the 2007 level: 93.5 million.[289] Stillwater Associates next assumed that the percentage of planted corn acres that would be harvested would equal the average percentage over the past decade: 91.3%.[290] Then Stillwater assumed that the corn yield would remain at its 2021 level—177.0 bushels / acre ("bu/ac")—even though it has increased at a virtually constant rate of 1.9 bu/ac annually since 1936, and 1.8 bu/ac annually since 2008.[291] Stillwater also determined that ethanol conversion rates have increased at an annual rate of 0.01 gallons / bushel of corn between 1982 and 2020.[292] Finally, Stillwater assumed that demand for corn for non-ethanol uses, including feed, food, seed, and other industrial uses, would increase consistent with population growth, and that corn imports and exports would equal USDA's latest estimates.[293] Putting this all together, and accounting for the feed co-products produced at ethanol plants, Stillwater calculates that 15.565 billion gallons of ethanol could be produced in 2022.[294]

Finally, past export demand for ethanol is irrelevant when projecting the feasibly available supply of ethanol in the future. As long as there is domestic demand for ethanol to comply with RFS obligations, domestically produced ethanol will be used to meet that demand rather than exported. That is because exported ethanol lacks the value of the associated D6 RIN; without that value, producers receive less for their ethanol in the export market than they do in

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[286] 2022 Stillwater Report at 1; *see* DRIA at 183.

[287] 2022 Stillwater Report at 1

[288] *Id.*

[289] *Id.* at 1, 4.

[290] *Id.* at 4.

[291] *Id.* at 3.

[292] *Id.*

[293] *Id.* at 4-5.

[294] *Id.* at 5-8.

the domestic market. No rational producer, therefore, will choose to export ethanol when there is existing demand for the ethanol under the RFS program. The only reason that producers have exported ethanol in recent years is that there was no demand for that fuel to comply with RFS obligations.[295]

B. Substantially More E85 and E15 Could Easily Be Delivered and Consumed

Analysis by Stillwater shows that EPA's expected volume of ethanol use in 2022—13.788 billion gallons—will use only a small fraction of the *existing* infrastructure to deliver and consume E85 and E15. And of course, the market can expand that infrastructure in response to appropriate incentives.

1. E85

With respect to E85, Stillwater determines that in 2020, the utilization rate for the country's existing E85 distribution infrastructure was between only 8% and 14%, depending on assumptions regarding the number of dispensers. EPA states that there were about 3,947 stations offering E85 in 2020.[296] More recent and reliable data, however, indicate that there are 4,125 stations selling E85.[297] Notably, these are existing dispensers that are compatible with and approved for use with E85.[298] On average, stations that sell E85 have 1.8 E85 dispensers.[299] These figures yield a range of existing E85 dispensers: from 3,947 dispensers (based on 3,947 stations with 1.0 E85 dispensers each) to 7,425 dispensers (based on 4,125 stations with 1.8 E85 dispensers each).[300] A typical dispenser can deliver 45,000 gallons of E85 per month through normal use, containing 33,000 gallons of ethanol.[301] Therefore, existing E85 infrastructure can deliver between 2.31 billion and 4.0 billion gallons of E85 per year.[302] But EIA projects that only 320 million gallons of E85 will be consumed in 2022.[303] That implies a utilization rate of 8-14%.[304]

Were the existing capacity used to typical full capacity for dispensers, between and 1.27 billion and 2.36 billion gallons of *additional* ethanol could be consumed *above* the ethanol in the

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[295] *Id.* at 16.

[296] DRIA at 192.

[297] 2022 Stillwater Report at 8.

[298] *Id.*

[299] *Id.*

[300] *Id.*

[301] *Id.*

[302] *Id.* at 8-9.

[303] DRIA at 38; 2022 Stillwater Report at 9.

[304] 8% = 320 million / 4 billion; 14% = 320 million / 2.31 billion.

E10 that would be replaced.[305] Put another way, each five-percentage point increase in utilization delivers an additional 116 million to 200 million gallons of E85, and an additional 85 million to 148 million gallons of ethanol above the ethanol in the replaced E10.[306] This analysis shows just how much room there is to increase the delivery of E85 right now. And it does not even account for the market's ability to add new E85 infrastructure, which can be done at low cost through ordinary upgrade cycles.

As explained above, ethanol producers could largely meet this additional potential demand. For 2022, EPA expects 13.788 billion gallons of ethanol to be used, but producers could produce 15.565 billion gallons or more. That difference of at least 1.777 billion gallons of ethanol is in the middle of the range of additional incremental ethanol that could be dispensed through existing infrastructure (1.27 bil gal to 2.36 bil gal).

There are also vastly more vehicles than needed to use this additional ethanol. EIA estimates that there will be 20.4 million FFVs on the road in 2022.[307] Based on projections of vehicle miles driven, each FFV could use 588 gallons of E85 per year, and the fleet of FFVs could use 12.65 billion gallons of E85 in a year.[308] At EIA's projected 2022 E85 volume of 320 million gallons, each FFV would use an average of 15.7 gallons of E85 for the year, which represents a vehicle utilization rate of 2.67%.[309] Each five-percentage point increase in vehicle utilization consumes an additional 376.32 million incremental gallons above the E10 it would replace. Thus, it is obvious that the vehicle fleet could easily consume the potential additional 1.777 billion gallons of ethanol production.

2. E15

The story is similar with respect to E15. According to EPA, there are 2,300 stations selling E15.[310] Stillwater estimates that these stations average 3.3 E15 dispensers each, meaning that there are about 7,540 E15 dispensers across the country.[311] Notably, these are existing dispensers that are compatible with and approved for use with E15.[312] Given that a typical dispenser can deliver 45,000 gallons of E15 per month through normal use, this existing E15 infrastructure can deliver about 2.9 billion gallons of E15 per year containing 0.145 billion gallons of ethanol above the ethanol in the replaced E10, accounting for the regulatory barrier to

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[305] 2022 Stillwater Report at 8-9.

[306] *Id.* at 9.

[307] *Id.*

[308] *Id.* at 9-10.

[309] *Id.* at 10.

[310] DRIA at 196.

[311] 2022 Stillwater Report at 11.

[312] *Id.* at 10-11.

selling E15 during the summer ozone season.[313] There is, as noted, certainly sufficient ethanol supply to meet that demand level.

And there are more than enough vehicles to use the maximize level of E15. More than 96% of gasoline-using vehicles, accounting for more than 98% of miles traveled, will be E15-compatible in 2022.[314]

C. The Principal Impediment to Increased Use of E85 and E15 Is Retail Price, Which Can Be Addressed Through Higher RFS Standards

For the reasons just discussed, there is no infrastructure impediment to increased distribution or consumption of E85 or E15. The primary reason that the use of those fuels has not increased faster is that they have not been priced low enough relative to E10 to entice consumers to switch to them from E10. Most gas consumers are highly price sensitive and creatures of habit. And higher-ethanol blends have lower energy content than E10. Consequently, as EPA observes, higher-ethanol blends must be priced below the point of E10 parity on an energy-equivalent basis to be widely competitive.[315]

In practice, however, this relative pricing has not been achieved. Analysis of historical E85 prices shows that on an energy-equivalent (or gasoline gallon equivalent) basis, E85 is priced at or below parity nowhere and generally is priced substantially above parity.[316] At such prices, E85 appears to be used largely only mandated fleets and consumers who are especially committed to ethanol—that is, price-insensitive consumers.[317] In other words, retailers are marketing E85 as a niche product sold at a premium price. In order to markedly increase its use, it would need to be marketed as a mass-market, lower-margin product.[318]

The RFS program provides a mechanism to redress this relative-pricing problem and spur greater conversion from E10 to higher-ethanol blends. More demanding RFS standards would reduce the supply of RINs and thereby raise their price. Because RINs function as a discount, or coupon, on transportation fuel, the higher the ethanol blend, the greater the RIN-based discount to the consumer. Consequently, higher RFS standards lower the prices of higher-ethanol blends

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[313] *Id.* at 11.

[314] Air Improvement Resource, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2022*, at 2 (Nov. 16, 2021), https://growthenergy.org/wp-content/uploads/2021/12/Analysis-of-Ethanol-Compatible-Fleet-for-Calendar-Year-2022-16Nov21.pdf (attached as Ex. 11); *see also* 2022 Stillwater Report at 12.

[315] DRIA at 37.

[316] 2022 Stillwater Report at 14-15.

[317] *Id.* at 15.

[318] *Id.*

relative to E10, eventually enabling them to be priced below parity with E10 on an energy-equivalent basis.[319] This is, in fact, precisely how the RFS is supposed to work.

D. EPA's Speculative Concerns About Misfuelling Liability Are Unfounded and Irrelevant

EPA's Draft Regulatory Impact Analysis states that a barrier to increased E15 and E85 use is a fear among some retailers about liability for misfuelling incompatible vehicles.[320] EPA, however, cites no evidence that misfuelling commonly occurs or is otherwise a legitimate concern. Indeed, EPA's only citation is a 2015 Comment from the Petroleum Marketers Association of America that itself offers zero citations in its one conclusory paragraph that floats this concern.[321] As EPA itself has repeatedly explained, regulations already "require pump labeling, a misfuelling mitigation plan, surveys, product transfer documents, and approval of equipment configurations, providing consumers with the information needed to avoid misfuelling."[322] These regulatory safeguards largely negate any risk of misfuelling.

And even if all these safeguards were to fail, the risk remains negligible because, as EPA again notes, "the portion of vehicles not designed and/or approved for E15 use continues to decline."[323] As noted, more than 96% of gasoline-using vehicles, representing more than 98% of vehicle miles travelled will be compatible with E15 in 2022.[324] Because all post-2001 models are E15 compatible, the risk will only continue to decrease each year as older vehicles exit the marketplace. There will also be an estimated 20.4 million E85 compatible FFVs in use in 2022.[325] Billions of miles have been driven on E15, reflecting millions of retail transactions. Misfuelling issues have not materialized despite such widespread use. And in any event, E15 is covered under retailers' liability insurance, like any other federally approved fuel.

Accordingly, even EPA has acknowledged that misfuelling fears are speculative and likely unfounded, but has said they remain relevant because, "warranted or not," "some retailers will continue to have concerns."[326] But it is unreasonable to cater to these unfounded concerns, using them as an excuse to avoid setting volumes high enough to incentivize readily available infrastructure growth—a goal Congress clearly intended the RFS to advance. The fundamental purpose of the RFS is to force more renewable fuel use than the industry would otherwise be willing to provide. EPA therefore abdicates its congressionally mandated role if it capitulates to

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[319] *Id.* at 15-16.

[320] DRIA at 196.

[321] *Id.* (citing Petroleum Marketers Association of America Comment 3, EPA-HQ-OAR-2015-0111-1197 (July 27, 2015)).

[322] *Id.* at 197.

[323] *Id.*

[324] Air Improvement Resource Report at 2.

[325] Air Improvement Resource Report at 1.

[326] *Renewable Fuel Standard Program -Standards for 2019 and Biomass-Based Diesel Volume for 2020: Response to Comments* 106-07, EPA-420-R-18-019 (Nov. 2018).

such a speculative industry concern, thereby nullifying the RFS's ability to nudge the industry into its next logical phase where higher ethanol blends are the norm. If EPA believes its regulations and the composition of the vehicle fleet mitigate misfuelling concerns, as they clearly do, then EPA must act accordingly. Surrendering to an unfounded misfuelling concern floated by the oil industry would be arbitrary and capricious because it is not only a concern "Congress has not intended [EPA] to consider," but also clearly "runs counter to the evidence before the agency."[327] Only once the RFS appropriately incentivizes retailers to adopt higher ethanol blends will retailers test and move past this unfounded concern.

E. Storage Infrastructure Compatibility Is Not a Meaningful Barrier to Increased Use of Ethanol or Expansion of Distribution Infrastructure

EPA's Draft Regulatory Impact Analysis presents the concern that E15 and E85 infrastructure growth is hindered by retailers' inability to demonstrate that their underground storage tank systems (USTs) are compatible with higher ethanol blends.[328] To be clear, even if this concern were well-founded, it would not be a meaningful barrier to increased use of ethanol because, as explained above, *existing* infrastructure, which is already compatible with and approved for use with these blends, can deliver vastly more ethanol than has historically been the case. There is no need to expand infrastructure to increase use. In any event, this concern about compatibility is not a serious impediment to infrastructure expansion.

Pursuant to EPA regulations promulgated in 2015,[329] owners and operators of fuel stations must be approved to use higher ethanol blends by demonstrating to state implementing agencies that their "UST system (which includes but is not limited to tanks, pumps, ancillary equipment, lines, gaskets, and sealants)"[330] is "compatible with the fuel stored to prevent releases to the environment."[331] Specifically, implementing agencies must at least require retailers to provide proof of compatibility through: 1) "Certification or listing of UST system equipment or components by a nationally recognized, independent testing laboratory," 2) written "Equipment

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[327] *State Farm*, 463 U.S. at 43.

[328] DRIA 196-197.

[329] *Revising Underground Storage Tank Regulations—Revisions to Existing Requirements and New Requirements for Secondary Containment and Operator Training*, 80 Fed. Reg. 41,566 (July 15, 2015).

[330] This generally covers everything but the above-ground fuel dispenser, which is not regulated by the EPA. *UST System Compatibility with Biofuels* at 5 (July 2020), EPA Report number EPA 510-K-20-001, available in docket EPA-HQ-OAR-2021-0324. Dispensers are regulated at the state and local levels. *Id.*

[331] *Id.*

or component manufacturer approval," or 3) "another option … no less protective of human health and the environment."[332]

The concern about storage compatibility is largely irrelevant because E15-compatible tanks are often unnecessary today. As EPA itself acknowledges, most E15 is now produced by blender pumps, which do not need to be connected to E15-compatible storage systems.[333] In any event, virtually all new tanks made today are not only compatible, but also laboratory-listed or manufacturer-approved and therefore ready for regulatory approval.[334] Focusing on the storage systems needed for non-blender pumps (rare though they are), EPA warns that the required compliance "documentation for … the types of materials used, and … installation dates, is often unavailable" even if equipment is compatible.[335] These concerns are misplaced and overstated.

To begin, EPA's concerns are self-imposed by regulations that it has recognized are unnecessarily burdensome and should change. EPA has in fact already proposed a rulemaking to ease these compliance regulations in ways that would greatly alleviate its concerns here.[336] As EPA states, the new UST proposal "will make it easier for owners and operators to meet compatibility requirements with their current infrastructure, if unable to demonstrate compatibility."[337] First and foremost, this proposal would immediately secure compatibility for an expected "24 percent" of the nation's fuel stations by approving any USTs that "have secondarily contained tanks and piping (including safe suction piping) and use interstitial monitoring."[338] And the percentage is likely much higher in many states, "including those in New England, New York, California, and Florida," which have "required full or partial secondary containment prior to … the Energy Policy Act of 2005 (EPAct)."[339] This safe and easy regulatory fix would alone usher in a huge expansion in the nation's approved E85 and E15 infrastructure. But EPA has completely failed to account for this in its Regulatory Impact Analysis for the RFS rulemaking at issue here.

Second, EPA's own UST proposal also finds that all steel tanks, all post-2005 fiberglass tanks, and all flexible reinforced plastic piping are E15-compatible and warrant no further

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[332] *See* EPA, *Emerging Fuels and Underground Storage Tanks (USTs)*, https://www.epa.gov/ust/emerging-fuels-and-underground-storage-tanks-usts#existing (summarizing applicable regulations).

[333] DRIA at 195; *see* 2022 Stillwater Report at 11.

[334] Stillwater Associates LLC, *Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017*, at 30 ("2016 Stillwater Report") (July 11, 2016) (attached as Ex. 6).

[335] DRIA at 197.

[336] *E15 Fuel Dispenser Labeling and Compatibility With Underground Storage Tanks*, 86 Fed. Reg. 5,094 (Jan. 19, 2021).

[337] *Id.* at 5,099.

[338] *Id.* at 5,099-5,100.

[339] *Id.*

demonstration requirements.[340] The proposal would also ensure all newly installed UST systems are compatible with up to 100% ethanol.[341] Growth Energy supports finalization of this proposal, which would go a long way toward removing the alleged infrastructure barriers EPA notes in this rulemaking. Data confirm that all steel tanks and all double-walled fiberglass tanks since 1990 are designed to store up to 100% ethanol.[342] Moreover, EPA could easily go further in exempting other safe equipment from compliance demonstration requirements. For example, based on robust compatibility analyses conducted by Oak Ridge National Laboratory, all metal and fiberglass UST system piping and the vast majority of flexible plastic piping is E15-compatible.[343] Growth Energy also recommends that EPA modify the existing regulations to allow a retailer to forgo demonstration if it conducts semi-annual third-party UST inspections and reports inspection results to its regulating agency.[344]

But even under the existing regulations EPA admits should change, EPA's concerns are overstated. The concern about whether stations with older tanks have the necessary documentation is largely unfounded, as "EPA's rule has created a cottage industry of consultants willing to help the station owner meet the documentation requirements."[345] Multiple online databases have also compiled ready-to-use compliance letters for common equipment, by manufacturer.[346] Moreover, a station can be approved as long as one tank is compatible and documented, and most stations have at least three tanks, and many have four.[347]

When retrofitting is necessary, average costs are not as high as EPA projects. As even EPA admits, "[m]any owners may already be able to demonstrate compatibility for the tanks and piping in their UST systems. These components are often the largest expenses …. In this situation, owners may be able to upgrade other components of their UST system with less operational downtime and less cost because they will not need to break the concrete pad over the

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[340] *Id.*

[341] *Id.* at 5,100-5,101.

[342] National Renewable Energy Laboratory, *E15 and Infrastructure* (May 2015), https://afdc.energy.gov/files/u/publication/e15_infrastructure.pdf.

[343] Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012) (attached as Ex. 7).

[344] *See* Growth Energy, *Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations*, Docket # EPA–HQ–OAR–2020–0448 (Apr. 19, 2021) (attached as Ex. 8).

[345] 2016 Stillwater Report at 5.

[346] *See, e.g.*, Petroleum Equipment Institute, *UST Component Compatibility Library*, https://www.pei.org/ust-component-compatibility-library (attached as Ex. 9).; Association of State and Territorial Solid Waste Management Officials, *Compatibility Tool*, https://astswmo.org/ust-compatibility-tool/ (attached as Ex. 10).

[347] 2016 Stillwater Report at 28.

UST system to replace tanks or piping."[348] Recognizing this, Stillwater has found that an incompatible station can generally offer E85 with just $30,000 in costs: $15,000 for an E85-capable dispenser, and $15,000 for underground infrastructure work.[349] Those costs can be reduced even further by taking advantage of the industry's regular cycle for replacing dispensers every seven years. By upgrading during the ordinary replacement cycle, the station's marginal cost of upgrading to E85 is just $20,000: $15,000 for the underground work and an incremental $5,000 for the E85-compatible dispenser over the $10,000 for an E10 dispenser.[350] Furthermore, as EPA's Regulatory Impact Analysis notes, government funds are also available to mitigate these costs. Specifically, in 2020, the USDA initiated its Higher Blends Infrastructure Incentive Program (HBIIP), which provides funds to help retail service station owners to upgrade or replace their equipment to offer higher ethanol blends.[351]

VII. IN SETTING RFS STANDARDS, EPA SHOULD BACKFILL SHORTFALLS WITH ANY OTHER AVAILABLE QUALIFYING RENEWABLE FUELS

Whenever EPA sets volume requirements, whether through a waiver, the reset, or otherwise, the statute and principles of reasoned decisionmaking require that backfill any renewable fuel shortfall with any other types of reasonably available qualifying renewable fuel unless doing so could trigger a waiver or otherwise cause important and severe harm.

As the D.C. Circuit and EPA have previously recognized, "Congress intended the Renewable Fuel Program to move the United States toward greater energy independence and to reduce greenhouse gas emissions."[352] All renewable fuel that qualifies for compliance under the RFS program reduces lifecycle greenhouse gas emissions by *at least* 20%—and usually far more—relative to the "baseline" lifecycle GHG emissions of gasoline or diesel.[353] Whenever there is a shortfall of a given category of renewable fuel relative to the volume that Congress expected for a given year, EPA faces a choice: it can allow fossil fuel to fill in the gap or it can call upon obligated parties to fill the gap with other qualifying renewable fuels. As long as there is additional renewable fuel that is reasonably available for compliance, the choice is clear: EPA must use that renewable fuel to backfill the shortfall and thereby fulfill the objectives of the RFS program.

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[348] *UST System Compatibility with Biofuels* at 16.

[349] 2016 Stillwater Report at 5-6.

[350] *Id.*

[351] DRIA at 195-196.

[352] *ACE*, 864 F.3d at 696; *see Renewable Fuel Standard Program: Standards for 2014, 2015 and 2016 and Biomass-Based Diesel Volume for 2017 ("2014-2016 Rule")*, 80 Fed. Reg. 77,420, 77,421 (Dec. 14, 2015).

[353] 42 U.S.C. § 7545(*o*)(2)(A)(i).

EPA undoubtedly has the power to do that under both the cellulosic waiver[354] and the reset power.[355] In fact, EPA's prior position was that it would use that power to backfill cellulosic shortfalls with available renewable fuel. In setting the 2016 standards, EPA said: "[W]e do not believe that it would be consistent with the energy security and greenhouse gas reduction goals of the statute to reduce the applicable volumes of renewable fuel set forth in the statute absent a substantial justification for doing so. When using the cellulosic waiver authority, we believe that there would be a substantial justification to exercise our discretion to lower volumes of total and advanced renewable fuels in circumstances where there is inadequate projected production or import of potentially qualifying renewable fuels, or where constraints exist that limit the ability of those biofuels to be used for purposes specified in the Act (i.e., in transportation fuel, heating oil or jet fuel). In particular, we believe that the cellulosic waiver authority is appropriately used to provide adequate lead time and a sufficient ramp-up period for non-cellulosic biofuels to be produced and constraints on their use for qualifying purposes eliminated, so they can fill the gap presented by a shortfall in cellulosic biofuels."[356]

That approach (whether under the cellulosic waiver power or the reset power) is compelled not only by Congress's purpose but also by EPA's duty to act rationally.[357] To satisfy that duty, EPA must account for any "important aspect of the problem" and "articulate a satisfactory explanation for" its action.[358] Clearly, the availability of renewable fuel that would serve the congressional goals of the RFS program is an important consideration in any standard setting under the RFS.

EPA's proposal for 2022 does not consider backfilling the implied non-advanced volume (which would mean increasing it above 15 billion gallons). Instead, EPA proposes mechanically to reduce the total standard by the same amount as the advanced.[359] As explained elsewhere in this comment, conventional ethanol reduces GHG emissions by more than 40% relative to baseline emissions and promotes energy security and independence, and even grandfathered biodiesel may reduce GHG emissions relative to the baseline. The is no concrete evidence of serious harms that could outweigh these benefits; as also explained elsewhere in this comment, for example, increasing the use of ethanol would not have significant adverse consequences for the environment or the economy. And as explained elsewhere in this comment, additional ethanol would be available to meet a higher total RFS requirement. In sum, the analysis is clear: EPA is obligated, consistent with Congress's purpose in creating the RFS program, to backfill

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[354] *See* 42 U.S.C. § 7545(*o*)(7)(D)(i) (allowing cellulosic waiver by "lesser" amount); *Alon Refining Krotz Springs, Inc. v. EPA*, 936 F.3d 628, 663 (D.C. Cir. 2019) ("the discretionary waiver provision necessarily empowers EPA to depart upward from the statutory level of non-cellulosic advanced biofuel for a given year").

[355] 42 U.S.C. § 7545(*o*)(2)(B)(ii)-(iv).

[356] *2014-2016 Rule* at 77,434.

[357] *Monroe Energy*, 750 F.3d at 916.

[358] *State Farm*, 463 U.S. at 43.

[359] NPRM at 72,451.

the projected 2022 cellulosic shortfall with available conventional ethanol (and other renewable fuel that could meet the implied non-advanced requirement).

Certainly, nothing in the statute requires EPA to apply the same cellulosic waiver to the total volume requirement that it applies to the advanced biofuels requirement. The statute says that if EPA reduces the cellulosic standard, it "may also reduce the applicable volume of renewable fuel and advanced biofuels requirement established under paragraph (2)(B) by the same or a lesser volume."[360] In the past, EPA has stressed the word "and," and asserted that the statutorily implied non-advanced volume of 15 bil gal is a hard cap. That misreads the statute. The total volume requirement could be reduced by a lesser amount than the cellulosic standard "*and*" the advanced volume requirement could be reduced by a lesser amount than the cellulosic standard, even if those two reductions are different. And nothing in the text of the statute says that the implied volume cannot exceed 15 bil gal after the application of waivers. On the contrary, for the reasons just discussed, congressional intent and statutory structure require the opposite. Indeed, the statute directs EPA to "ensure" that "at least" the specified amount of each category of renewable fuel is used.[361] Using the cellulosic waiver to reduce the total requirement by less than the advanced requirement, to backfill a cellulosic shortage with available conventional ethanol, accords with that directive.

VIII. EPA MUST INCLUDE CARRYOVER CELLULOSIC RINS IN THE AVAILABLE VOLUME WHEN REDUCING THE CELLULOSIC VOLUME REQUIREMENT

Regardless of how EPA otherwise manages the RIN bank, it must at least count carryover cellulosic RINs toward the "projected volume" of cellulosic fuel "available during [each] calendar year" for purposes of determining the extent to which it exercises its cellulosic waiver power.[362] And although the reset provision does not contain the same language, because the reset is, as explained above, an advance multi-year waiver, it is subject to the same constraint.

The cellulosic waiver provision's term "the projected volume available during [a] calendar year" means all cellulosic volume obligated parties may use to comply with their RFS obligations.[363] That includes carryover RINs. Indeed, the D.C. Circuit has said that carryover RINs are "*available* for compliance."[364] This accords with the basic concept of the waiver: it "authorizes EPA to ease the … Program's requirements *when complying with those requirements would be infeasible*," and it is *feasible* to meet the requirements to the extent there is production *plus* carryover RINs.[365]

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[360] 42 U.S.C. § 7545(*o*)(7)(D)(i).

[361] *Id.* § 7545(*o*)(2)(A)(i).

[362] *Id.* § 7545(*o*)(7)(D)(i).

[363] *Id.*

[364] *Monroe Energy*, 750 F.3d at 918 (emphasis added); *see American Fuel & Petrochemical Manufacturers v. EPA*, 937 F.3d 559, 582 (D.C. Cir. 2019) (similar).

[365] *ACE*, 864 F.3d at 708 (emphasis added).

Comparison with earlier language in the same provision reinforces this conclusion. The waiver is triggered if "the projected volume of cellulosic biofuel production is less than" the statutory volume.[366] That phrase is not the reference of the later "projected volume available." "Where Congress uses certain language in one part of a statute and different language in another, it is generally presumed that Congress acts intentionally"[367]—"especially" where different words "are used in the same sentence."[368] This presumption is appropriate here because Congress easily could have re-used the phrase "of cellulosic biofuel production" instead of "available": "For any calendar year for which the projected volume of cellulosic biofuel production is less than the minimum applicable volume …, the Administrator shall reduce the applicable volume of cellulosic biofuel … to the projected volume *of cellulosic biofuel production* during that calendar year." Or Congress could have written: "… shall reduce … to *that* projected volume during that calendar year." Either of those approaches would be a more natural and clear way to direct EPA to set the cellulosic standard to the level of projected production, without regard to available carryover RINs.

Including carryover RINs in "the projected volume available" also furthers Congress's intent that the RFS program serve as a market forcing policy to increase the use of renewable fuels. Excluding carryover RINs from the "projected volume available" inflates the supply of RINs, depressing RIN prices and discouraging the very investment Congress intended to incentivize. EPA's proposal even recognizes this dynamic: "despite the continued rapid growth in cellulosic biofuel volumes, excess carryover cellulosic RINs in 2018 and 2019 resulted in low cellulosic RIN prices, which in turn may have negatively affected investment in cellulosic biofuel production."[369]

ACE is not to the contrary. *ACE* held that EPA need not consider carryover RINs when determining whether there is "inadequate domestic supply" for purposes of the general waiver under § 7545(*o*)(3)(B)(ii). That holding is irrelevant here because the cellulosic waiver provision differs from the general waiver provision in two important ways. First, the relevant text here is "the projected volume available." This differs from "inadequate domestic supply" especially in its use of "available" as a modifier of "volume" rather than "production" or "supply." In fact, the phrase "the projected volume available" has no analogue in the general waiver. The phrase "inadequate domestic supply" in the general waiver defines the *trigger* for the waiver, and its analogue in the cellulosic waiver is "the projected volume of cellulosic biofuel production," a term that admittedly does not encompass carryover RINs. In contrast to the cellulosic waiver, the general waiver contains no language instructing EPA about the level to which EPA must reduce the applicable volume.

Second, *ACE* credited EPA's explanation that, "were [EPA] to consider carryover RINs as a supply source …, the number of carryover RINs would be reduced to almost zero,"

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[366] 42 U.S.C. § 7545(*o*)(7)(D)(i).

[367] *National Fed'n of Indep. Bus. v. Sebelius*, 567 U.S. 519, 544 (2012).

[368] *Northeast Hosp. Corp. v. Sebelius*, 657 F.3d 1, 12 (D.C. Cir. 2011) (quotation marks omitted).

[369] NPRM at 72,455-72,456.

eliminating critical "flexibility and liquidity provided by carryover RINs."[370] That rationale—though dubious for reasons discussed above—does not apply to cellulosic RINs because the Clean Air Act also directs EPA to enable obligated parties to satisfy their cellulosic volume obligations by purchasing cellulosic waiver credits, whenever the cellulosic waiver is triggered.[371] These credits provide the "market liquidity[,] transparency," and "certainty" that EPA otherwise relies on RINs to provide.[372] EPA nonetheless insists that "the benefits of carryover RINs … also apply to cellulosic carryover RINs," without any explanation of how that could be so given the availability and role of the waiver credits.[373] That kind of "ipse dixit conclusion … epitomizes arbitrary and capricious decisionmaking."[374]

Finally, although including carryover cellulosic RINs in "the projected volume available" when exercising the cellulosic waiver power would represent a change in EPA policy, that is permissible. "Agencies are free to change their existing policies as long as they provide a reasoned explanation for the change."[375] EPA could easily satisfy this requirement by adopting the explanation offered here for the change in policy.

IX. THE PROPOSED RFS STANDARDS WOULD NOT APPRECIABLY RAISE RETAIL PRICES FOR FOOD OR GASOLINE

As EPA observes, its proposed volume requirements would have negligible effects on food and retail gas prices.

With respect to food prices, EPA "estimate[s] that the proposed volumes would have minimal impacts … (increases of total food expenditures of 0.15% and 0.40% in 2021 and 2022 respectively)."[376] EPA is incorrect with respect to 2021; its proposal cannot affect food prices in 2021 at all because 2021 is already over. As for 2022, EPA's assessment is substantially overstated, but in any event, there is no reason to expect that the effect could be greater than EPA's assessment. As Stillwater explains, the amount of corn needed to produce the volume of ethanol EPA assumes—or even to meet the full 15-billion gallon implied non-advanced volume—would not increase the demand for corn relative to recent prior years and therefore would not be expected to raise corn prices at all. Moreover, as EPA notes, "corn and soy are a relatively small proportion of most foods purchased and consumed in the United States,"[377] and

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[370] 864 F.3d at 715.

[371] 42 U.S.C. § 7545(*o*)(7)(D)(ii)-(iii).

[372] *Id.* § 7545(*o*)(7)(D)(iii).

[373] NPRM at 72,456.

[374] *American Pub. Commc'ns Council v. FCC*, 215 F.3d 51, 53 (D.C. Cir. 2000) (citation omitted).

[375] *Encino Motorcars, LLC v. Navarro*, 579 U.S. 211, 221 (2016).

[376] DRIA at 225.

[377] DRIA at 225.

only a fraction of corn and soybean are used for renewable fuel. So, any effect of the RFS standards on food prices will be limited to the margin.

With respect to retail gas prices, EPA "project[s] relatively small price impacts of the proposed volumes …, with slight decreases in the price of gasoline (–0.11 and –0.02 cents per gallon in 2021 and 2022 respectively) and increases in the price of diesel (0.70 and 3.22 cents per gallon in 2021 and 2022 respectively)."[378] Again, EPA's proposal cannot affect gas prices in 2021 at all. As for 2022, EPA's expectation that its proposal would slightly decrease gasoline prices is sound and well-supported by its evidence.

X. EPA'S PROPOSED RESPONSE TO *ACE* REMAND IS NECESSARY AND APPROPRIATE

Growth Energy applauds EPA's proposed remedy for the unlawful general waiver of the 2016 standards on remand from the D.C. Circuit in *ACE*.[379] In setting the percentage standards for 2016, EPA invoked its "inadequate domestic supply" general-waiver power to reduce the total volume by 500 million gallons.[380] But the D.C. Circuit invalidated that action because EPA impermissibly considered "demand-side constraints that affect the consumption of renewable fuel by consumers."[381] Accordingly, the court "vacate[d] EPA's decision to reduce the total renewable fuel volume requirements for 2016 through use of its 'inadequate domestic supply' waiver authority, and remand[ed] the rule to EPA for further consideration in light of [its] decision."[382] EPA thus had an unlawful 500-million-gallon deficit, which it has now proposed to cure through 250-million-gallon supplemental requirements in 2022 and 2023. Growth Energy stresses, however, that the proposed 250-million-gallon supplemental requirement would fulfill EPA's remedial duty only if EPA also finalizes its promised 250-million-gallon supplemental requirement for 2023.

EPA has a duty to adjust future standards—as it has proposed to do—to remedy the unlawful 2016 waiver. *ACE* held that EPA lacked statutory authority to waive the 500 million gallons, and EPA is "without power to do anything which is contrary to either the letter or spirit of the mandate construed in the light of the opinion" rendered in *ACE*.[383] Pursuant to the mandate and EPA's general duty to "ensure" that the statutory volume requirements are met,

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[378] *Id.*

[379] 864 F.3d 691 (D.C. Cir. 2017).

[380] Renewable Fuel Standard Program: Standards for 2014, 2015, and 2016 and Biomass-Based Diesel Volume for 2017 ("2016 Rule"), 80 Fed. Reg. 77,420, 77,439 (Dec. 14, 2015); *ACE*, 864 F.3d at 701-702.

[381] *ACE*, 864 F.3d at 696.

[382] *Id.* at 696-697.

[383] *City of Cleveland v. Federal Power Comm'n*, 561 F.2d 344, 346 (D.C. Cir. 1977) (quotation marks omitted); *accord U.S. Postal Serv. v. Postal Regulatory Comm'n*, 747 F.3d 906, 910 (D.C. Cir. 2014).

EPA must cure its adjudicated legal error.[384]

EPA also has the power to remedy its prior error by setting future supplemental requirements standards, as it has proposed. Congress directed EPA to "ensure" that the transportation fuel sold in the United States "contains *at least*" the statutorily specified amount of renewable fuel.[385] Invoking this power, EPA on two prior occasions made up a prior year's requirements by adding it to, or supplementing, a future year's requirements.[386] EPA can use this power again to impose the proposed remedial supplemental obligations.

EPA's proposal raises no issues of retroactive rulemaking. The proposed supplemental obligations are not *retroactive*. Instead of "attach[ing] new legal consequences to events completed before its enactment,"[387] the supplemental obligations would apply only to future conduct by obligated parties, namely, to their activity in 2022 (and 2023). Moreover, whether viewed through the retroactive lens or not, the supplemental obligation would be reasonable and therefore permissible because it would not unsettle legitimate "expectation[s]."[388] Obligated parties were always legally bound to meet the 2016 statutory volume requirement except to the extent EPA validly waived it; obligated parties could not have had settled "expectation[s]" in an ultra vires waiver.[389] Further, by proposing a future obligation, the proposal affords obligated parties ample notice and opportunity to plan their future activity to achieve compliance. And even if that were not sufficient to render the proposal reasonable, obligated parties could rely on carryover RINs to satisfy the supplemental obligation, as EPA notes.[390]

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[384] *See WildEarth Guardians v. EPA*, 830 F.3d 529, 535 (D.C. Cir. 2016) ("The necessary consequence of vacating the Implementation Rule on the ground that it failed adequately to adhere to Subpart 4 would be some kind of corrective EPA action strictly implementing that Subpart …."); *Multicultural Media, Telecom & Internet Council v. FCC*, 873 F.3d 932, 936 (D.C. Cir. 2017) (A "decision that the agency's action was substantively unreasonable generally means that, on remand, the agency must exercise its discretion differently and reach a different bottom-line decision"); *Chicago & S. Air Lines, Inc. v. Waterman S.S. Corp.*, 333 U.S. 103, 113 (1948) ("Judgments, within the powers vested in courts by the Judiciary Article of the Constitution, may not lawfully be revised, overturned or refused faith and credit by another Department of Government.").

[385] 42 U.S.C. § 7545(*o*)(2)(A)(i); *see also ACE*, 834 F.3d at 698-699 (quoting 42 U.S.C. § 7545(*o*)(3)(B)(i)) (emphasis added) (quotation marks omitted).

[386] *NPRA*, 630 F.3d at 156-157, 163; *Monroe Energy*, 750 F.3d at 919-921.

[387] *Landgraf v. USI Film Prods.*, 511 U.S. 244, 269-270 (1994); *NPRA*, 630 F.3d at 159.

[388] *Monroe Energy*, 750 F.3d at 920.

[389] *Id.*

[390] NPRM at 72,455-72,456.

XI. EPA SHOULD RETAIN THE STANDARD EQUATION AS REVISED IN THE 2020 RULE

As Growth Energy explains in a separate comment on EPA's proposed denial of all pending SRE applications,[391] EPA should deny all such applications and, for the same reasons, should reverse and deny all SREs that were remanded to EPA by the D.C. Circuit in *Sinclair Wyoming Refining Co. v. EPA*.[392]

Regardless of whether EPA denies the pending and remanded SRE applications, it should retain the standard equation as revised in the 2020 rule, so that the equation adjusts for projected SREs. The revised equation does not prescribe a particular prediction method; it may be appropriate for EPA to update its method in light of new standards or empirical data affecting the likelihood of granting SREs for a given year (such as the standards and data underlying the proposed denial of all pending SREs). Maintaining the standard equation as revised in the 2020 rule would thus enable EPA to set standards that realistically reflect the obligations needed to achieve full compliance with the applicable volume requirements, especially should EPA change course and decide to grant SREs in some future year.

In fact, as Growth Energy has explained before, EPA *must* adjust the percentage standards to account for SREs. First, Congress designed the RFS program "to force the market to create ways to produce and use greater and greater volumes of renewable fuel each year."[393] Thus, in setting annual volume requirements EPA has a "statutory mandate to 'ensure[]' that … [volume] requirements are met,"[394] as well as a statutory mandate to promulgate general rules for the RFS program that "ensure that transportation fuel sold or introduced into commerce in the United States … contains at least the applicable volume of renewable fuel."[395] If EPA does not "adjust renewable fuel obligations to account for exemptions," it creates a "renewable-fuel shortfall," "imped[ing] attainment of overall applicable volumes."[396] Or, as EPA put it in the 2020 rule, "any SREs granted after we issued the annual rule containing the percentage standards for that year effectively reduced the required volume of renewable fuel for that year."[397] Thus, as EPA recognized in modifying the standard equation in the 2020 rule, raising the percentage standards to account for SREs has "the effect of ensuring that the required volumes of renewable fuel are met when small refineries are granted exemptions"[398]; refusing to make this adjustment

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[391] *See* EPA, *EPA Proposes to Deny All Pending RFS Small Refinery Exemption Petitions* (Dec. 2021), https://www.epa.gov/sites/default/files/2021-12/documents/420f21065.pdf.

[392] Order, No. 19-1196, ECF No. 1925942 (D.C. Cir. Dec. 8, 2021).

[393] *ACE*, 864 F.3d at 710.

[394] *Id.* at 698-699 (quoting 42 U.S.C. § 7545(*o*)(3)(B)(i)).

[395] 42 U.S.C. § 7545(*o*)(2)(A)(i); *see also id.* § 7545(*o*)(2)(A)(iii)(I).

[396] *American Fuel*, 937 F.3d at 571, 588.

[397] Renewable Fuel Standard Program: Standards to 2020 and Biomass-Based Diesel Volume for 2021 and Other Changes: Final Rule, 85 Fed. Reg. 7016, 7050 (Feb. 6, 2020).

[398] *Id.*

violates EPA's duty to set percentage standards that "ensure" that the volume requirements are met.

Second, in setting the standards, EPA must "consider [all] important aspect[s] of the problem" and "examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made."[399] Because SREs have the effect of lowering the required volumes and preventing the required volumes from being met, how to account for SREs is an integral part of the problem EPA faces whenever it sets percentage standards; EPA cannot set standards by blinding itself to them.

Third, refusing to account for retroactive extensions impermissibly converts its exemption power into a *waiver* power, in contradiction of the statute's plain text and structure. In several provisions of the statute, Congress explicitly granted EPA the power to reduce the required nationwide volumes, and labeled those powers "waivers."[400] These "waiver" powers may be exercised "only in *limited* circumstances," namely, the circumstances specified in the statute.[401] In contrast, the provisions allowing EPA to exempt small refineries contain neither of those features: they do not say that EPA may reduce the nationwide volume requirements or use the label "waiver"; rather, they are labeled "exemption," and they authorize EPA to determine merely that the *compliance obligation* "shall not apply to" the specific applicant refinery because of special circumstances relating to that refinery.[402] There is no reason to depart from "the usual rule that when the legislature uses certain language in one part of the statute and different language in another, [courts and agencies must] assume[] different meanings were intended."[403] Refusing to account for retroactive SREs in effect converts SREs into waivers of the nationwide volume requirements. That is pernicious because it would expand EPA's waiver power to situations that would not meet the statutorily specified triggers for a waiver. As EPA has acknowledged, "small refinery exemptions are held to a different standard than a waiver," including a waiver for "severe economic harm."[404] There is no reason to think "Congress would have established the severe-harm waiver standard 'only to allow waiver'" under the small refinery exemption provision "based on lesser degrees of economic harm."[405] If Congress had intended to grant EPA a power to waive nationwide volume requirements based on findings that individual refineries will suffer "disproportionate economic hardship" if they must comply, it

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[399] *State Farm*, 463 U.S. at 43 (quotation marks omitted).

[400] *See* 42 U.S.C. § 7545(*o*)(7)(A) & (D)-(E), (8)(D).

[401] *NPRA*, 630 F.3d at 149 (emphasis added).

[402] 42 U.S.C. § 7545(*o*)(9).

[403] *United States v. Monzel*, 641 F.3d 528, 533 (D.C. Cir. 2011).

[404] Renewable Fuel Standard Program-Standards for 2019 and Biomass-Based Diesel Volume for 2020: Response to Comments 19, EPA (Nov. 2018), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100VU6V.pdf.

[405] *ACE*, 864 F.3d at 712.

would have said so—it knew how to. EPA has no authority to rewrite the statute or create a new, non-textual waiver power.[406]

Contrary to the views of some commentors, the fact that Congress, in 42 U.S.C. § 7545(*o*)(3)(C)(ii), directed EPA to account for the behavior of small refineries in one particular respect does not mean that Congress intended implicitly to forbid EPA from taking account of small refineries in any other way. The *expressio unius* canon does not "mean that anything not required is forbidden."[407] Rather, the question is whether Congress's silence on a specific issue is so closely related to issues it addressed explicitly that it is appropriate to infer from the different treatment that Congress intended to withhold authority from EPA on the silent issue.[408]

No such inference is warranted here. As EPA recognized during the 2020 rulemaking, section 7545(*o*)(3)(C)(ii) and the Supplemental 2020 NPRM represent two different solutions to two distinct and opposite problems: § 7545(*o*)(3)(C)(ii) tells EPA what to do when a refinery that was exempt during the prior compliance year nonetheless used renewable fuel that year, i.e., it directs EPA to account for potential *overcompliance*.[409] In contrast, the revised standard equation addresses the problem of near certain *undercompliance*. It is not surprising that Congress saw fit to address the specific situation where renewable fuel was used by exempt refineries (a problem that EPA's RIN system quickly rendered a nonissue),[410] while at the same time failing to mention the (now) much more pressing problem of unaccounted for exempt fossil fuels. Indeed, Congress likely did not consider the problem of retroactive exemptions at all, given its expectation that SREs would exist only on a "[t]emporary" basis, would be "extend[ed]" only upon a showing of "disproportionate economic hardship,"[411] and would accordingly fade away within a few years of the program's start. In fact, it would be nonsensical

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[406] *See, e.g.*, *In re Sealed Case*, 237 F.3d 657, 670 (D.C. Cir. 2001) ("Agencies are not empowered to carve out exceptions to statutory limits on their authority.").

[407] 2A Sutherland, *Statutes and Statutory Construction* § 47:25 (7th ed. updated Nov. 2021).

[408] *See, e.g.*, *Barnhart v. Peabody Coal Co.*, 537 U.S. 149, 168 (2003) ("[T]he canon *expressio unius est exclusio alterius* does not apply to every statutory listing or grouping; it has force only when the items expressed are members of an 'associated group or series,' justifying the inference that items not mentioned were excluded by deliberate choice, not inadvertence." (quoting *United States v. Vonn*, 535 U.S. 55, 65 (2002)))

[409] *See* Renewable Fuel Standard Program-Standards for 2020 and Biomass-Based Diesel Volume for 2021 and Other changes: Response to Comments 167-168 ("2020 Response"), EPA (Dec. 2019), https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100YAPQ.pdf; 42 U.S.C. § 7545(*o*)(3)(C)(ii) ("In determining the applicable percentage for a calendar year, the Administrator shall make adjustments … to account for the use of renewable fuel during the previous calendar year by small refineries that exempt under paragraph (9).").

[410] *See* Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program: Notice, 74 Fed. Reg. 24,904, 24,954 (May 26, 2009) (explaining that the volume of renewable fuel generated by exempt refineries is "expected to be very small" and that EPA's RIN-credit trading system accounts for such volumes in any event).

[411] 42 U.S.C. § 7545(*o*)(9).

to infer that, by addressing overcompliance, Congress intended to bar EPA from addressing undercompliance given the statutory command that EPA "ensure" that the standards are met and the overarching objective to compel increased annual use of renewable fuel.[412]

Moreover, the *expressio unius* argument proves far too much. It would mean that *any* adjustment of percentage standards to account for exempt volumes would violate the statute, even if the exemptions had already been granted at the time of EPA's rulemaking. If that were true, EPA's percentage standard formula would have been invalid from the start,[413] and EPA would be powerless to extend SREs in appropriate cases while still "ensuring" the target volumes are met. This result flouts the statutory structure, as Growth Energy has already explained at length. Whatever *expressio unius* inference may exist is far too weak to justify such a disharmonious result.

Finally, some commentors have argued that the revised standard equation violates the statutory requirement to avoid "redundant obligations."[414] It does not. That statutory section merely provides that EPA should not require an obligated party to "satisfy the RFS standards more than once for the same volume of gasoline and diesel."[415] For instance, redundancy could arise if an obligated party that functioned as both a refinery and an importer were required to meet its obligation twice for the same volume of fuel it introduced into commerce. The revised standard equation requires no such result. It merely calls for the percentage obligation that applies to all obligated parties to be adjusted in light of the exempt volume of transportation, and still requires each (non-exempt) obligated party to meet that obligation only once.

XII. ROBUST RFS REQUIREMENTS PROMOTE RURAL ECONOMIC HEALTH

EPA is correct that "[h]igher volumes of … renewable fuel could result in more domestic jobs in the biofuels industry" and "rural economic development."[416] Moreover, *maintaining* pre-pandemic levels of demand for renewable fuel is imperative for protecting the economic health of the renewable fuel industry and the jobs of those who work in the industry or adjacent industries. The ethanol industry supported nearly 305,000 jobs, created $19 billion in household income, and contributed over $34 billion in GDP in 2020.[417] And that was 19% below 2019's GDP contribution due to the pandemic.[418] These contributions to rural economies could grow significantly if appropriate management of the RFS transitions the nationwide market to E15.

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[412] *ACE*, 864 F.3d at 710.

[413] *See* 40 C.F.R. § 80.1405 (requiring EPA at minimum to account for nonretroactive SREs when setting percentage standards).

[414] 42 U.S.C. § 7545(*o*)(3)(C)(i).

[415] *See* 2020 Response at 182.

[416] NPRM 72,447, 72,451.

[417] Renewable Fuels Association, *Contribution of the Ethanol Industry to the Economy of the United States in 2020* 10 (Feb. 2, 2021) (attached as Ex. 12).

[418] *Id.* at 8-9.

Specifically, transitioning to E15 would create more than 180,000 new jobs, spurring $10.5 billion in household income and $17.8 billion in additional GDP.[419]

XIII. EPA IS OBLIGATED TO ADJUST THE 2022 RFS STANDARDS TO MAKE UP FOR PAST RETROACTIVE SREs

EPA has previously refused to adjust standards to account for the retroactive exemptions granted for prior years. In its current proposal, EPA again omits any adjustment for the billions of RINs lost to prior retroactive exemptions. Without such an adjustment, EPA violates its statutory duties to set RFS standards that will "ensure" that the volume requirements are met and to engage in reasoned decisionmaking. EPA's refusal reflects a failure to address an important issue—how the standards would be affected by past retroactive exemptions—or to rationally connect the standards to the evidence before it. EPA's refusal also converts the *exemptions* into a *waiver*, contrary to the statute. So voluminous are the past retroactive exemptions that EPA's refusal to account for them undermines Congress's intent that the RFS standards force the market to use increasing amounts of renewable fuel annually.

A. EPA's Refusal Violates Its Statutory Duty to Set Standards That "Ensure" That the Required Volumes Are Met

"After EPA determines the volume requirements for the various categories of renewable fuel" by considering whether any statutory waivers are appropriate, "it has a 'statutory mandate' to 'ensure[]' that those requirements are met" by setting percentage standards that will achieve those volumes.[420] EPA violated this duty by refusing to adjust the 2020 standards to account for past retroactive exemptions.

If EPA does not "adjust renewable fuel obligations to account for exemptions," it creates a "renewable-fuel shortfall," "imped[ing] attainment of overall applicable volumes."[421] Recognizing that fact, EPA "raises the percentage standard" for a given year to account for the exemptions "that were granted … before [it] established the percentage standard for that year."[422] That solution, however, is "only partial" because it does "not … account for small refinery exemptions granted after [EPA] promulgates percentage standards for that year—so-called retroactive exemptions."[423]

In the 2020 Rule, EPA finally recognized that to fulfill its "ensure" duty, it must also adjust the standards to account for retroactive exemptions—but it did so only with respect to the retroactive exemptions it projected it would grant for 2020.[424] EPA correctly explained that

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[419] ABF Economics, *Economic Impact of Nationwide E15 Use* 1-2 (June 10, 2021) (attached as Ex. 13).

[420] *ACE*, 864 F.3d at 698-699 (quoting §7545(o)(3)(B)(i)).

[421] *American Fuel*, 937 F.3d at 571, 588.

[422] *Id*. at 588.

[423] *Id*.

[424] 85 Fed. Reg. at 7,049.

"should [it] grant [exemptions] without accounting for them in the percentage formula, those exemptions would effectively reduce the volumes of renewable fuel required by the RFS program, potentially impacting renewable fuel use in the U.S."[425] Raising the standards to account for projected retroactive exemptions, EPA declared, has "the effect of ensuring that the required volumes of renewable fuel are met."[426]

That is only partially true because granting retroactive exemptions in past years without accounting for them in any annual volume standards also—as EPA acknowledged—"effectively reduced the required volume of renewable fuel for th[ose] year[s]."[427] Thus, the sound premises of EPA's analysis implied more remediation: they required EPA to also adjust the 2020 standards to account for past retroactive exemptions. EPA's refusal to do that violated its "ensure" duty.

EPA is not relieved of that duty just because the compliance years for which those prior retroactive exemptions were granted are past; their depressive effect on the RFS program's volume requirements continue today.

Because EPA did not account for past retroactive exemptions granted when it set the standards for those years, those exemptions freed up RINs corresponding to the exemption volumes for compliance in a future year. By "effectively reduc[ing]" the volume of renewable fuel that obligated parties were required to use in the covered years, the past retroactive exemptions provided obligated parties with a RIN windfall—RINs that should have been needed to meet the required volumes but, because of the retroactive exemptions, were not. Using the mechanism of the RIN bank, obligated parties carried their RIN windfall forward for compliance in a future year, in effect transferring the renewable-fuel shortfall caused by the retroactive exemptions to a later year. By disregarding the shortfall from past retroactive exemptions that was embedded in the RIN bank, EPA sets standards that cannot "ensure" that the market would use the required amount of renewable fuel in 2022.

This conclusion follows from how carryover (or banked) RINs and RFS compliance work. As EPA recognized when it set the 2020 standards (and many times before), and as it recognized again in this rulemaking, obligated parties will necessarily use all available carryover RINs to comply with their RFS obligations because any unused carryover RINs would expire and become worthless.[428] To meet their RFS obligations, obligated parties first apply their carryover RINs to their fullest extent and then use renewable fuel produced in the compliance year until they meet their volume obligation. Thus, the effective volume requirement—the amount of renewable fuel that the standards actually require obligated parties to use—is the nominal volume requirement minus the available carryover RINs, i.e., minus the RIN bank. If

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[425] *Id.* at 7,050.

[426] *Id.*

[427] *Id.*

[428] DRIA at 43; 85 Fed. Reg. at 7,021 n.15; *see also* 77 Fed. Reg. 70,759, 70,775 ("[T]he availability of rollover RINs can significantly affect the potential impact of implementation of the RFS volume requirements.").

and to the extent that obligated parties use more than the effective volume requirement, that is only because of purely voluntary decisions, not because the standards actually required them to do so—and the RINs from such additional use are banked for the next year.[429] That the bank appears to maintain a "balance" from one year to the next thus is a fiction, concealing the reality that the bank is regenerated—often enabled by the carryover RINs from the prior year. See id.

So, to the extent the RIN bank contains RINs because of unaccounted-for past retroactive exemptions, the standards will not force the market to use the required renewable fuel. And accordingly, to the extent EPA sets the 2022 standards without accounting for such RINs, EPA sets standards that cannot "ensure" that the required volumes of renewable fuel would be met.[430]

B. EPA's Refusal Is Arbitrary and Capricious

EPA's refusal to account for past retroactive exemptions in setting RFS standards is arbitrary and capricious, rather than the product of reasoned decisionmaking. In setting the standards, EPA must "consider [all] important aspect[s] of the problem" and "examine the relevant data and articulate a satisfactory explanation for its action including a rational connection between the facts found and the choice made."[431] EPA's refusal does not do so.

As explained above, when EPA sets standards, EPA knows it has a duty to set standards that will ensure that the required volumes of renewable fuel will be used, and it knows—or at least should know given its experience with the RFS program and the data it has regarding the volume of past retroactive exemptions and the size of the RIN bank—that if it does not adjust the standards to account for those past retroactive exemptions, the standards will not ensure that the required volume of renewable fuel are used and the inflated supply of carryover RINs will create disincentives for new production. EPA thus blinds itself to a critical problem with the standards it is setting, and sets standards that cannot rationally be justified by the evidence before it. EPA in fact is proposing to set standards it knows will not achieve their goal, even if all of its projections for 2022 prove 100% accurate. That is arbitrary and capricious.

Moreover, EPA has the tools to make the necessary adjustment. As discussed above, EPA has at least two available options for accounting for past retroactive exemptions, both of which it has used before. First, EPA could apply a lesser discretionary cellulosic waiver to the advanced and total volume requirements. Second, EPA could increase the nominal 2022 volume requirements or impose a supplemental requirement, much as it did with the 2009 and 2010 standards.

C. EPA's Refusal Impermissibly Creates for Itself a Non-textual Waiver Power

By refusing to adjust the standards to account for past retroactive exemptions, EPA also impermissibly converts the exemptions into waivers, contrary to the statute's text. As discussed, the effect of the unaccounted-for retroactive exemptions is to reduce the nationwide volume

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[429] 85 Fed. Reg. at 7021 n.15.

[430] *See National Petrochemical*, 630 F.3d at 153 ("ensure" means "make sure, [or] certain").

[431] *State Farm*, 463 U.S. at 43 (quotation marks omitted).

requirement, but Congress authorized EPA to reduce that requirement only through a duly issued "waiver."

Congress expressly granted EPA the power to "reduce" nationwide volume requirements, but labeled those powers "waiver,"[432] and permitted EPA to use them "only" in the "limited circumstances" specified in the statute,[433] such as where "implementation of the [statutory volume] requirement would severely harm the economy … of a State, a region, or the United States."[434] In contrast, the "exemption" provision—as Congress labeled it—does not say that EPA may "reduce" the volume requirements, but rather authorizes EPA to determine merely that the compliance obligation "shall not apply to" a specific refinery because of a different special circumstance, namely, that compliance would cause the refinery "disproportionate economic hardship."[435]

"[T]he usual rule [is] that when the legislature uses certain language in one part of the statute and different language in another"—here, exemption rather than waiver—courts and agencies must "assume[] different meanings were intended,"[436] and there is no reason to depart from that rule here. Indeed, as EPA has acknowledged, exemption petitions "are held to a different standard"—"economic hardship"—"than a waiver under severe economic harm."[437] Congress would not have "established the severe-harm waiver standard only to allow waiver" under the small-refinery exemption provision "based on lesser degrees of economic harm."[438] EPA has no authority to rewrite the statute to convert its "exemption" power into a new "waiver" power.[439]

XIV. BIOINTERMEDIATES

Growth Energy appreciates EPA's efforts to advance regulatory clarity regarding the use of biointermediates in the production of renewable fuels. Since the 2016 proposed "Renewables Enhancement and Growth Support Rule" (REGS proposal), it has become even more important for renewable fuel producers to have the flexibility to use biointermediates in fuel production in order to lower costs and drive innovation. EPA should ensure that the final biointermediates regulations facilitate use of biointermediates for production of specific advanced renewable fuels such as SAF, while also ensuring sufficient flexibility as renewable fuel producers continue to innovate to produce low carbon fuels using various feedstocks and biointermediate products. Though we appreciate the importance of preserving the integrity of the RFS program,

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[432] 42 U.S.C. § 7545(o)(7), (8)(D).

[433] *National Petrochemical*, 630 F.3d at 149.

[434] 42 U.S.C. § 7545(o)(7)(A).

[435] 42 U.S.C. § 7545(o)(9)(A)(i), (B)(i).

[436] *United States v. Monzel*, 641 F.3d 528, 533 (D.C. Cir. 2011).

[437] EPA, 2020 RFS Response to Comments at 14.

[438] *ACE*, 864 F.3d at 712 (quotation marks omitted); *see also* 42 U.S.C. § 7545(o)(7)(A).

[439] *See, e.g.*, *Mingo Logan Coal Co. v. EPA*, 829 F.3d 710, 721 (D.C. Cir. 2016); *Ethyl Corp. v. EPA*, 51 F.3d 1053, 1061 (D.C. Cir. 1995).

we believe modifications of the proposed regulations are warranted to ensure the framework is not unduly burdensome on potential biointermediates and renewable fuel producers without compromising program integrity. Below we briefly address our primary concerns with the proposed framework.

- *Definition of "Biointermediate"*: In order to preserve flexibility, we support EPA reverting back to its approach in the REGS proposal of defining types of products that constitute biointermediates while excluding other substances that only undergo form changes. We are concerned that if EPA must undertake an entirely new rulemaking any time renewable fuel producers wish to utilize a different type of biointermediate in fuel production, it will be impose unnecessary regulatory burdens on the Agency and create substantial time delays for parties wishing to make investments in development and introduction of innovative renewable fuels to the market. Rather than specifying particular biointermediates and requiring rulemaking to add more, we suggest that EPA has adequate flexibility through the registration process to impose conditions on types of biointermediates that it views as posing greater compliance oversight concerns. Specifically, consistent with EPA's practice of including conditions on approval of a petition submitted pursuant to the Efficient Producer process, it could require as part of the registration approval process particular conditions applicable both to the biointermediate producer and the renewable fuel producer to address any such concerns.

  In addition, to the extent the Agency is concerned that the previously-proposed definition may be too broad and inadvertently encompass substances that it does not intend to regulate as biointermediates, it could clarify these issues with producers as questions arise (e.g., encourage the industry to inquire and then to inform a producer it need not register as a biointermediate producer). Finally, if EPA decides to proceed with the current specifically delineated list of biointermediates, Growth Energy supports inclusion of the identified substances, recommends adding cellulosic sugars (such as those derived from paper production processes) , and recommends that EPA develop a streamlined approval process to address new biointermediates. A model for that streamlined process is the Efficient Producer Petition Process, which provides producers clarity as to the information EPA needs to approve registration under a pathway, facilitates expedited EPA review, and allows EPA to tailor conditions on approval as necessary.

  Relatedly, Growth Energy encourages EPA to confirm that corn oil produced as a byproduct from the ethanol production process that may undergo form changes (such as the addition of water, physical separation, and drying) prior to sale to a biodiesel producer would *not* be considered a biointermediate. EPA could do so by expressly including pre-processing of corn oil as an acceptable form change that does not result in treatment of the corn oil as a biointermediate.

- *Voluntary QAP*: EPA should allow participation in the Quality Assurance Plan (QAP) process on a voluntary basis, rather than imposing an additional mandatory cost and burden on biointermediates producers and renewable fuel producers. To be sure, many parties will likely participate, but other parties may view contractual arrangements and/or alternative oversight mechanisms as sufficient assurances that RINs will be valid. Given the breadth of the proposed liability provisions applicable to all regulated parties in a fuel production chain that involves biointermediates, the proposed regulations have ample safeguards even without requiring mandatory QAP.

- *Necessary Update to Ethanol Carbon Intensity*: As addressed in detail above, it is imperative that EPA update its GHG LCA for corn starch-based ethanol. The current value, which greatly underestimates the GHG benefits of ethanol, could adversely affect the use of undenatured ethanol as a biointermediate in advanced fuel production. Production of other advanced fuels such as SAF using ethanol may have its own energy requirements that impact overall lifecycle GHG emissions of the resulting fuel. It is therefore very important that SAF and other advanced fuels that may utilize ethanol as a biointermediate should accurately reflect ethanol's full GHG benefits. Failure to account for all such benefits could improperly disqualify such fuels from appropriate treatment under the RFS program.

We welcome the opportunity for further engagement on these issues in order to advance EPA's finalization of a regulatory path for use of biointermediates in renewable fuel production.

XV. EPA SHOULD APPROVE KERNEL FIBER REGISTRATIONS AND PENDING BIOFUEL PATHWAYS

Growth Energy urges EPA to act speedily to approve the numerous pending registration applications for simultaneous production of starch and cellulosic ethanol from corn kernel feedstock. Through the RFS program, Congress especially sought to encourage the production of cellulosic biofuel, which achieves the greatest reduction in GHG emissions relative to gasoline. This Administration has underscored the importance of advanced and cellulosic biofuels in helping the United States to achieve its ambitious and necessary GHG reduction goals. Removal of regulatory barriers and prompt approval of the pending kernel fiber registrations is important to encourage and reward investment in technology to convert cellulose to ethanol.

Additionally, to further producer innovation and the production of advanced biofuels, we urge EPA to prioritize and expedite pathways for carbon capture, utilization, and storage. We also urge EPA to expedite approval of the pending petition from the Corn Refiners Association (CRA) to allow biodiesel and renewable diesel facilities to utilize corn oil produced from corn wet mills as a feedstock.

XVI. EPA SHOULD ADOPT THE PROPOSED APPROACH TO CONFIDENTIAL BUSINESS INFORMATION

Growth Energy supports EPA's proposal to not withhold basic information from small-refinery exemption ("SRE") petitions and decisions as confidential business information ("CBI") pursuant to exemption 4 of the Freedom of Information Act ("FOIA"). [440]

Transparency over SRE petitions and decisions is necessary so that the public can monitor the production of renewable fuel in compliance with the RFS program. Starting with the 2016 compliance year, the number of SREs dramatically increased, which resulted in a "renewable-fuel shortfall" where millions of gallons of "renewable fuel simply [went] unproduced."[441] Many of these SRE decisions were highly suspect.[442] Yet, the decisions were made in secret, and basic information about the exemptions was withheld under FOIA. As the D.C. Circuit observed, the story of EPA's administration of SREs "paint[s] a troubling picture of intentionally shrouded and hidden agency law" that leaves "those aggrieved by the agency's actions without a viable avenue for judicial review."[443] Transparency is necessary because EPA cannot lawfully make secret exemptions that undermine the RFS program goals.

None of the information covered by EPA's proposal plausibly qualifies as exempt from disclosure under FOIA. As EPA explains in its proposal, the Supreme Court addressed the meaning of "confidential" in its decision in *Food Marketing Institute v. Argus Leader Media*, 139 S. Ct. 2356 (2019) ("*Argus Leader*").[444] The Court held that information is "confidential" under Exemption 4 "[a]t least" where the information is "both customarily and actually treated as private by its owner and provided to the government under an assurance of privacy."[445] The Court then identified two potential conditions for satisfying this standard.

First, the information must be "customarily kept private, or at least closely held, by the person imparting it."[446] Here, small refineries do not do that. They have publicly disclosed the same or similar facts. For example, HollyFrontier has disclosed all these facts (and more) in its securities filings, including: the fact of exemption extensions for two of its refineries, their names and locations, the years for which the refineries received extensions, when the extensions were granted, the effects of those extensions *(e.g.*, "RINs cost reduction"), and how EPA effectuated the extensions (e.g., providing "vintage RINs to replace the RINs previously retired" or

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[440] NPRM at 72,476-72,478; Growth Energy only comments on the portion of the Proposed Rule's "Public Access to Information" section proposing to disclose certain basic information relating to small refinery exemptions. For convenience and readability, however, we use the Proposed Rule as a shorthand to refer to that portion.

[441] *American Fuel,* 937 F.3d at 571

[442] *See Renewable Fuels Ass'n v. EPA*, 948 F.3d 1206, 1214 (10th Cir. 2020).

[443] *Advanced Biofuels Ass'n v. EPA*, 792 F. App'x 1, 5 (D.C. Cir. 2019).

[444] NPRM at 72,476.

[445] *Argus Leader*, 139 S. Ct. at 2366.

[446] *Id.* at 2363.

"reinstat[ing] the RINs previously submitted").[447] A news article also reported that a particular company (Husk Energy) told the reporter that it inherited a small refinery exemption for 2017 when it acquired a plant in Superior, Wisconsin, and that it will seek an exemption for the Superior plant for 2018.[448]

Second, *Argus Leader* suggested that a second condition may also have to be met to qualify for Exemption 4: that "the party receiving [the information] provide[d] some assurance that it will remain secret."[449] The Department of Justice has issued guidance regarding the second condition.[450] DOJ's guidance clarifies that Exemption 4 cannot be claimed by an agency when "the Government provides an express or implied indication to the submitter prior to or at the time the information is submitted to the Government that the Government would publicly disclose the information."[451] EPA's proposal is therefore an appropriate way to preclude Exemption 4 protection by conclusively establishing that EPA will deny such assurances of confidentiality: it will "not consider certain basic information incorporated into EPA actions on petitions and submissions … to be entitled to treatment as CBI under Exemption 4 of the FOIA."[452] Nothing more is required to disqualify the information for Exemption 4. This approach accords with the Department of Justice's guidance,[453] EPA's proposal would be an express statement that EPA will not treat the information as confidential.

Taking steps to ensure that this basic information relating to SREs is not withheld under Exemption 4 is also long overdue. EPA previously proposed a similar rule twice before without adopting it. In 2016, EPA first proposed a similar rule.[454] EPA explained then "basic information related to [EPA's] decisions on small refinery/refiner exemption petitions is not entitled to treatment as CBI."[455] In April 2019, EPA appeared ready to adopt the a similar rule

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[447] HollyFrontier Corp., SEC Form 10-K, at 41, 43, 77-78 (Feb. 20, 2019) ("HollyFrontier 2018 10-K"); HollyFrontier Corp., SEC Form 10-K, at 40-41, 77 (Feb. 21, 2018) ("HollyFrontier 2017 10-K").

[448] Jarrett Renshaw & Chris Prentice, *Exclusive: Chevron, Exxon Seek 'Small Refinery' Waivers From U.S. Biofuels Law*, Reuters (Apr. 12, 2018), https://www.reuters.com/article/us-usa-biofuels-epa-refineries-exclusive/exclusive-chevron-exxon-seek-small-refinery-waivers-from-u-s-biofuels-law-idUSKBN1HJ32R (attached as Ex. 14).

[449] 139 S. Ct. at 2363.

[450] *See* Office of Information Policy, U.S. DOJ, Exemption 4 After the Supreme Court's Ruling in *Food Marketing Institute v. Argus Leader* Media and Accompanying Step-by-Step Guide, (Oct. 4, 2019), https://www.justice.gov/oip/exemption-4-after-supreme-courts-ruling-food-marketing-institute-v-argus-leader-media.

[451] NPRM at 72476.

[452] NPRM at 72,477.

[453] *Id.*

[454] Renewables Enhancement and Growth Support Rule, 81 Fed. Reg. 80,828, 80,909 (Nov. 16, 2016).

[455] *Id.*

again, but inexplicably abandoned it once more.[456] In the interim, EPA has publicly disclosed only the aggregate number of extensions and renewable fuel volumes exempted despite numerous requests for further transparency,[457] and even refused to provide any specific information on the exemption extensions to members of Congress.[458] This has led to litigation over the EPA's opposition to providing basic information about SRE petitions—information that EPA had previously determined in 2016 was not CBI.[459] Now is the time to finalize this rule and expose its SRE decisions to some sunlight. As EPA notes, the proposed approach will "provide certainty" regarding how EPA will treat the information,[460] and will likely lead to fewer lawsuits and reduce unnecessary compliance costs.

For example, in past litigation, EPA was forced to evaluate whether information in SRE petitions were confidential on a case-by-case basis.[461] Refineries submitted substantiations of their confidentiality claims, and EPA then had to perform its own exhaustive search of public sources to confirm whether the information was previously published.[462] As to seven decision documents, the D.C. District Court found EPA's CBI determination "unpersuasive" after *in camera* review.[463] Notwithstanding the inadequacy of EPA's past CBI determinations, the process of reviewing and purportedly substantiating each claim by each refinery undoubtedly introduces unnecessary compliance costs, especially given the dubious confidentiality over the information in the first place.

Growth Energy further believes that EPA should not withhold additional categories of information in connection with its decisions on exemption extensions, including: (i) the specific standards EPA actually applied to decide whether to grant or deny the extension; (ii) EPA's final analysis of whether to grant or deny the extension; and (iii) if an extension is granted, the means by which EPA effectuated the extension, such as allowing the refinery to unretire RINs. Records

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[456] *See* Renewables Enhancement and Growth Support (REGS) Rule (Apr. 11, 2019).

[457] *See, e.g.*, Growth Energy FOIA Request (Apr. 9, 2018), EPA-HQ-2018-006398; Growth Energy FOIA Request (Apr. 12, 2018), EPA-HQ-2018-006524; Growth Energy FOIA Request (July 23, 2018), EPA-HQ-2018-009898; Growth Energy FOIA Request (Mar. 19, 2019), EPA-HQ-2019-004370; *see also* Growth Energy 2019 Comment at 17-22.

[458] Letter from Senator Charles E. Grassley, et al. to Administrator of EPA, Scott Pruitt, at 2 (Apr. 12, 2018), https://www.grassley.senate.gov/imo/media/doc/Pruitt%20Small%20Refinery%20Letter%204.12.18.pdf; *see* Letter from Assistant Administrator of EPA, William L. Wehrum, to Senator Charles E. Grassley, at 1 (July 12, 2018), http://www.ascension-publishing.com/EPA-RIN-Waivers-071818.pdf.

[459] *See, e.g.*, Def's Opp. Mot. Summ. J., *Renewable Fuels Ass'n v.EPA*, No. 18-2031, ECF #58 (D.C. Cir. Dec. 15, 2020).

[460] NPRM at 72,478.

[461] *Renewable Fuels,* No. 18-2031, ECF #58.

[462] *Id.*

[463] Opinion, *Renewable Fuels,* No. 18-2031, ECF #62 at 25, (D.C. Cir. Feb. 4, 2021).

embodying the standards EPA uses to grant an exemption extension, its final analysis on a refinery's entitlement to an extension, and the means EPA uses to effectuate an extension are all "interpretations" or "considered statements" of EPA's policy on SRE extensions, including on the scope of EPA's statutory authority to grant an extension and to allow retroactive remedies using RINs.[464] This information is not covered by the deliberative process privilege or predecisional. Such SRE decisions are not "advisory opinions, recommendations," or "personal opinions of the writer" that "reflect internal deliberations on the advisability of any particular course of action."[465] Instead, they are what EPA actually applied or decided—actions to which the deliberative process privilege "can never apply."[466]

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[464] *Public Citizen v. Office of Mgmt. and Budget*, 598 F.3d 865, 874 (D.C. Cir. 2009); *Tax Analysts v. IRS*, 117 F.3d 607, 609, 617 (D.C. Cir. 1997); *Coastal States Gas Corp. v. Dep't of Energy*, 617 F.2d 854, 869 (D.C. Cir. 1980); *Sterling Drug, Inc. v. FTC*, 450 F.2d 698, 708 (D.C. Cir. 1971).

[465] *Public Citizen*, 598 F.3d at 875 ("an agency's application of a policy to guide further decision-making does not render the policy itself predecisional").

[466] *NLRB v. Sears, Roebuck & Co.*, 421 U.S. 132, 153-154 (1975).

<u>Exhibit List</u>

Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Volume 1

Exhibit Number	Title of Exhibit
1	Environmental Health & Engineering, Inc., *Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards* (Feb. 3, 2022)
2	Life Cycle Associates, LLC, *Review of GHG Emissions of Corn Ethanol under the EPA RFS2* (Feb. 4, 2022)
3	Net Gain, *Analysis of EPA's Proposed Rulemaking for 2020, 2021, and 2022 RVOs, Regarding Land Use Change, Wetlands, Ecosystems, Wildlife Habitat, Water Resource Availability, and Water Quality* (Feb. 3, 2022)
4	*Comments of Drs. Fatemeh Kazemiparkouhi, David MacIntosh, Helen Suh,* EPA-HQ-OAR-2021-0324 (Feb. 3, 2022)
5	Stillwater Associates, LLC, *Comments to EPA on 2020-2022 RFS Rule, Prepared for Growth Energy* (Feb. 4, 2022)
6	Stillwater Associates LLC, *Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017* (July 11, 2016)
7	Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012)
8	Growth Energy, *Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations*, Docket # EPA–HQ–OAR–2020–0448 (Apr. 19, 2021)
9	Petroleum Equipment Institute, *UST Component Compatibility Library*
10	Association of State and Territorial Solid Waste Management Officials, *Compatibility Tool*
11	Air Improvement Resource, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2022* (Nov. 16, 2021)
12	Renewable Fuels Association, *Contribution of the Ethanol Industry to the Economy of the United States in 2020* (Feb. 2, 2021)
13	ABF Economics, *Economic Impact of Nationwide E15 Use* (June 2021)
14	Jarrett Renshaw & Chris Prentice, *Exclusive: Chevron, Exxon seek 'small refinery' waivers from U.S. biofuels law*, Reuters (Apr. 12, 2018)
15	Stillwater Associates LLC, *Potential Increased Ethanol Sales through E85 for the 2019 RFS* (Aug. 17, 2018)

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 1

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February 3, 2022

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Docket Number: EPA-HQ-OAR-2021-0324

Comments of David MacIntosh[1,2], Tania Alarcon[1,3], Brittany Schwartz[1]
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[2] Harvard T.H. Chan School of Public Health, Boston, MA
[3] Tufts University, Boston, MA

RE: Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards

We are writing to comment on topics raised by the proposed RFS rule dated December 7, 2021, and the associated Draft Regulatory Impact Analysis (DRIA) dated December 2021 (EPA-420-D-21-002). We provide information to further the discussion of the impacts of renewable fuels on land use change (LUC) and greenhouse gas emissions (GHG). Our comments are based on the literature for corn starch ethanol published since the U.S. Environmental Protection Agency's (USEPA) most recent life cycle analysis (LCA) of GHG impacts for renewable fuels that was released in 2010.[1]

We at Environmental Health & Engineering, Inc. (EH&E) are a multi-disciplinary team of environmental health scientists and engineers with expertise in measurements, models, data science, LCA, and public health. Members of our team authored a manuscript titled "Carbon intensity of corn ethanol in the United States: state of the science"[2] which was published in Environmental Research Letters in January 2021. We conducted a state of the science review of the carbon intensity (CI) for corn ethanol in the United States (U.S.), applied objective criteria limited to the U.S. regulatory context, and derived an evidence-based central CI estimate and credible range as of 2020. Our manuscript concludes that assessments of GHG intensity for corn ethanol have decreased by approximately 50% over the prior 30 years and converged on a

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[1] US Environmental Protection Agency (USEPA) 2010 Renewable Fuel Standard program (RFS2) regulatory impact analysis (RIA) Report No.: EPA-420-R–10–006 (Washington, DC: United States Environmental Protection Agency, Assessment and Standards Division Office of Transportation and Air Quality US Environmental Protection Agency).

[2] Scully MJ, Norris GA, Alarcon Falconi TM, MacIntosh DL. 2021a. Carbon intensity of corn ethanol in the United States: state of the science. *Environmental Research Letters*, 16(4), pp.043001.

current central estimate value of approximately 51 grams of carbon dioxide equivalent emission per megajoule (gCO_2e/MJ). That continues to be our view. Later in these comments, we discuss our approach for determining a credible range for the CI of corn ethanol and draw upon our published reply to commentary on our paper. Our experience informs the comments that follow regarding the proposed RFS rule.

Our comments focus on three major topics within the DRIA: 1) LUC estimates, 2) LUC uncertainties, and 3) the Agency's illustrative scenario. Our detailed comments on those topics are presented following the summary.

SUMMARY

A critical evaluation of the best available science on indirect LUC (iLUC) shows that current estimates of GHG impacts from LUC associated with corn starch ethanol are substantially lower than findings published in the USEPA 2010 RIA. The change in estimated iLUC impact results from improvements in agroeconomic models and data used to forecast impacts of supply and demand for agricultural products. The Agency's own work during the 2010 rulemaking process demonstrates that advancement of LUC models can impact their output and lead to substantial changes in estimated GHG impacts for iLUC. By relying only on its 2010 GHG analysis for the current rulemaking, the Agency is not giving due consideration to the best available science.

Uncertainties in estimates of LUC, while extant, can be managed in a time-sensitive manner by incorporating central best estimates from the existing generally accepted and commonly used LUC models. This approach would allow a range of credible iLUC values to be determined based on existing models and literature without conducting a full new analysis at this time.

We also comment on the validity of the Agency's illustrative GHG scenario for corn ethanol. That scenario presumes the proposed volumes will cause new demand for cropland in 2021 and 2022, but that assumption appears to conflict with actual levels of U.S. corn and ethanol production available from the U.S. Department of Agriculture (USDA) and Department of Energy (DOE). Observations of these data suggest existing U.S. corn production capacity is sufficient to meet the modest increase in demand for ethanol projected by the Agency. Hence, we encourage the Agency to evaluate the premise of its illustrative scenario in the context of available U.S. corn and ethanol production data.

We look forward to continued engagement with the Agency on the important issue of LCA modeling for biofuels, including at the upcoming Workshop on Biofuel Greenhouse Gas Modeling.[3]

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[3] *Announcing Upcoming Virtual Meeting on Biofuel Greenhouse Gas Modeling*, 86 Fed. Reg. 73756 (Dec. 28, 2021).

LAND USE CHANGE ESTIMATES

GHG impacts of corn ethanol projected for 2022 by the USEPA in its 2010 RIA agree reasonably well with current estimates of impacts, with one notable exception: LUC. Table 1 shows the results of our published study alongside the Agency's 2010 projection for 2022 and the latest estimates from the Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model (GREET) based on the Global Trade Analysis Project-biofuel model (GTAP-BIO). As our study was focused on the U.S. regulatory landscape for renewable fuels, we reviewed U.S.-based studies and selected a 2004 baseline year to reflect the impacts of the RFS. Table 1 shows that total LUC represents the largest difference between the Agency's GHG emission estimates made in 2010 and the current comparison analyses.

Table 1 Comparison of Reported Life Cycle Analysis Emission Categories of Corn Ethanol in the U.S.

Emission Category	USEPA 2010 2022 Projection[a]	EH&E 2020 Topical Review[c]	GREET 2021[d]
Farming Net Co-product	14.1	13.2	16.3
Fuel Production	26.5	29.6	28.1
Other Inputs (fuel & feedstock transport, rice methane*, livestock*, denaturant, tailpipe)	6.4	4.7	3.7
Total Land Use Change	26.1	3.9	7.4
Total Carbon Intensity Value (gCO_2e/MJ)	**73.1**	**51.4**	**55.6**
Lower Bound of Total Carbon Intensity Value (gCO_2e/MJ)	51.2[b]	37.6	--
Upper Bound of Total Carbon Intensity Value (gCO_2e/MJ)	91.9[b]	65.1	--

* Broken out explicitly in EPA analysis.

USEPA	United States Environmental Protection Agency
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model
gCO_2e/MJ	Gram carbon dioxide equivalent emission per megajoule

a US Environmental Protection Agency (USEPA) 2010 Renewable Fuel Standard program (RFS2) regulatory impact analysis (RIA) Report No.: EPA-420-R–10–006 (Washington, DC: United States Environmental Protection Agency, Assessment and Standards Division Office of Transportation and Air Quality US Environmental Protection Agency). Figure 2.6-2.

b USEPA. Federal Register 40 CFR Part 80 Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule. March 26, 2010. Table V.C-1.

c Scully, MJ, Norris, GA, Alarcon Falconi, TM. and MacIntosh, DL 2021a. Carbon intensity of corn ethanol in the United States: state of the science. *Environmental Research Letters*.

d Argonne National Laboratory. The Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model. 2021.

iLUC is a substantial component of the USEPA 2010 analysis to estimate GHG impacts associated with corn ethanol and warrants an update according to the best available science. The 2021 DRIA that informs the proposed RFS rule states that "LUC emissions have the potential to constitute a large portion of the total emissions attributable to crop-based biofuels, but such estimates also have significant uncertainty."[4] In the Agency's 2010 RIA, LUC accounted for 29% (28.2 of 98.2 kilograms carbon dioxide equivalent emissions per million

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[4] USEPA 2010 RFS2 RIA, page 66.

British thermal units [kgCO_2e/mmBtu])[5] of the total estimated GHG emissions. With estimated impacts of 32 kgCO2e/mmBtu for iLUC and -3.8 kgCO2e/mmBtu for domestic LUC (dLUC), iLUC was the dominant component of total LUC impacts in the Agency's analysis. As described below, the Agency's 2010 forecast of LUC impacts is substantially different from most recent estimates.

Most current iLUC estimates for corn starch ethanol, including models developed in the U.S. and Europe, are substantially lower than findings published by USEPA in 2010. Several publications recognize that estimates of iLUC impacts for corn starch ethanol over the last decade have trended downward (See Attachment A).[6,7,8,9] In fact, most estimates of iLUC GHG impact from U.S. demand for corn ethanol are 2-fold to 4-fold lower than USEPA estimates published in 2010 as illustrated by Figure 2 in Scully et al.[10] and an updated version of that figure presented below as Figure 1. This updated figure includes iLUC estimates from the most current relevant and applicable modeling efforts in the U.S. (shown in blue) and in Europe (shown in red). The four commonly relied upon models—GTAP-BIO, Food and Agricultural Policy Research Institute- Center for Agricultural and Rural Development (FAPRI-CARD), MIRAGE, and Global Biosphere Management Model (GLOBIOM)—provide estimates that are lower than the USEPA central estimate and lower bound value published in 2010.

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[5] USEPA 2010 RFS2 RIA..

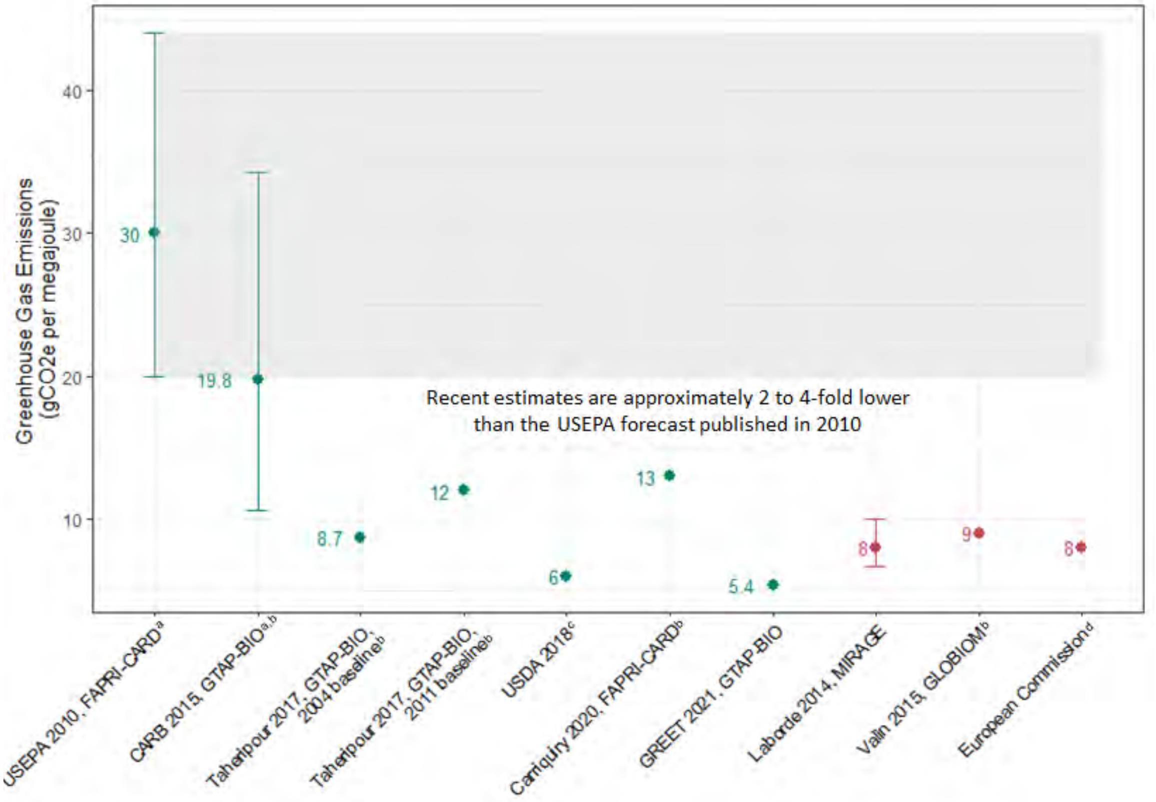
[6] Lee U, Hoyoung K, Wu M, Wang M. 2021. Retrospective analysis of the U.S. corn ethanol industry for 2005-2019: implications for greenhouse gas emission reductions. *Biofuels, Bioproducts & Biorefining*, 15(5), pp.1318-1331.

[7] Dunn JB, Mueller S, Kwon H-Y and Wang MQ. 2013. Land-use change and greenhouse gas emissions from corn and cellulosic ethanol. *Biotechnology for Biofuels*, 6(1), pp.1-3.

[8] Taheripour F, Mueller S and Kwon H. 2021. Appendix A: supplementary information to response to 'How robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?' *Journal of Cleaner Production*., 310, pp.127431.

[9] Carriquiry M, Elobeid A, Dumortier J and Goodrich R. 2020. Incorporating sub-national Brazilian agricultural production and land-use into US biofuel policy evaluation. *Applied Economic Perspectives and Policy*, 42, pp.497-523.

[10] Scully et al. 2021a.



[a] Use older versions of the model
[b] Indirect and direct land use change
[c] Based on a review of primary land use change analyses
[d] Policy based on primary land use change analyses

Figure 1 Comparison of USEPA's iLUC estimates with relevant most recent studies from the U.S. and Europe

LUC estimates have changed because the models and data that go into them have improved over time. Our publication on LCA of corn ethanol[11] and our reply to comments on the paper,[12] as well as a recent retrospective analysis of corn ethanol LCAs by Lee et al.,[13] summarize the enhancements made to the two iLUC models, FAPRI and GTAP-BIO, used in U.S. regulatory contexts for evaluation of corn ethanol. Briefly, the changes in estimates of iLUC impacts are attributable to: (1) addition of new modules that allow for more accurate simulation of real-world agricultural practices, (2) addition of more spatially resolved information on land cover, and (3) tuning of parameters that describe rates of land conversion and land transformation (See

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[11] Scully et al. 2021a.

[12] Scully MJ, Norris GA, Alarcon Falconi TM, MacIntosh DL, 2021b. Reply to comment on 'Carbon intensity of corn ethanol in the United States: state of the science. *Environmental Research Letters*, 16(11), pp.118002.

[13] Lee et al. 2021.

Attachment A). Details on important changes made over time to FAPRI and GTAP-BIO are available in the literature.[14],[15],[16],[17],[18],[19]

Enhancements to FAPRI and GTAP-BIO are particularly relevant to the current RFS rulemaking because USEPA relied on both models for its 2010 forecast of GHG impacts from iLUC and relies on that former analysis in the current rulemaking. Here we summarize key literature on enhancements to the models and examples of their effect on estimated iLUC and GHG emissions.

An early example of refinements to models and data that lead to substantial changes in estimated GHG impacts for iLUC is found within the Agency's 2010 rulemaking process itself. After review of comments on the proposed rule for the 2010 RFS2, the Agency made updates to iLUC estimates.[20] These changes were made possible by the availability of updated studies, including numerous improvements to the FAPRI-CARD model that are detailed in the 2010 RFS2 final rule.[21] Table 2 shows that the Agency's central estimate of iLUC emissions decreased by approximately 50% when using the updated version of FAPRI-CARD. **Thus, the Agency's own prior work demonstrates that advancement of models can impact their output and lead to substantial changes in estimated GHG impacts for iLUC.**

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[14] USEPA 2010 RFS2 RIA.

[15] Babcock BA, Iqbal Z. 2014. Using recent land use changes to validate land use change models. Staff report 14-SR 109. Center for Agricultural and Rural Development, Iowa State University.

[16] Carriquiry et al. 2020.

[17] Taheripour F, Zhao X and Tyner W E. 2017. The impact of considering land intensification and updated data on biofuels land use change and emissions estimates. *Biotechnology for biofuels*, 10(1), pp.1-16.

[18] Taheripour F and Tyner W. 2013. Biofuels and land use change: applying recent evidence to model estimates. *Applied Science*, 3(1), pp.14–38.

[19] Kwon H, Liu X, Dunn J B, Mueller S, Wander MM and Wang M. 2020. Carbon calculator for land use and land management change from biofuels production (CCLUB) Argonne National Library, Division ES September 2020.

[20] USEPA 2010 RFS2 RIA.

[21] USEPA Federal Register 40 CFR Part 80 Regulation of Fuels and Fuel Additives: Changes to Renewable Fuel Standard Program; Final Rule. March 26, 2010.

Table 2 USEPA's Central Estimates of International Land Use Change Associated with Corn Ethanol for Biofuel Over 30 Years, 2022[a]

Author	Study Year	Land Use Change Model	Model Adjustments	Central Estimate of International LUC Emissions (g CO_2e per MJ)
USEPA	2009 (original RFS2 analysis)	FAPRI	NA	60.37[a]
	2010 (revised RFS2 analysis)	Updated FAPRI-CARD, including Brazil module[c]	• Price-induced crop yields • Animal feed replacements • Improved satellite data	30.13[b]

USEPA	U.S. Environmental Protection Agency
g CO2e per MJ	gram carbon dioxide equivalent emissions per megajoule
RFS	Renewable Fuel Standard
FAPRI	Food and Agricultural Policy Research Institute
NA	not applicable
FAPRI-CARD	Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development

[a] US Environmental Protection Agency (USEPA). Lifecycle Greenhouse Gas (GHG) Emissions Results Spreadsheets (30 October 2008). Docket: EPA-HQ-OAR-2005-0161.

[b] USEPA 2010 Renewable Fuel Standard program (RFS2) regulatory impact analysis (RIA) Report No.: EPA-420-R–10–006 (Washington, DC: United States Environmental Protection Agency, Assessment and Standards Division Office of Transportation and Air Quality US Environmental Protection Agency).

[c] Per RFS2 RIA (February 2010), Section 5.1.2.6.

Carriquiry et al.[22] presents a more recent example using FAPRI, the same modeling platform used by USEPA in the 2010 LCA for corn ethanol. The authors use a 2016 version of FAPRI-CARD that includes effects of demand for ethanol on the price and supply of corn and other agricultural products, multiple cropping, and conversion of pasture area in Brazil to cropland. Improvements made between the 2008 GHG Model and the 2016 GHG Model used to determine emission factors include enhanced quality of spatial data, a refined relationship between crop yield and crop price, and other adjustments. As shown in Table 3, the enhanced data and additional detail contributed to the model result in up to a 44% reduction of total LUC emissions.

Table 3 CARD/FAPRI Central Estimates of Total Land Use Change Associated with Corn Ethanol for Biofuel Over 30 Years, ending in 2021/2022[a]

Author	Land Use Change Model	Emissions Factors	Central Estimate of LUC Emissions (g CO_2e per MJ)
Carriquiry et al.	FAPRI-CARD	2008 model	23.2
		2016 model without sub-national land use data and inputs for Brazil	18.2
		2016 model with sub-national land use data and inputs for Brazil	13.1

FAPRI-CARD	Food and Agricultural Policy Research Institute-Center for Agricultural and Rural Development
LUC	land use change
g CO2e per MJ	gram carbon dioxide equivalent emissions per megajoule

[a] Carriquiry, M., Elobeid, A., Dumortier, J. and Goodrich, R., 2020. Incorporating sub-national Brazilian agricultural production and land-use into US biofuel policy evaluation. *Applied Economic Perspectives and Policy*, 42(3), pp.497-523.

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[22] Carriquiry et al. 2020.

Updates to GTAP-BIO since the Agency's use of this model in 2010 provide another example of decreases in estimated iLUC that result from model development and refinement. Taheripour et al.[23] describe updates to the land use module of GTAP-BIO that among other items included land transformation elasticities tuned to trends in regional land cover data across the globe observed from 2003 – 2013. As shown in Table 4, the updated version of GTAP-BIO, which was tuned to observed land cover change for 2003 – 2013, produced estimates of LUC GHG impacts approximately 40% lower than those from the prior (untuned) version of GTAP-BIO.

Table 4 GTAP-BIO Central Estimates of Total Land Use Change Associated with Corn Ethanol Biofuel Over 30 Years. [a] Modeled greenhouse gas emissions were estimated with an older version of GTAP-BIO ("Untuned land use module") and a newer version ("Updated land use module") that has parameters tuned to observed changes in cropland and harvested area in the U.S., Brazil, and other regions of the world.

GTAP-BIO Model Version	GTAP-BIO Economic Database (Baseline Year)	Ethanol Expansion (billion gallons)	Land Use Change Emissions (g CO_2e per MJ)	Reference
Untuned land use module	Version 7 (2004)	11.59 BG (3.41 to 15 BG)	13.4	a, b
Updated land use module			8.7	a, b
Untuned land use module	Version 9 (2011)	1.07 BG (13.93 to 15 BG)	23.3	a, b
Updated land use module			12.0	b

GTAP-BIO	Global Trade Analysis Project-biofuel model
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies model
g CO2e per MJ	gram carbon dioxide equivalent emissions per megajoule
BG	billion gallons

[a] Taheripour F, Cui H, Tyner WE. 2016. An exploration of agricultural land use change at the intensive and extensive margins: implications for biofuels induced land use change. In: Qin Z, Mishra U, Hastings A, editors. *Bioenergy and land use change*, pp.19-37. American Geophysical Union (Wiley).

[b] Taheripour F, Zhao X, Tyner WE. 2017. The impact of considering land intensification and updated data on biofuels land use change and emissions estimates. *Biotechnology for Biofuels* 10(1), pp.1-16.

In consideration of the preceding discussion and examples, we find strong evidence that current versions of iLUC models produce substantially lower estimates of GHG emissions compared to earlier versions of these same models used by USEPA in 2010 to prepare its estimate of iLUC impacts. **By relying only on its 2010 LUC analysis for the current rulemaking, the Agency is not giving due consideration to the best available science.** We encourage USEPA to consider recent LUC modeling tools, data, and/or results for purposes of the current rulemaking.

UNCERTAINTY OF LAND USE CHANGE ESTIMATES

The 2021 DRIA contains several statements regarding the uncertainty of LUC estimates for biofuels, characterizes the extent of that uncertainty as "considerable," and concludes that the Agency is unable to perform the extensive modeling needed to assess GHG effects of the

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[23] Taheripour et al. 2017.

proposed volumes.[24] **The Agency should consider alternative approaches for quantifying LUC impacts that would allow it to incorporate the best available science in lieu of conducting extensive new modeling for this rulemaking.**

As described by Plevin et al.,[25] both lack of knowledge about the correct model (model uncertainty) and the correct values for input parameters to a model (parameter uncertainty) contribute to uncertainty over the true but unknown value of LUC, especially iLUC. Similarly, the authors of a report issued by the International Civil Aviation Organization (ICAO) identify four main categories of uncertainty for iLUC analyses: (1) methodology, (2) model design, (3) data, and (4) parameters.[26] Descriptions of the types of uncertainty provide a useful framework for prioritizing research into its causes and resolution. Here, we comment on quantitative indicators of uncertainty about GHG impacts of iLUC demonstrated in the literature.

The literature demonstrates that current, widely used central estimates of iLUC impacts are of similar magnitude despite being the product of models with different methods, designs, data, and parameter values. In addition, our recent published review of the literature found that variability of central estimates of iLUC impacts has decreased over time.[27],[28] Several examples from the literature indicate that uncertainty about central estimates of iLUC impacts produced from different models and research teams are in reasonably good agreement with each other.

- Carriquiry et al. stated that contemporary iLUC estimates from FAPRI-CARD of 13 g CO_2e/MJ were in line with a contemporary estimate of 13 g CO_2e/MJ from GTAP-BIO.[29]
- iLUC central estimates from analyses conducted by European investigators with the MIRAGE model[30] and GLOBIOM model[31] agree to within 1 gCO_2e/MJ of each other, reporting 8 gCO_2e/MJ and 9 gCO_2e/MJ, respectively[32]
- Based on the preceding information, iLUC central estimates from MIRAGE and GLOBIOM are within 5 gCO_2e/MJ of the FAPRI-CARD and GTAP-BIO estimates referred to by

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[24] For example, see pp. 66 – 68.

[25] Plevin RJ, Beckman J, Golub AA, Witcover J, O'Hare M. 2015. Carbon accounting and economic model uncertainty of emissions from biofuel-induced land use change. *Environmental Science and Technology*, 49(5), pp.2656-26564.

[26] ICAO. 2019. CORSIA Supporting Document: CORSIA Eligible Fuels – Life Cycle Assessment Methodology, International Civil Aviation Organization, Montreal.

[27] Scully et al. 2021a.

[28] Scully et al. 2021b.

[29] Carriquiry et al. 2020.

[30] Laborde D, Padella M, Edward R, Marelli L. 2014. Progress in Estimates of iLUC With MIRAGE Model. Report EUR 27119 EN. European Commission Joint Research Center, Institute for Energy and Transport.

[31] Valin H, Peters D, van den Berg M, Frank S, Havlik P, Forsell N, Hamelinck C. 2015. The Land Use Change Impact of Biofuels Consumed in the EU. Ref. Ares(2015)4173087 – 8/10/2015, ECOFYS, Utrecht.

[32] Original values adjusted to a 30-year averaging period to be comparable to the results from GTAP-BIO and FAPRI-CARD.

Carriquiry et al. (2020). Notably, the MIRAGE results provide the scientific basis for European Commission policy on GHG emissions from iLUC associated with biofuels from corn and cereal grains.[33],[34]

- Separate analyses of iLUC impacts of sustainable aviation fuel produced from corn starch ethanol conducted with GLOBIOM and GTAP-BIO produced identical results.[35],[36]

While more research would be helpful to refine model parameters and data further, the distribution of uncertainty around central estimates of iLUC is reasonably well characterized in the literature. The Agency and others have used Monte Carlo and similar simulation methods to characterize the effects of parameter uncertainty on estimated iLUC impacts.[37],[38] These analyses report distributions of uncertainty about iLUC estimates for corn ethanol that are approximately symmetric or moderately right skewed with a coefficient of variation of approximately 20%. Other studies have conducted uncertainty analyses with the aim of determining the relative influence of individual parameter uncertainty on overall uncertainty.[39] Those studies show that iLUC uncertainty is dominated by lack of knowledge about crop yield elasticity with respect to price (YDEL). Experts disagree on the 'correct' value and there likely is no single true value for YDEL around the globe or over time.[40] Model developers have addressed this uncertainty in part by developing values for YDEL and other parameters for distinct geographic regions of the world.[41] Nonetheless, uncertainty about key model parameters remains and some analysts have suggested that these uncertainties will not be resolved in the foreseeable future.[42] Thus, we encourage the Agency to support continued refinement of iLUC model parameters, but not let uncertainty deter it from using the best available science to derive a current central estimate of iLUC impacts. In fact, in the 2010 RIA, the Agency relied upon a central estimate of iLUC for rulemaking and related policy despite the uncertainty characterized in its own analysis.[43]

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[33] Directive (EU) 2015/1513 of the European Parliament and of the Council of 9 September 2015 amending Directive 98/70/EC relating to the quality of petrol and diesel fuels and amending Directive 2009/28/EC on the promotion of the use of energy from renewable sources. Official Journal of the European Union. L 239/1.

[34] Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources. Official Journal of the European Union. L 328/82.

[35] ICAO. 2019.

[36] Zhao X, Taheripour F, Malina R, Staples M, Tyner W. 2021. Estimating induced land use change emission for sustainable aviation biofuel pathways. *Science of the Total Environment*, 779, pp.146238.

[37] USEPA 2010 Final Rule, Table V.C-5.

[38] Laborde et al. 2014.

[39] Plevin et al. 2015.

[40] Plevin et al. 2015.

[41] For example, Taheripour et al. 2017.

[42] Hertel TW, Tyner WE. 2013. Market-mediated environmental impacts of biofuels. *Global Food Security*, 2(2), pp. 131-137.

[43] USEPA 2010 RFS2 RIA.

Given the availability of numerous estimates of iLUC from generally accepted or commonly used models, we believe the Agency could conduct a systematic review of the literature to derive an updated central estimate of iLUC-related GHG emissions for the proposed rulemaking. Scully et al.[44] and Lewandrowski et al.[45] provide examples of authoritative reviews of the LUC literature that the Agency could build upon to conduct its own systematic review of central estimates for iLUC of corn ethanol and the associated uncertainty.

THE AGENCY'S ILLUSTRATIVE SCENARIO

In this section, we comment on the illustrative scenario for GHG impacts that is presented in the 2021 proposed rule and DRIA published by the Agency. On page 68 of the DRIA, the Agency states "This scenario is not EPA's assessment of the likely greenhouse gas impacts of this proposed rule" but instead "an illustrative scenario of the GHG impacts of biofuel consumption following the implementation of the proposed standards." **We encourage the Agency to evaluate the premise of its illustrative scenario in light of available U.S. corn and ethanol production data.**

As described in the DRIA, the illustrative scenario uses corn starch ethanol consumption of 12.5 billion gallons in 2020 as the baseline condition. This baseline reflects a 13% reduction in ethanol consumption due to the pandemic, compared to the average of the prior five years.[46] The scenario assumes that ethanol consumption increases by 953 million gallons to 13.453 billion gallons in 2021 and increases by an additional 335 million gallons to 13.788 billion gallons in 2022. Data published by the DOE Energy Information Agency (EIA) report that actual U.S. fuel ethanol consumption in 2020 was 12.7 billion gallons, which is 0.2 billion gallons higher than the baseline in EPA's illustrative scenario.[47] EIA data indicates that U.S. fuel ethanol consumption is likely to be approximately 13.8 billion gallons in 2021, in good agreement with the Agency's scenario for total consumption in 2021.[48] As shown in Table 5, the Agency's estimates of ethanol fuel consumption in 2021 and 2022 are lower than consumption reported by EIA for 2015 – 2019, the five year period preceding the COVID-19 pandemic. These data indicate that existing U.S. ethanol production capacity is sufficient to meet the demand projected by the Agency.

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[44] Scully et al. 2021a.

[45] Lewandrowski J, Rosenfeld J, Pape D, Hendrickson T, Jaglo K, Moffroid K. 2019. The greenhouse gas benefits of corn ethanol – assessing recent evidence. *Biofuels* 11(3), pp. 361-375.

[46] We calculated this 13% by comparing the average consumption between 2015 and 2019 with the 12.5 billion gallons of the USEPA baseline.

[47] U.S. Department of Energy, Energy Information Administration. Total Energy, Table 10.3 Fuel Ethanol Overview. https://www.eia.gov/totalenergy/data/browser/?tbl=T10.03#/?f=M.

[48] Ibid.

Table 5 Annual U.S. Ethanol Production, 2015 – 2021[a]

Calendar Year	Fuel Ethanol Production (Billion gallons)	Fuel Ethanol Consumption (Billion gallons)
2015	14.8	13.9
2016	15.4	14.4
2017	15.9	14.5
2018	16.1	14.4
2019	15.8	14.6
2020	13.9	12.7
2021*	14.7	13.8

* Ethanol data for the missing 2021 Q4 was estimated as a function of consumption in Q1, Q2,and Q3.

a U.S. Department of Energy, Energy Information Administration. Total Energy, Table 10.3 Fuel Ethanol Overview. https://www.eia.gov/totalenergy/data/browser/?tbl=T10.03#/?f=M.

Similarly, records from USDA show that domestic corn feedstock production is also sufficient to meet the increase in demand for 2021 and 2022 contained in the Agency's illustrative scenario. As shown in Table 6, U.S. corn production for ethanol during the four market years[49] (2015 – 2018) that preceded the COVID-19 pandemic ranged from 5.2 – 5.6 billion bushels.[50],[51] Production dropped to 4.9 billion bushels in market year 2019 and increased to 5.0 billion bushels in market year 2020, still below production levels for market years 2015 – 2018. Based on yield of 2.85 gallons of ethanol per bushel,[52] we estimate that 0.12 billion bushels of corn production are required to produce the additional 953 million gallons projected for 2021 in the Agency's illustrative scenario. An increment of 0.12 billion bushels on top of the 4.9 billion bushels produced in market year 2019 (total of 5.02 billion bushels) or on top of the 5.0 billion bushels produce in market year 2020 (total of 5.12 billion bushels) are both approximately 7% lower than average production during the four years that preceded the COVID-19 pandemic.

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[49] A market year is defined as September 1 – August 31. For example, market year 2018 is September 1, 2018 – August 31, 2019, which preceded the COVID-19 pandemic. Market year 2019 is September 1, 2019 – August 31, 2020, which includes approximately the first 6 months of the COVID-19 pandemic. All of market year 2020 occurred during the COVID-19 pandemic.

[50] US Department of Agriculture (USDA), Economic Research Service. Feed Grains Custom Query. https://data.ers.usda.gov/FEED-GRAINS-custom-query.aspx.

[51] USDA, Farm Service Agency. Crop Acreage Data. https://www.fsa.usda.gov/news-room/efoia/electronic-reading-room/frequently-requested-information/crop-acreage-data/index.

[52] Argonne National Laboratory. The Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies Model. 2021.

Table 6 Annual U.S. Corn Production, Market Years 2015 – 2020[a,b]

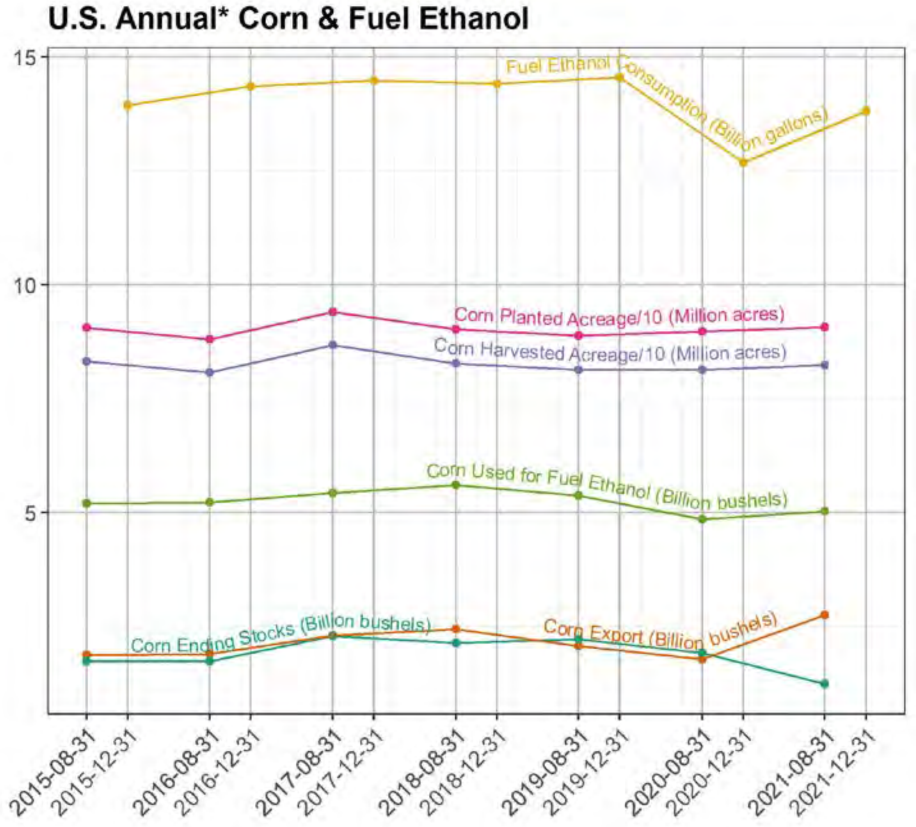
Market Year*	Corn Production (Billion bushels)	Corn Used for Fuel Ethanol (Billion bushels)	Corn Export (Billion bushels)	Corn Planted Acreage/10 (Million acres)	Corn Harvested Acreage/10 (Million acres)
2015	13.6	5.2	1.9	8.8	8.1
2016	15.1	5.4	2.3	9.4	8.7
2017	14.6	5.6	2.4	9.0	8.3
2018	14.3	5.4	2.1	8.9	8.1
2019	13.6	4.9	1.8	9.0	8.1
2020	14.1	5.0	2.8	9.1	8.2

* The U.S. corn market year runs from September 1 of the listed year to August 31 of the following year.

[a] US Department of Agriculture (USDA), Economic Research Service. Feed Grains Custom Query. https://data.ers.usda.gov/FEED-GRAINS-custom-query.aspx.

[b] USDA, Farm Service Agency. Crop Acreage Data. https://www.fsa.usda.gov/news-room/efoia/electronic-reading-room/frequently-requested-information/crop-acreage-data/index.

As shown in Figure 2, cropland acreage planted and harvested for corn has remained stable since 2015, including during the pandemic. These data suggest that the ethanol volumes proposed by the Agency for 2021 were met by existing U.S. corn production capacity and that the same corn production capacity will meet the volumes proposed for 2022.



Source: U.S. Department of Agriculture - Economic Research Service &
U.S. Energy Information Administration
*End of the market/calendar year values

Figure 2 Trends in Annual U.S. Corn and Fuel Ethanol Production

In consideration of these data, we encourage the Agency to evaluate whether the proposed volumes for corn ethanol contained in the illustrative GHG scenario of the DRIA are likely to induce LUC and generate the estimated GHG impact presented in the 2021 DRIA. We emphasize LUC impacts since historically this effect has been estimated to be a major contributor of GHG emissions of corn ethanol. In the Agency's illustrative scenario, iLUC contributes over 92% of the estimated GHG emissions in the first year.[53] In brief, we encourage the Agency to reconsider the validity and usefulness of the illustrative scenario.

Given (1) the limitations of the Agency's illustrative scenario, (2) its stated inability to carry out an in-depth uncertainty analysis of LUC impacts for corn ethanol at this time, and (3) the deviation between USEPA 2010 LUC results and the current best available science, we encourage the Agency to apply current central estimates of LUC produced by modeling efforts in the U.S. and Europe to the current proposed rule. Our prior work provides an example of an authoritative review of the literature that the Agency could build upon to determine its own current best central estimate of iLUC and total GHG emissions of corn ethanol.[54],[55]

CONCLUSION

We thank the Agency for this opportunity to comment on the proposed RFS rule. Throughout this letter, we have discussed improvements of data and models that estimate emissions from land use change associated with corn ethanol. We encourage the Agency to incorporate these refined data and advanced models into the calculations that determine GHG impacts and thus inform the proposed volume standards for biofuels. By relying only on its 2010 analysis for the current rulemaking, the Agency is not giving due consideration to the best available science. As noted previously, our published research concludes that assessments of GHG intensity for corn ethanol have decreased by approximately 50% over the prior 30 years and converged on a current central estimate value of approximately 51 gCO2e/MJ. Even if EPA intends to solicit additional data and analysis in its forthcoming workshop on LCA, this is not a reason to continue to rely on outdated information. There is sufficient updated information available for EPA to adopt, at least on an interim basis, a carbon intensity estimate that is closer to current central estimates and relies on the current state of the science.

Enclosures
Attachment A—Downward Trend in Land Use Change GHG Estimates

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[53] USEPA Lifecycle Greenhouse Gas (GHG) Emissions Results Spreadsheets (30 October 2008). Docket: EPA-HQ-OAR-2005-0161.

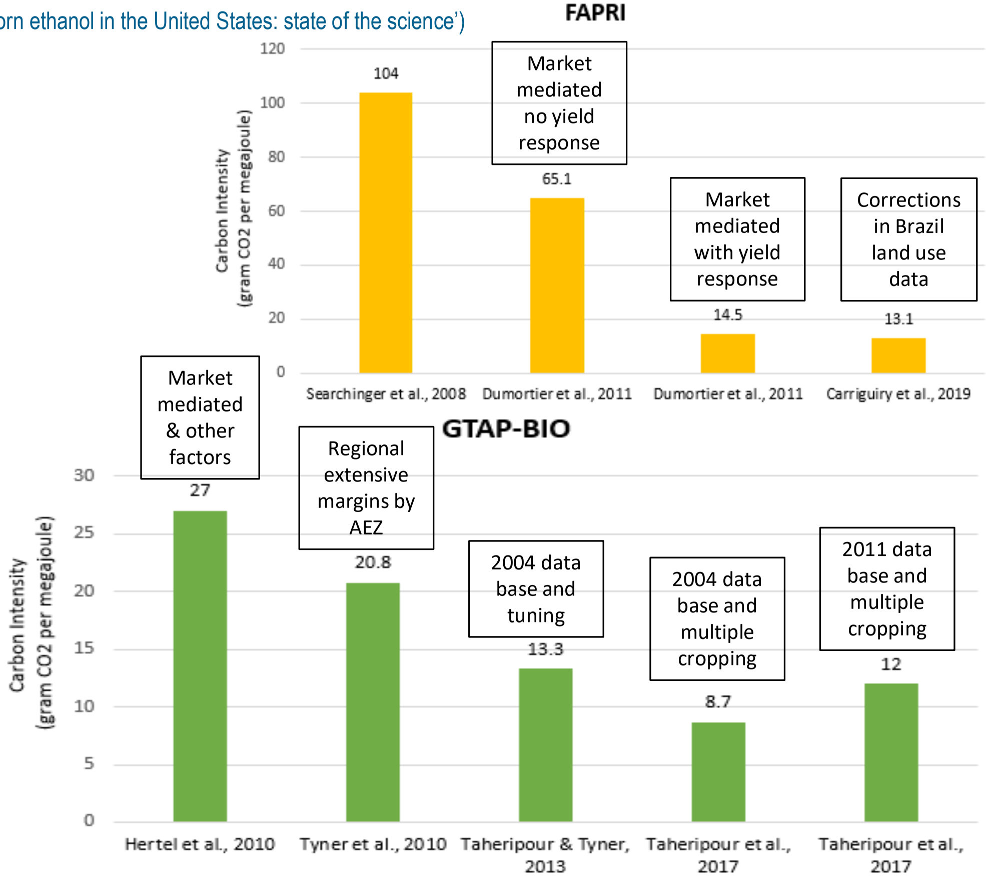
[54] Scully et al. 2021a.

[55] Scully et al. 2021b.

Attachment A
Downward Trend in Land Use Change GHG Estimates

"The concept of an observed downward trend in corn ethanol LUC modeling is not novel and we are not the first to acknowledge it" (Scully et al 2021. Reply to Comment on 'Carbon intensity of corn ethanol in the United States: state of the science')

- **Lewandrowski et al (2019):** "across studies, estimates of corn ethanol-driven iLUC emissions trend down over time"
- **Malins et al (2020):** "various academic and working papers have, however, tended to decrease iLUC emissions compared to previous estimates"
- **Lee et al (2019):** "the downtrend in simulated LUC emissions is a result of better developed and calibrated economic models and better modeling of GHG emissions from LUC"
- **Taheripour et al (2021):** "reduction in land use emissions due to model and data improvements," which "is not limited to the GTAP-BIO model but is a common finding of the literature."
- **Carriquiry et al (2019):** "The addition of detailed modeling in Brazil, e.g., double-cropping, reduced estimates considerably and highlights the importance of continuous improvements in global agricultural models."



Charts reproduced from Taheripour et al 2021. Supplementary information to Response to 'How robust are reductions in modeled estimates from GTAP-BIO of the indirect land use change induced by conventional biofuels?'

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 2

Review of GHG Emissions of Corn Ethanol under the EPA RFS2

LCA.8120.200.2022
4 February 2022

Life Cycle Associates

Prepared by:
Stefan Unnasch

DISCLAIMER

ACKNOWLEDGEMENT

Life Cycle Associates, LLC performed this study under contract to Growth Energy.

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CONTENTS

TABLES

FIGURES

TERMS AND ABBREVIATIONS

aLCA	Attributional Life Cycle Analysis
ANL	Argonne National Laboratory
ARB	California Air Resources Board
CA	California
CA-GREET	The standard GREET model modified for use in CA LCFS
CH_4	Methane
CI	Carbon intensity
cLCA	Consequential Life Cycle Analysis
CO	Carbon monoxide
CO_2	Carbon dioxide
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
g CO_2e	Grams of carbon dioxide equivalent
GHG	Greenhouse Gas
GREET	The Greenhouse gas, Regulated Emissions, and Energy use in Transportation model
GWP	Global Warming Potential
HC	Hydrocarbon
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis or Life Cycle Assessment
LCFS	Low Carbon Fuel Standard
LCI	Life Cycle Inventory
LCFS	Low Carbon Fuel Standard
LHV	Lower Heating Value
N_2O	Nitrous oxide
NG	Natural Gas
RIA	Regulatory Impact Analysis
RFS2	Revised Federal Renewable Fuels Standard
UN	United Nations
UNFCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound
WTT	Well-To-Tank
WTW	Well-To-Wheel

EXECUTIVE SUMMARY

Twelve years of experience and improved analysis methods have provided new insight into the life cycle greenhouse gas (GHG) emissions from corn ethanol. This study reviews the key factors that affect the life cycle emissions from corn ethanol production as well as the most recent agricultural data. Some of the key factors affecting corn ethanol have evolved as predicted in EPA's 2010 Regulatory Impact Analysis (2010 RIA), while other factors point towards substantially lower life cycle GHG emissions.

EPA developed a consequential LCA approach that estimated the emissions associated with the incremental ethanol capacity induced by the RFS policy as well as the incremental crop production required to make up for the net effect of corn crops diverted to ethanol production and distiller's grains sold as animal feed. The modeling approach involved a combination of the FASOM model that has been used to develop the U.S. inventory for agricultural emissions, the FAPRI model, which estimates the effect of the use of agricultural products on global agricultural production, and the GREET model, which estimates life cycle GHG emissions from the fuel used in ethanol plants. EPA's analysis aligned the economic modeling of the FASOM and FAPRI modeling and calculated emission impacts that are tied to the model predictions including changes in rice and beef consumption as well as deforestation associated with new crop production.

The 2010 RIA overestimated the GHG impact of corn ethanol due largely to overestimating indirect land use conversion (ILUC) emissions as well as numerous small details associated with the life cycle of corn ethanol. EPA's agro-economic models rely on economic projections to attribute land use change to crop production without considering factors such as changes in farming and cattle production practices. Recent data on deforestation has shown that land ownership is much more important in affecting deforesting than the macro-economic pressure or crop prices. Burning in the Amazon has declined and increased due to policies associated with land ownership. A more accurate representation of the effect of crops on pasture conversion is represented in more recent publications based on the GTAP model and EPA would generate similar results if its ILUC modeling tools included an accurate representation of factors such as flexibility in changing cattle stocking rates. The analysis inputs to GTAP modeling would yield similar results in the FASOM/FAPRI modeling system. If EPA continues to use the FAPRI results for its international LUC analysis, the results could be scaled to reflect the values from GTAP that more accurately represent the interaction between pasture and cropland.

Several other factors affecting corn ethanol have also changed since the publication or the 2010 RIA. Corn ethanol uses about 0.7 kWh to produce one gallon of ethanol and the GHG intensity of electric power has declined substantially with increased natural gas production, a reduction in coal-based power, and growth in renewable power. The RIA also underestimated the adoption of low emission technologies that have resulted in lower emissions from ethanol plants and many small details associated with each step of the ethanol life cycle.

More significantly, EPA underestimated the effect of distiller's grains and corn oil. Much of the corn used for ethanol production has resulted in the displacement of soybean production. The same acre of land that was producing soybeans and converted to corn for ethanol produces the same amount of feed via the distiller's grains from the ethanol plant. Therefore, any change in net feed requirements is subtle at best. The GREET model also underestimates the displacement effect of both soybeans and urea that would otherwise be fed to cattle. Even though soybeans fix nitrogen[1], USDA data shows that they have required more nitrogen fertilizer than projected in the RIA. Also, the emissions associated with urea feed in the GREET model omit the displacement of fossil carbon[2] in urea. Corn ethanol plants have produced significant quantities of corn oil as predicted in the 2010 RIA. However, about half of the corn oil is used as biodiesel which corresponds to about 2.5% of the energy output of an ethanol plant. The GHG emissions associated with corn production and any ILUC should be partially assigned to biodiesel.

These factors should be incorporated in EPA's GHG analysis of corn ethanol in this 2020, 2021, 2022 Renewable Volume Obligation (RVO) rulemaking, including the following considerations:

- ILUC and soil carbon storage should reflect the latest research.
    - ANL soil carbon storage modeling (CCLUB) shows increased soil carbon storage with corn farming that was not taken into account in the 2010 RIA.
    - New analysis based on the GTAP shows the effect of pasture intensification which predicts lower rates of forest conversion to agriculture.
    - CARB revised ILUC for LCFS from 30 g CO_2e/MJ to 19.8 g CO_2e/MJ with the newest GTAP results showing 7.5 g CO_2e/MJ.
- The FASOM and FAPRI modeling system predict effects that are not tied to ethanol use and should be corrected.
    - The latest data and science demonstrate that deforestation rates occur due to many factors and the supply and demand of agricultural products has little effect on this phenomenon.
- Co-product credit value of distillers' grain solubles (DGS) is higher than anticipated due to:
    - Greater emissions from the displacement of soybean meal;
    - Higher nitrogen (N) application rate on soybeans than originally anticipated;
    - Displacement of fossil CO_2 in urea feed.
- A high adoption rate of corn oil extraction has led to the rapid growth in use of corn oil as biodiesel feedstock.
    - The preferred use of corn oil is biodiesel; so, the appropriate co-product treatment for 50% of the corn oil is as an energy product via allocation.

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[1] Soybeans and other legumes assimilate nitrogen from the atmosphere into organic compounds through a process known as fixation.

[2] The GHG intensity of urea in the GREET model represents the life cycle emissions per ton of urea. The urea molecule includes carbon that is derived from natural gas. When urea is used as fertilizer or animal feed, the carbon is metabolized to produce CO_2. GREET counts the field emissions for urea when used as fertilizer but omits the emissions when it is used as a co-produce animal feed.

  - Corn oil when used as a biodiesel feed displaces fats such as soy oil and palm oil which have much higher indirect land use change (ILUC) values than corn oil when treated as DGS mass.
- Ethanol plants produce lower GHG emissions than estimated in the 2010 RIA due to:
  - Elimination of coal for dry mill plants with natural gas;
  - Lower carbon intensity for electric power used by ethanol plants;
  - Use of biogas motivated by California low carbon fuel standard (LCFS) program;
  - Ongoing efficiency improvements from many sources;
  - Utilization of CO_2 to displace fossil sources and CO_2 sequestration.
- 2005 Petroleum baseline in the 2010 RIA is underestimated because the baseline fails to adequately account for:
  - Higher rates of methane venting and flaring from oil production;
  - Mix of secondary oil recovery technologies and oil sands.

This study found that corn ethanol has resulted in greater GHG emission reductions compared to those originally predicted in the 2010 RIA. The results for dry mill corn ethanol plants from this Study (Figure S.1) are aligned with the approach in the 2010 RIA. The emissions are based on GREET calculations and adjustments to reflect EPA's categories with projections for energy use in 2022 developed in this study. The emissions include allocation of half of the GHG emissions associated with corn oil to biodiesel. Higher nitrogen application rates for soybean farming, which affect the DGS co-product credit as well as fossil carbon displaced in urea feed are also considered in the analysis. The lower carbon intensity of electric power compared to 2010 projections is reflected in fuel production emissions. The small effect on rice methane and livestock emissions is based on the recent study funded by the U.S. Department of Agriculture by ICF (Rosenfeld, 2018). These results compared with appropriate adjustments to EPA's 2005 baseline translate into about a 48% reduction in GHG emissions as shown in Figure S.1.

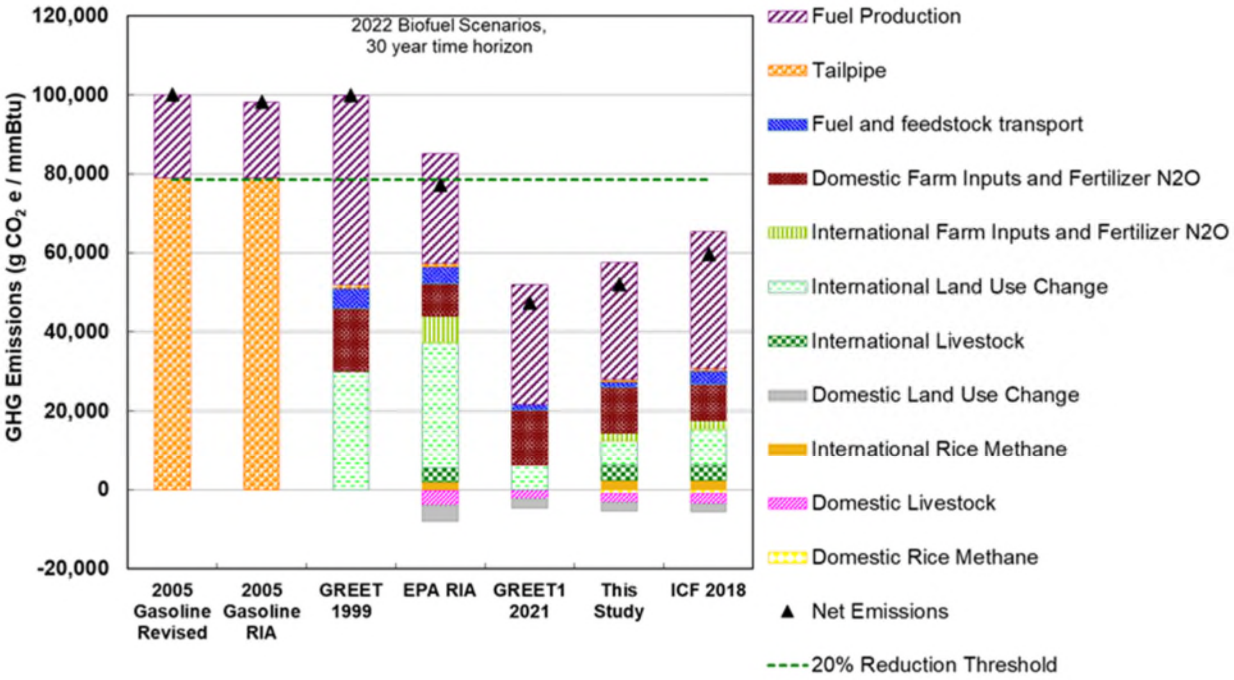

Figure S.1. Life Cycle GHG Emissions from Dry Mill Corn Ethanol and 2005 Petroleum Gasoline.

1. INTRODUCTION

As part of EPA's 2010 Regulatory Impact Analysis (2010 RIA) of the Renewable Fuel Standard (RFS), it conducted a life cycle assessment (LCA) of the biofuels specified in RFS2 by accounting for direct and indirect emissions for the year 2022. The 2010 RIA identified 11 emission sources which capture the full life cycle GHG profile of corn ethanol and compared these emissions with those of gasoline (Figure 1.1). The highest GHG emissions for corn ethanol correspond to international land use change (LUC) followed by Fuel Production. International LUC corresponds to the change in carbon associated with the growth of new crops outside the U.S. EPA estimated that these emissions include the release of soil carbon and avoided carbon storage from forest and pastureland when these lands are converted to cropland. The landcover change is predicted with the FAPRI model and is combined with carbon stock factors developed by Winrock International. Fuel production emissions include the emissions associated with natural gas combustion as well as upstream natural gas and electric power. International farm inputs and N_2O correspond the crop farming activity required to make up for changes in U.S. farm exports. The modeling system estimated the effect of expansion in corn production.

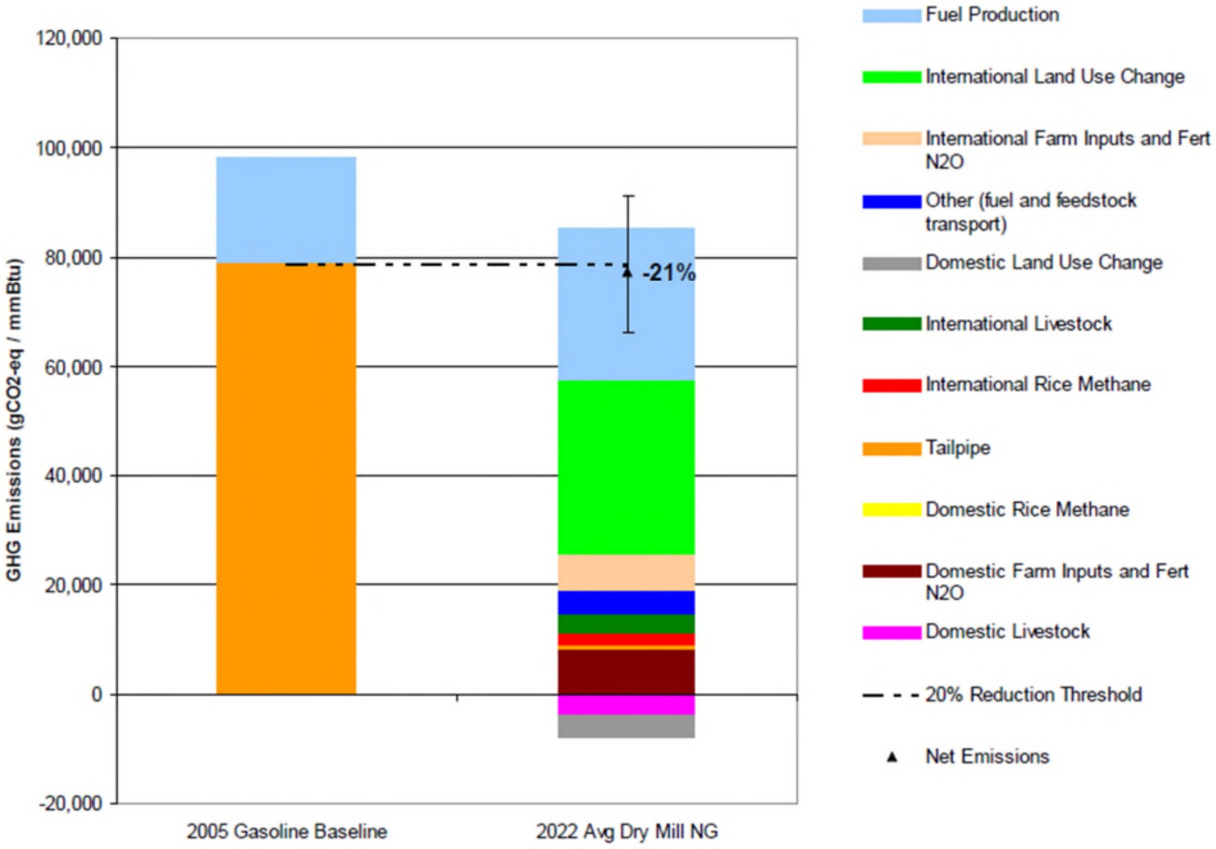

Figure 1.1. EPA's Analysis of Corn Ethanol GHG emissions. (EPA, 2010)

The objective of this study is to evaluate EPA's analysis based on the availability of new data and a better understanding of models and assumptions. This study focuses on emission categories with the highest impacts such as international land use change and compares the results of 2010 RIA with the new findings. Another key effect examined in the study is the impact of co-product credits and different methods of allocation. The study includes the following sections.

- Sections 1.1 to 1.4 provides an introduction to corn ethanol life cycle GHG emissions.
- Section 2 presents domestic and international land use change and their impacts on corn ethanol carbon intensity.
- Section 3 discusses farming inputs and the sensitivity analysis.
- Section 4 presents the impact of different co-products and their allocation factors on corn ethanol carbon intensity.
- Section 5 describes technologies used in ethanol production and their advancements.
- Section 6 analyzes the energy sources used in the fuel production stage.
- Section 7 describes the GHG emissions related to various types of extraction of fossil fuels and their projection.
- Section 8 presents the results of this study and compares them with those of other studies and EPA RIA.
- Finally, Section 9 summarizes this Study's conclusions.

1.1 Life Cycle GHG Analysis

The RFS2 and other biofuel policies around the world require GHG reduction targets relative to the conventional fossil fuels. The GHG reduction is measured through life cycle assessments (LCAs), which account for cradle-to-grave emissions (and/or other environmental impacts), starting with raw material extraction and ending with fuel consumption. LCA is a technique used to model the environmental impacts associated with the production of materials. LCA models assess environmental impacts over a range of categories, including energy consumption, GHG emissions, criteria air pollution, eutrophication, acidification, water use, land use, and others. The analysis includes a full inventory of all the inputs and outputs involved in a product's life cycle. Determining life cycle emissions for all inputs requires an iterative analysis of these components because some components of the life cycle of fuels depend on inputs that are part of the LCA. The net GHG emissions are converted to a CO_2-equivalent basis and then normalized by the energy content of the fuel (e.g. g CO_2e/MMBtu). This carbon intensity (CI), when compared with the CI of petroleum fuels, provides a measure of the net GHG reductions of renewable fuels.

In the case of corn ethanol, with the U.S. the largest producer of corn in the world, the hypothesis is that diverting corn to biofuel feedstock reduces the supply of corn in food and feed markets. This effect is realized through increases in the price of corn and other agricultural commodities globally. In order to address the shift in corn supply, farmers across the globe switch from other crops to corn (direct land use change) or convert grasslands, wetlands, or forests which are carbon sinks to crop production. The conversion of land to cropland results in indirect land use change (ILUC) emissions due to the release of carbon in the soil, above ground biomass, and the foregone sequestration of CO_2. Two different approaches covering the extent of life cycle impacts are referred to as attributional and consequential LCA. Attributional LCA (aLCA) focuses on the direct processes used to produce and consume a product while consequential LCA (cLCA) examines the consequences of possible (future) changes between alternative product systems (Brander et al., 2009). An aLCA identifies the direct energy inputs and emissions associated with corn farming and ethanol production. A cLCA identifies the net change in global emissions due to induced impacts of corn consumption, energy inputs for ethanol plants, and ethanol use. The 2010 RIA is aimed at calculating cLCA emissions based on the displacement effect of corn diverted to ethanol production.

1.2 Land Use Change

The correlation between LUC and an expansion in biofuel is typically estimated with agro-economic models. Economic models that simulate market behavior (particularly those in the agricultural sector) are often linked to predict the location of land cover change and the emissions associated with conversion to crops as illustrated in Figure 1.2

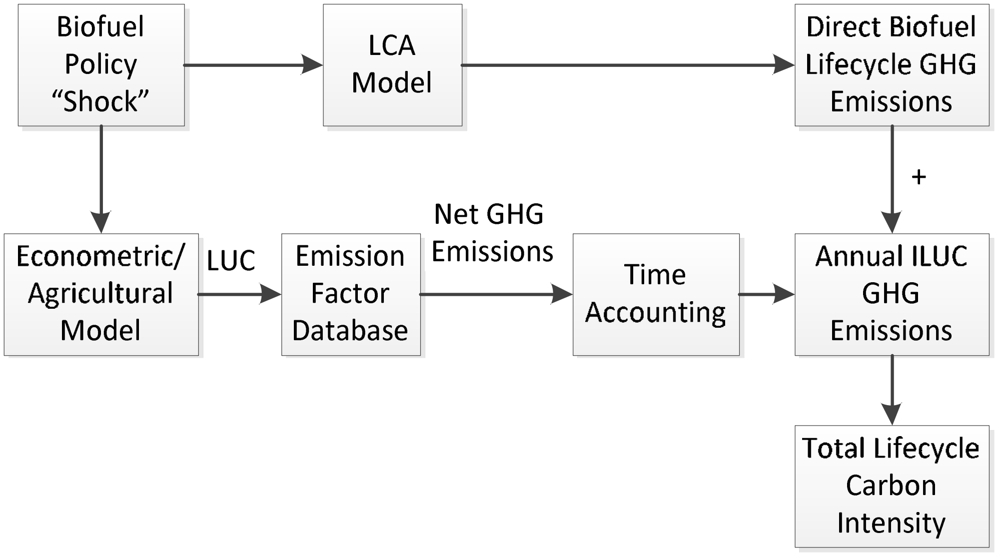

Figure 1.2. Modeling Flow for Determination of Total Biofuel Lifecycle Carbon Intensity, Including Both Direct and Indirect Effects.

1.3 Modeling Approaches

The system boundary defines the scope of activities and emissions associated with a life cycle analysis. The inputs to the system and emission flows are counted in the analysis are defined in a system boundary diagram (SBD). The system boundary identifies how far emissions are tracked and the treatment of co-products.

1.3.1 Approach for Revised GHG Analysis

This study combines new data on corn ethanol production with the methods used by EPA in the RIA to develop a revised estimate of the GHG emissions associated with corn ethanol. Repeating the details of the modeling in the RIA is not practical due to the complexity of the FASOM and FAPRI modeling systems. This study estimated the emission categories within the 2010 RIA methodology based on energy inputs and co-product yields thereby allowing for a comparison with the 2010 RIA results.

The system boundary used in this study is shown in Figure 1.3. Ethanol and corn oil for biodiesel are fuel products. Corn oil is also used as animal feed as modeled in the 2010 RIA but current fuel policies favor the use of corn oil as a biodiesel feedstock. Fermentation CO_2 is another coproduct for many ethanol plants. This study compares data on corn production, ethanol inputs and ethanol plant yields with those in the 2010 RIA and then estimates emissions for each of the RIA categories based on the best available data. The effect of each of the co-products on the net life cycle emissions is examined here.

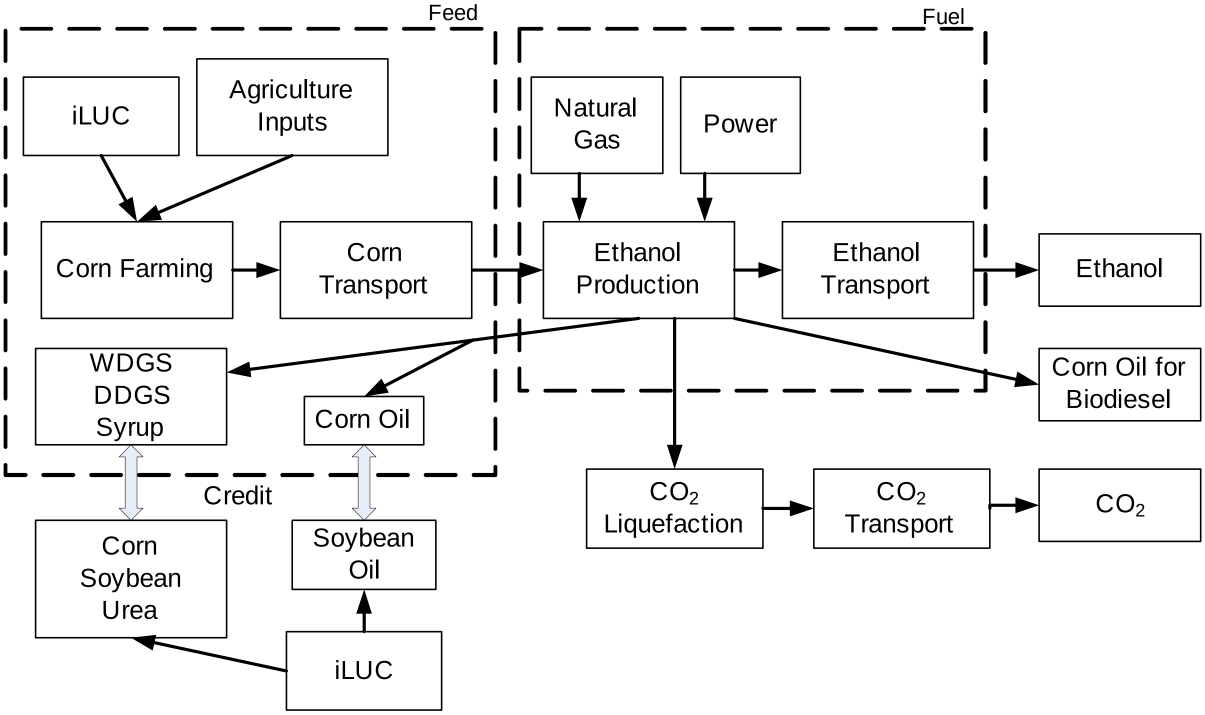

Figure 1.3. System Boundary Diagram for Corn Ethanol Production.

1.4 Global Warming Potential

The global warming potential (GWP) represents GHG emissions based on their radiative forcing and lifetime in the atmosphere on equivalent units of carbon dioxide (CO_2). These factors are estimated by the Intergovernmental Panel on Climate Change (IPCC) and updated in each IPCC Assessment Report (AR). The 2010 RIA used the factors provided by the IPCC's Second

Assessment Report (SAR), however, these factors have been updated since 2010 and the most recent one is the Fifth Assessment Report (AR5) shown in Table 1.1 (IPCC, 2014). This study uses the AR4 factors to calculate the CI of fuels since these values are currently adopted by the EPA for calculations of the national GHG inventory.

Table 1.1. Global Warming Potential (100-year time horizon).

Greenhouse Gas	SAR	AR4	AR5
CO_2	1	1	1
CH_4	21	25	28
N_2O	310	298	265

2. DOMESTIC AND INTERNATIONAL LAND USE CHANGE

Since 2010 when EPA conducted the RIA, new findings and data on actual deforestation across the globe, crop prices, soil organic carbon stocks, corn and ethanol yields have shown that the 2010 RIA overestimated the contribution of LUC towards the CI of corn ethanol. The 2010 RIA's approach, as well as new studies on LUC, are discussed below. EPA's approach to ILUC modeling, improved ILUC estimates, and the estimates used in this study are discussed.

2.1 EPA RIA Approach for Land Use Change

The 2010 RIA takes into account the incremental change of diverting corn crops to biofuel production. The modeling attempts to answer the question: what would change if U.S. ethanol use increased to 15 billion-gallon per year[3] while holding constant the consumption of food. Both the incremental farming inputs as well as the incremental effects of land conversion on crops were estimated through macroeconomic modeling.

2.1.1 EPA Modeling Approach

The system boundary used in 2010 RIA is shown in Figure 2.1. The analysis includes the direct emissions associated with tailpipe emissions, fuel production, fuel and feedstock transport. The carbon in fuel is treated on a carbon neutral basis with zero emissions associated with the short cycle carbon in ethanol and ethanol plant fermentation emissions. The effects of the corn feedstock are analyzed in a cLCA with estimates of the effects of an incremental increase in the use of ethanol and consumption of corn. The modeling takes into account the direct farming emissions in the U.S. and internationally as well as the effect on rice and livestock methane emissions due to shifts in the production of agricultural products. The U.S. emissions are predicted with the FASOM model and the international crop production is predicted with the FAPRI model combined with emission factors for land cover change and agricultural inputs.

The 2010 RIA also includes the indirect farming emissions associated with new crops in addition to LUC. This method is intended to represent the replacement crop inputs as well as land use conversion.

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[3] EPA 2010 RIA, Section 1.1.1.1

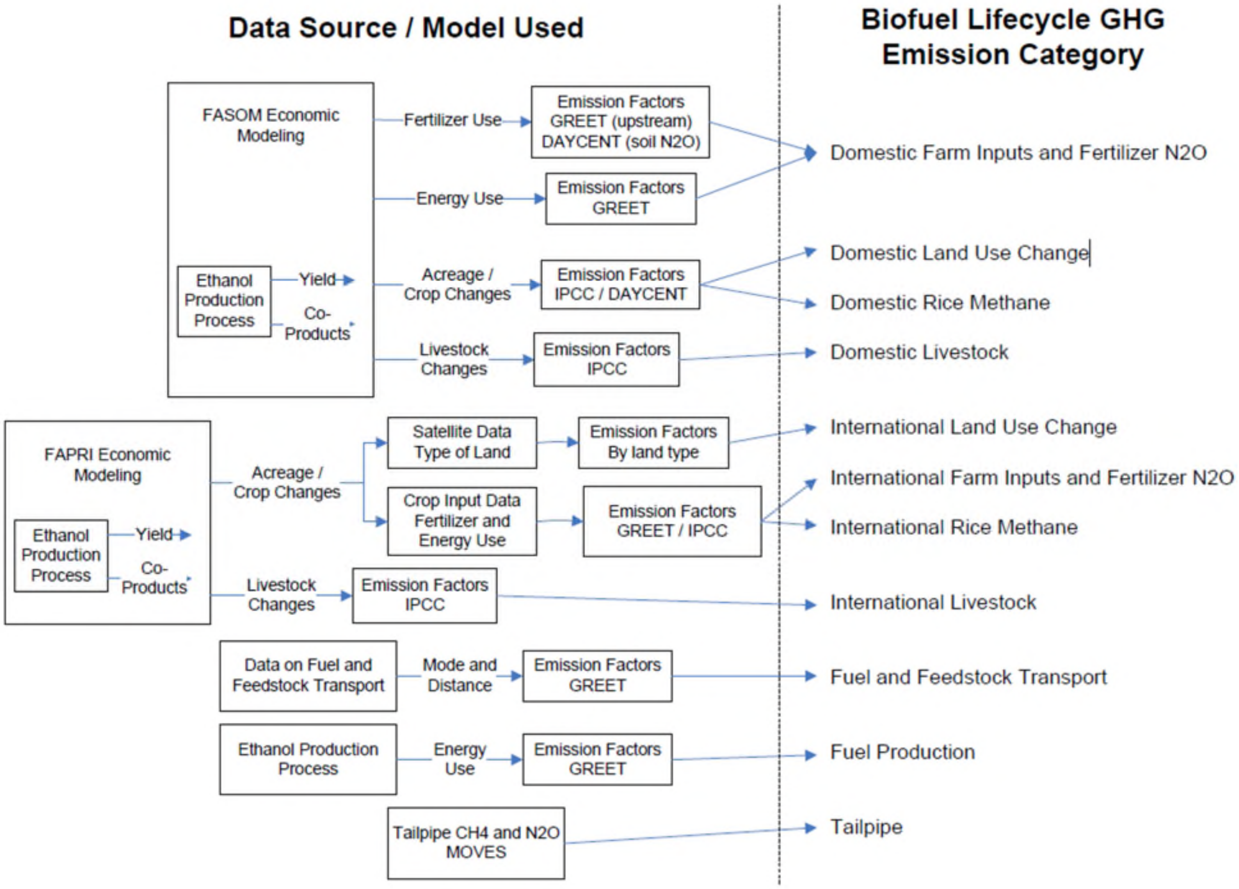

Figure 2.1. System Boundary Used in EPA RIA Study. (EPA, 2010)

For the purposes of discussion in this study direct and indirect land use change are described separately.[4] Direct land use change refers to land already used for a specific purpose (e.g. growing food) and whose future use will achieve the same result. For instance, in response to an increase in production of corn ethanol, lands previously used for food production might be converted to corn for fuel. On the other hand, indirect land use change refers to the land whose ultimate purpose is essentially changed from its previous use (Farm Energy, 2019). For instance, converting forests or grasslands to agricultural land is called indirect land use change. The 2010 RIA aggregated the impacts of direct and indirect land use change in the U.S. and called it “domestic land use change.” Also, the RIA assumed international land use change occurred as a result of domestic biofuel production expansion.

EPA used the Forestry and Agricultural Sector Optimization Model (FASOM), developed by Texas A&M University and others, to estimate the changes in crop acres resulting from increased biofuel production. FASOM is a partial equilibrium model of the forest, agriculture,

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[4] Some argue that all LUC is indirect since corn used for biofuel production is diverted from the overall U.S. corn supply.

and livestock for the United States. The model tracks U.S. cropland by county and estimates emissions associated with the conversion to cropland (i.e. domestic land use change). Within the model, the linked agricultural and forestry sectors compete for a portion of the land within the U.S. Prices for agricultural and forest sector commodities as well as land are endogenously determined given demand functions and supply processes. The FASOM model maximizes the net present value of the sum of consumers' and producers' surpluses (for each sector) with producers' surplus estimated as the net returns from forest and agricultural sector activities. The GHG calculations are based on available data on inputs from crop budgets coupled with estimates from EPA, the IPCC, and the DAYCENT model developed by Colorado State University. The FASOM model also estimates the energy consumption, as well as fertilizer use, of crop production. The projection of farm inputs by FASOM was used in 2010 RIA to calculate the GHG emissions of corn ethanol in 2022. The model takes into account shifts among agricultural production including changes in livestock population due to changes in corn prices. The population provides the basis for estimating livestock methane emissions.

Since FASOM is only applicable for modeling the land use change within the U.S. (domestic LUC), EPA employed the integrated Food and Agricultural Policy and Research Institute international models, as maintained by the Center for Agricultural and Rural Development (FAPRI-CARD) at Iowa State University (as summarized in CRC, 2014), to estimate the changes in crop acres and livestock production by type and by country globally (international LUC) in the 2010 RIA. While FAPRI-CARD models how much cropland will change, it does not predict what type of lands such as forest or pasture will be converted. Therefore, EPA used Winrock International's data to estimate what land types are converted into cropland in each country (EPA, 2010). EPA also used the GTAP model and confirmed that the GTAP results were consistent with outputs of FASOM and FAPRI models. Since then, the GTAP model has undergone several revisions, but EPA has not compared its findings with the new results from the GTAP model.

FASOM also predicted that cultivation of corn increases the soil carbon storage while conversion of cropland pasture and forestland leads to more GHG emissions. Overall, the FASOM results showed that expanding corn cultivation resulted in carbon storage (negative value for domestic LUC). However, the results from FAPRI showed that production of 15 billion gallons of corn ethanol reduced the corn export from the U.S. which causes other countries to allocate more lands to corn cultivation and subsequently convert more pasture and forestland to corn farms which leads to more GHG emissions. Conversion of Brazilian forests to corn farming had the highest share from total emissions associated with international LUC under the methodology used in the 2010 RIA.

2.1.2 Challenges with 2010 RIA Land Use Change Analysis

While the direct emissions from ethanol production vary among the studies, the table below shows the large variability in estimates which are largely due to LUC. Early studies employed worldwide agricultural models to estimate emissions from land use change (Searchinger et al.,2008; Searchinger, et al., 2015; Fargione et al., 2008) with higher net GHG emissions for corn ethanol compared to gasoline.

More recent studies, (Hertel et al., 2010) found that the emissions associated with land use change were less than one-third of those projected by Searchinger (2008) and even smaller values of land use change effect were reported by Tyner et al. (2010). The inconsistency in indirect land use change predictions is mainly due to the differences in methods and assumptions. Key factors include elasticity factors that affect the selection of land cover change and carbon stocks. Further, some argue the modeled predictions of indirect land use change are not meaningful because there is not a causal relationship between biofuel use and land conversion (Zilberman et al., 2010). In the 2010 RIA, conversion of Brazilian forestland to corn farm had a significant contribution to the international LUC. However, new studies found that agricultural intensification and governmental policies and regulations have had a great impact on GHG emissions reduction as well as decreasing the deforestation in Brazil (Silva et al., 2018; Garrett et al., 2018). Brazil, for example, is seeking to reduce greenhouse gas (GHG) emissions by 37% below 2005 levels by 2025 and 43% by 2030 through its announced Nationally Determined Contribution (NDC). The role of agricultural intensification in response to increasing commodity prices was not fully considered in the 2010 RIA and therefore international LUC was over-estimated (Rosenfeld et al., 2018).

Table 2.1. Addressing Uncertainties in LUC Assessments

LCA parameter	Uncertainty	Recommendation
New LUC studies estimate lower emissions associated with international LUC.	LUC estimates vary greatly with model, structure, assumptions and target year.	While it is true that LUC modeling is greatly based on assumptions and model structure, we believe that after 10 years, with the availability of new data, we can see that most of those assumptions were not realistic. The current rate of deforestations, yield price elasticity, type of land being converted, etc. are not close to what EPA projected in 2010.
Soil C sequestration of corn is higher than what assumed in 2010 RIA.	The SOC data resulted from recent studies are inconclusive due to variation between studies and dependence on experiment duration.	Recent long-term studies on SOC in Midwest such as Poffenbarger et al. (2017) shows that corn farming results in a significant increase in SOC storage. Various practices such as no-tillage and optimum fertilization increases the SOC storage and more farmers are applying these practices now.

2.2 New Findings on Land Use Change

The emissions associated with LUC include the net accumulation of carbon, taking into account both the carbon release from land conversion and the foregone carbon sequestration. Figure 2.2 shows a simplified breakdown of the factors that affect the LUC presented by the CARB and modeled in GTAP. The significant differences between the GTAP modeling and the FASOM/FAPRI modeling include the carbon stock factors for released carbon as well as the regional detail for crop shifting. GTAP, for example, takes into account prior trade history between countries. All agro-economic models solve for prices that result in a supply and demand equilibrium. GTAP is a general equilibrium model that includes all sectors of the economy. FASOM and FAPRI are models including only agriculture and, in the case of FASOM, forestry. Those models are more detailed on individual agricultural commodities. All of the models project changes in land cover and predict changes in carbon stock through different carbon accounting mechanisms and carbon stock data sets. All of the modeling systems need to allocate emissions over time as they are predicting an initial “shock” of biofuel demand that is distributed over a period of biofuel production.

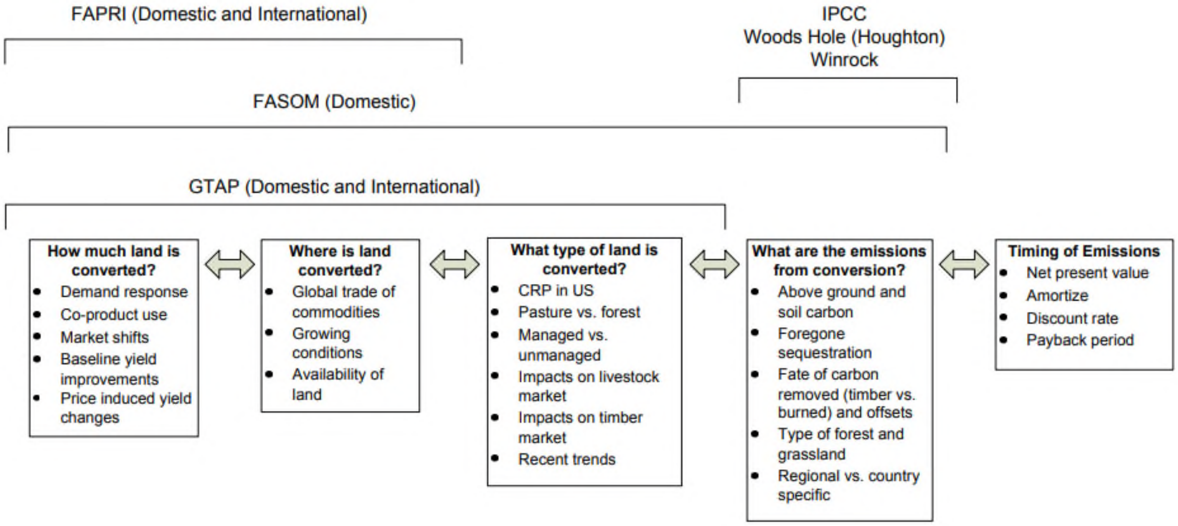


Figure 2.2. Approaches to LUC Modeling.
(CARB, 2018)

While the modeling represents the inputs to the GTAP system, the basic principles are the same for all LUC models. Improving crop yields, production of co-products, and high carbon stocks for converted lands reduce LUC emissions. The recent key findings for corn ethanol affecting LUC with GTAP have been:

- Low conversion of land in the U.S.;
- Increase in soil carbon storage due to corn farming practices;
- Overall decline in deforestation rates globally;
- High substitute value of Distillers' grain solubles (DGS) as feed;
- Increased cattle stock rate with pasture intensification;
- Corn oil producing biodiesel increases overall fuel output.

Since an acre of land producing corn for ethanol produces as much animal feed (i.e. DGS) as an acre of soybeans (soybean meal), the net LUC emissions in recent studies by ANL (Dunn, 2017), which are below 10 g CO_2e/MJ appear reasonable.

2.2.1 CCLUB and GTAP

LUC models also predict changing yields, both to the biofuel crop being examined as well as other crops grown globally. These yield improvements include both projected future improvements due to better farming practices (some of which may have nothing to do with an expansion in biofuels), as well as yield improvements that are due to higher prices sending a signal to the market to incentivize better farming practices, more efficient harvest, and technology improvements. Expanded use of crops for biofuels will also affect feed prices and shift the use of agricultural commodities. The production of DGS from corn affects feed markets. The removal of land from feed production will also result in market shifts due to price mediation. Higher corn prices, for example, could result in a shift from feedlot-fed cattle to other sources of meat that are less feed intensive. The effect of displacement by DGS as well as shifts in crop usage may be the most significant factor. Demand mediation or a reduction in the demand for feed and food also reduces the overall requirement for land. Another key LUC prediction is associated with cattle stocking rates on pasture as well as the selection of forest land, marginal land or grassland. These predictions affect the carbon stock factor for LUC.

2.2.2 Other Corn Ethanol Studies

Two studies conducted by ICF for the U.S. Department of Agriculture (USDA) examined the 2010 RIA. Each study calculated the CI of corn ethanol under different scenarios (Flugge et al., 2017; Rosenfeld et al., 2018). The studies investigated domestic and international land use change based on recent studies and models and concluded that both domestic and international land-use change emissions for corn ethanol are lower than those in the 2010 RIA. Moreover, their estimates of GHG emissions of fuel production stage as well as tailpipe were also lower than those in the RIA.

CARB has revised its estimation of international LUC (CARB, 2015) due mainly to using a newer version of GTAP with an updated database, re-estimating energy sector demand and supply elasticity values, the addition of cropland pasture to the U.S. and Brazil, improved treatment of corn ethanol co-product (DGS), improved treatment of soy meal, soy oil, and soy biodiesel, improved estimation of crop yield across the world, improved estimation of emissions factors, and revision of demand and yield responses to price, among other things. The reduction in estimated forest conversion is an important factor since the GHG emissions associated with conversion of forest is significant.

Argonne National Laboratory (ANL) and California Air Resource Board (CARB) developed GREET and CA-GREET models, respectively, which include the LCA for corn ethanol. CARB's estimates of ILUC have dropped from 30 g CO_2e/MJ to 19.8 g CO_2e/MJ based on refinements in modeling (Tyner, 2010) and the changing CI of ethanol in Table 2.2 reflects both the ILUC and mix of fuel production technologies. CARB's original modeling with GTAP assumed a 1:1 displacement of DGS with corn, but that has since been revised. Subsequent modeling has also taken into account the displacement of other agricultural products.

Table 2.2. Life Cycle Studies Examining Corn Ethanol.

Year	Study	Model/ Database	ILUC CI (gCO_2e/MJ)
2008	Searchinger et al. (2008)	FAPRI-CARD/GREET	100
2009	CARB	CA-GREET.8b/GTAP	30
2010	EPA RIA	GREET/FASOM/FAPRI	28
2018	ANL	CCLUB/GTAP/GREET	3.9 to 7.5
2017	Flugge et al. (2017)	FASOM/ FAPRI	8 to 14
2018	Rosenfeld et al. (2018)	GREET/IPCC/GTAP	7 to 14
2014	CARB[a]	CA-GREET2/GTAP	19.8
2021	Scully (2021)	Review of Models	3.9

[a] Average of approved pathways.

These models however, look backward at prior data crop expansion, yield, and land use data. Ten years of increased biofuel production in the United States allows for a revised assessment of the assumptions and results of the 2010 RIA.

2.2.3 Empirical Data

Showing the effects of LUC is challenging since the effect occurs even absent biofuel production. No experiment can prove the "counterfactual" effect of land use change absent biofuel production. However, significant empirical data suggests that the relationship between crops used for biofuel production and land use change may not be as significant as predicted in the 2010 RIA. Deforestation rates have declined in the past decade and farming practices continue to store carbon in the soil. In fact, the drivers for deforestation are not directly related to crop production (Zilberman, 2017).

The international LUC effect related to the conversion of Brazil's Amazon region was significant in the 2010 RIA, however, this anticipated relationship was not borne out in reality. When comparing the deforestation in Brazil and corn ethanol production in the U.S. from 2004 to 2015, we can see that not only did U.S. corn ethanol production *not* cause an increase in deforestation in Brazil but annual deforestation rates in Brazil's Amazon region actually *decreased* over 75 percent over that decade (Figure 2.3). These trends in forestry loss are decoupled from biofuel use and this lack of correlation is not, but should be, incorporated into EPA's analysis.

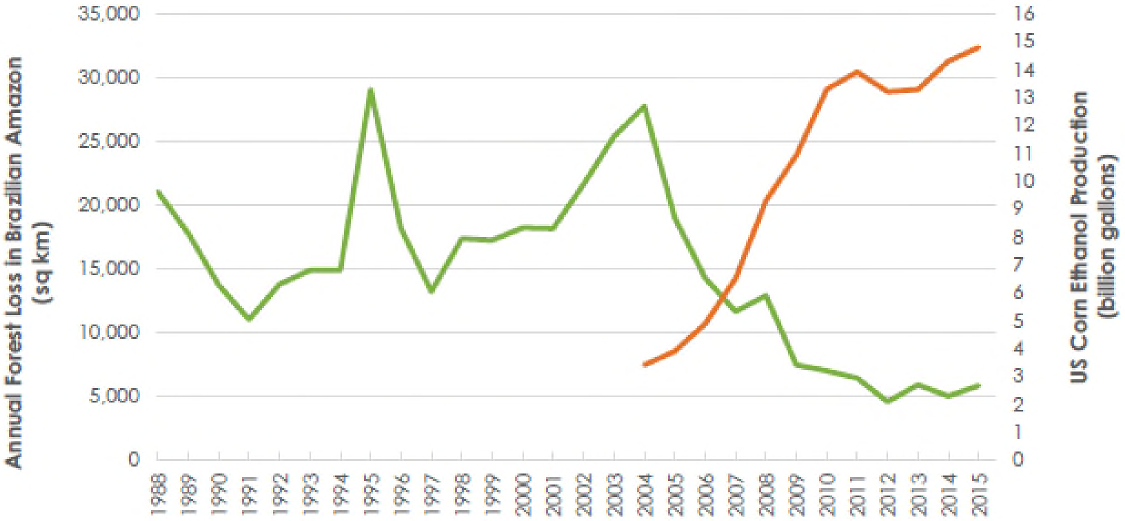


Figure 2.3. Comparison of Brazilian Deforestation and U.S. Corn Ethanol Production. (Rosenfeld et al., 2018)

Moreover, several studies have shown that corn crops produce large amounts of high carbon root and residue and this has a major positive impact on soil carbon stocks (ACE, 2018). Figure 2.5 implies that the organic matter content of the soil has improved over time due to corn farming. Part of domestic LUC is the carbon stock change due to crop cultivation and based on Figure 2.5, the carbon stock due to corn cultivation is improving which leads to more GHG emissions saving and lower impact of domestic LUC. Clay et al. (2012) studied the impact of corn yield on soil carbon sequestration and reported that in many regions, surface soils are carbon sinks when seeded with corn.

The issue of soil carbon storage is illustrated in comments in the literature regarding LUC modeling. The authors of critiques of CCLUB, which represents the newest ILUC analysis from GTAP, (Malins, 2020) argue that the Winrock data for domestic crop conversion is more accurate (which is an option to utilize in GTAP). This is not a defensible position. Much of the debate around LUC estimates as presented in GTAP pertains to the use of emission factors associated with soil carbon release. CCLUB uses the CENTURY emission factors as defaults with Winrock data used by default for international emissions. Figure 2.4 shows the comparison of different emission factors, which support the argument that the higher Winrock emission factors for domestic ILUC would be an appropriate estimate; however, this argument is inconsistent with EPA’s GHG accounting as used in the U.S. GHG inventory, which uses FASOM. Shifting to greater corn production from other crops along with the deployment of low carbon farming practices stores carbon, as reflected in FASOM and CCLUB. Accordingly, criticisms of the more recent versions of GTAP are misplaced; the LUC emissions in the U.S. should be negative as shown in the 2010 RIA (which utilizes FASOM) and in CCLUB.

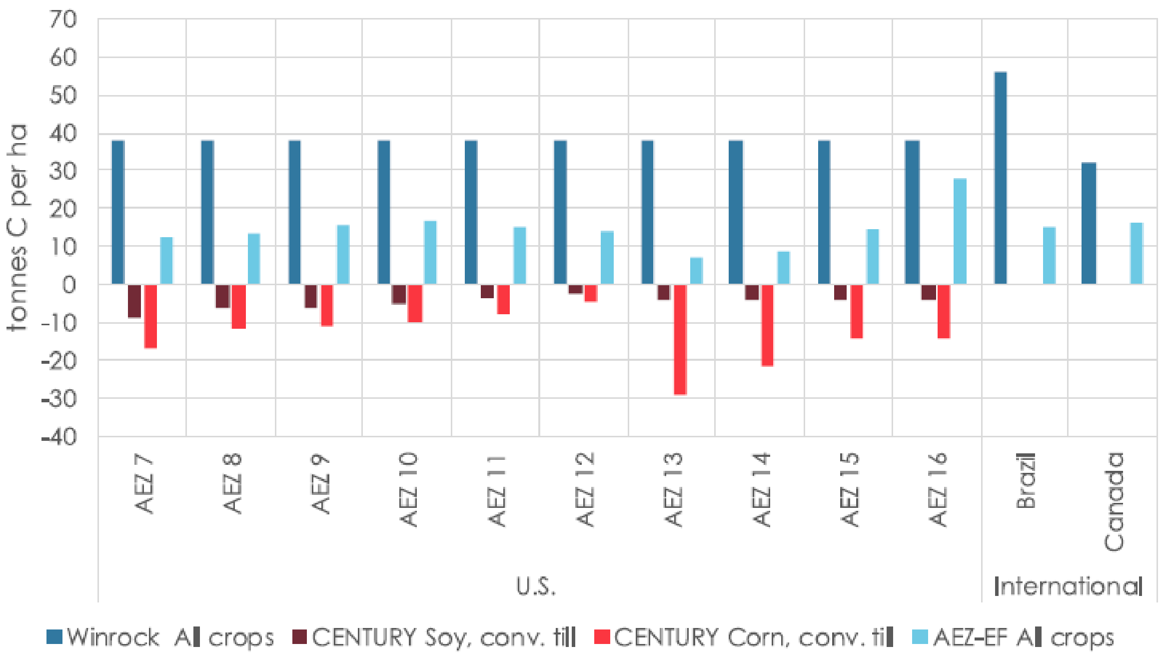
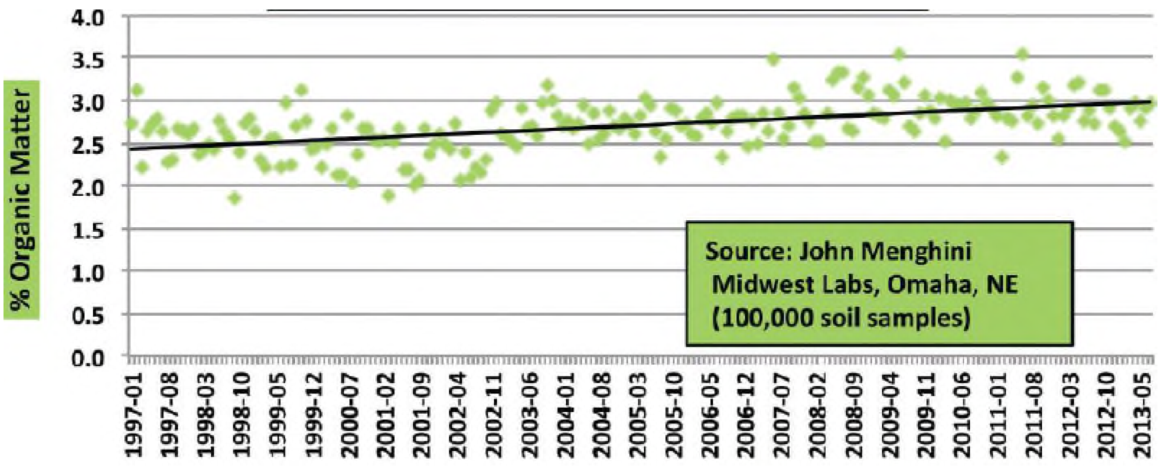


Figure 2.4. Carbon loss following cropland pasture conversion using Winrock, CENTURY and AEZ-EF emission factor models. (Malins, et al., 2020).



Source: John Menghini
Midwest Labs, Omaha, NE
(100,000 soil samples)

Figure 2.5. South Dakota Top Soil Organic Matter. (ACE, 2018)

2.2.4 Modeling Results

Since 2010, numerous studies have examined the international LUC for corn ethanol and their results showed that the international LUC was significantly lower than the 2010 RIA's estimation (Figure 2.6). These emissions correspond to the land cover change outside the U.S. induced by a change to corn ethanol. Typically, agro-economic models predict a reduction in U.S. crop exports for both corn and soybean as either corn exports are reduced or corn-soy rotation is converted to continuous corn. The models take into account the price effects of agricultural commodities as well as yield improvements and predict the type of land converted to crop production. The initial ILUC estimate from the California Air Resources Board (CARB, 2009), was a total of 30 g CO_2e/MJ of which about half was international LUC (see Figure 2.6). CARB revised its ILUC analysis with a total international component of 15 g CO_2e/MJ. These values are roughly comparable to the EPA international LUC result in Figure 2.5 though the 2010 RIA analysis includes additional categories. A series of peer-reviewed publications have shown that the international LUC is even lower. Publications from Purdue University (Tyner et al., 2010; Taheripour et al., 2017) are based on the GTAP model; which was employed by Argonne National Laboratories and incorporated into GREET (the model used by CARB and other state Low Carbon Fuel Standards, such as Oregon's Clean Fuels Program).

As discussed earlier, several studies based on GTAP evaluated biofuels induced land use changes and GHG emissions. Tyner et al. (2010) estimated the land use change and emissions associated with corn ethanol production using GTAP in support of the LCFS with the newer analysis resulting in lower ILUC emissions. A more recent study (Taheripour et al., 2017) incorporated a newer database (2011 database instead of 2004 database), added an intensification option to the model, and updated the yield price elasticity based on new data from the Food and Agriculture Organization (FAO). As Taheripour et al. (2017) stated, the previous versions of the GTAP model did not account for the intensification of pasture and assumed that a change in the harvested area equals a change in land cover, thus overestimating the emissions associated with ILUC.

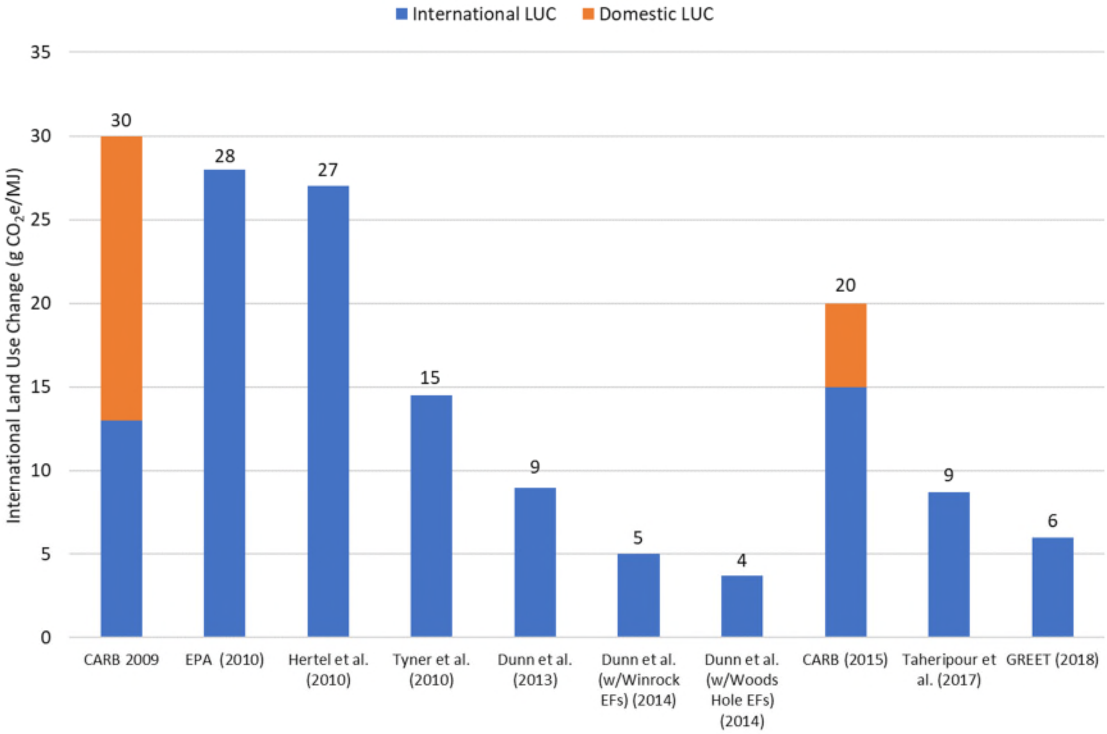


Figure 2.6. International Land Use Change Estimated by Several Studies. (Rosenfeld et al., 2018; ANL, 2018)

2.2.5 Summary of LUC Effects

International LUC for corn ethanol CI was overestimated in the 2010 RIA as shown by recent studies, availability of more recent data, and more realistic assumptions. Any estimation of LUC involves significant uncertainty with the largest uncertainties associated with the yield predictions on new and marginal land as well as the selection of land cover type. Shifts among agricultural commodities further complicates the analysis and adds a level of opacity to the modeling (CRC, 2014). While the results of LUC modeling are intrinsically uncertain, improvements in models such as those documented in recent GTAP studies indicate that EPA's assessment of both international LUC as well as U.S. LUC are overstated. In fact, soil carbon storage effects from corn farming should lead to a negative LUC in the U.S.

While the study by Searchinger et al. (2008) was the basis of international LUC calculation in the 2010 RIA, Zilberman (2017) has recently evaluated the assumptions made by Searchinger et al. (2008) and concluded that "Searchinger et al. (2008) results may now be seen as fundamentally flawed not just because the ILUC is uncertain and estimates vary considerably, but also because it fails to capture the basic features of agricultural industries and land resources." Dumortier et al. (2011) employed the same model used by Searchinger et al. (2008), but used more realistic assumptions and obtained completely different results (lower emissions). Rosenfeld et al. (2018) used the simulation results of the 2013 GTAP-BIO model available in ANL's CCLUB tool to calculate the impact of international LUC on corn ethanol CI under several scenarios and reported that the emissions associated with international LUC ranged from 1.3 to 16.9 g CO_2e/MJ. These findings that elasticity factors and other contributors to ILUC were overstated by the 2010 RIA were confirmed in a recent paper by Scully, et al. (2021). Finally, studies that compare ILUC modeling place a strong emphasis on Winrock land use conversion factors where a critical assumption is that crop land pasture emission rates are half those of pasture conversion (Malins, 2020). These same studies criticize the overestimation of soil carbon storage from ongoing corn farming practices predicted by CENTURY. However, the studies fail to recognize the merits of FASOM's analysis as used in the U.S. emission inventory that reflects real-world soil carbon storage effects.

Modeling Approach for This Study

This study combines the elements of several approaches to provide an updated assessment of the GHG intensity of corn ethanol. Repeating the steps in the 2010 RIA is a challenging process and EPA acknowledges this issue in the 2021 draft RIA; however, there are reasonable ways to update corn ethanol's CI without undertaking the extensive modeling effort completed in 2010. Here, domestic and international LUC were calculated based on the GREET (2021) model adjusted for the corn oil to biodiesel yield as shown in Table 2.3. The domestic and international ILUC emissions are multiplied by an allocation factor that assigns half of the emissions associated with corn oil production to biodiesel. The GREET model uses CCLUB (Dunn et al., 2017) to estimate the soil organic carbon storage as well as land conversion and associated emissions in response to biofuel expansion. Domestic LUC is based on average tillage practice in the U.S.; however, the more no-tillage practice is used by corn farmers, the more carbon will be stored in the soil and thus the impact of LUC will reduce.

Table 2.3. Change in GHG Emissions Due to Land Use Change (g CO_2e/MMBtu).

Study	Domestic	International
EPA 2010 RIA	-4,033	31,797
Rosenfeld et al. (2018)	-2,038	9,082
GREET1_2020	-2,314	6,300
GREET1_ 2020, allocated to corn oil	-2,199	5,986

The following calculation approach was used in this study. It allows for the assessment of the newest corn farming data, addition of the GTAP analysis for ILUC, and inclusion of the original 2010 RIA emission categories.

Emissions Allocated to Corn Ethanol and Corn Oil by Energy Content
Domestic ILUC: CCLUB
International ILUC: CCLUB
Domestic Rice Methane: ICF 2018
Domestic Farm Inputs: GREET minus international fertilizer
International fertilizer: ICF 2018 (to align with RFS categories, subtracted from domestic farm
International Rice Methane: ICF 2018

Emissions Assigned to Corn Ethanol
Tailpipe: ICF 2018
Fuel Production: GREET

3. CORN FARMING

The consumption of farming inputs such as fertilizers, pesticides, and energy such as diesel and LPG affect the GHG intensity of corn or crops that are grown to make up for corn used for biofuel production. Crop yields yield affect both the land required for crop production and LUC. This section includes new data on corn yield as well as crop inputs. This section also reviews recent data on farming and aligns it with the estimates in the 2010 RIA and the current GREET model.

3.1 Corn Farming

Historical data on corn yield indicates that the yield has increased steadily over time, from 85 bu/ac in 1988 to 172 bu/ac in 2020 as shown in Figure 3.1. The adoption of double-cross hybrid corn, continued improvement in crop genetics, adoption of N fertilizer and pesticides, and agricultural mechanization resulted in a steady increase of corn yield in the U.S. (Nielsen, 2017). Aside from the steady increase of corn yield, the harvested area of corn has increased over time. Due to the continuous improvement of corn yield, the production quantity has an upward trend (USDA NASS, 2018). The 2010 RIA estimated the corn yield for 2022 as 185 bu/ac, based on past 30 years of corn yields from USDA database. EPA's projection of corn yield for 2022 is consistent with the trendline of current data in Figure 3.1.

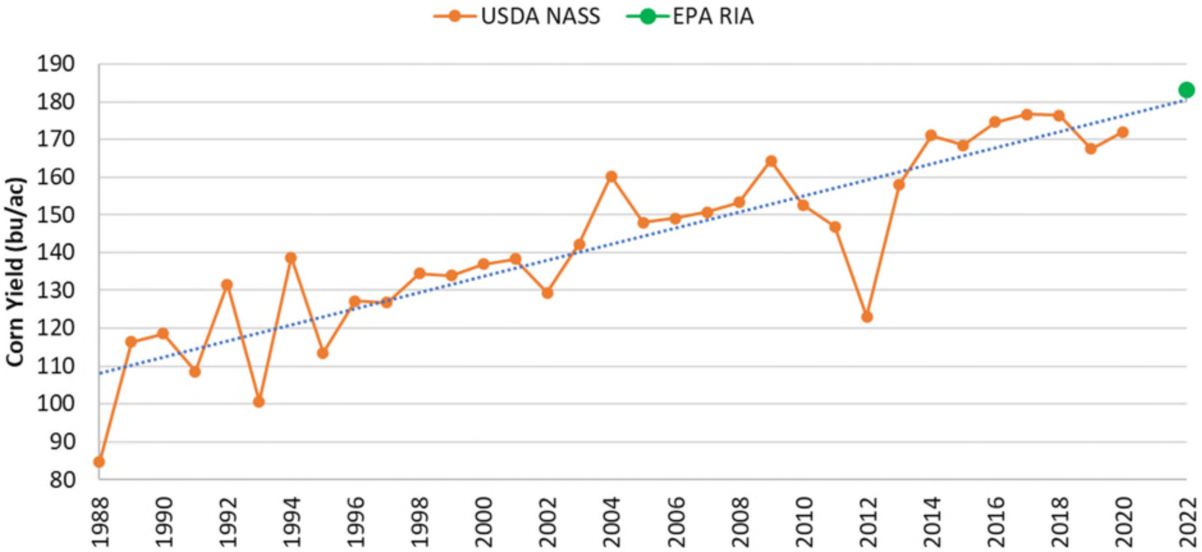


Figure 3.1. Corn Yield Over Time. (USDA NASS, 2020)

Management practices such as tillage, and nitrogen (N) application rate affect the GHG intensity of crops. In order to decrease the environmental footprint and lower production costs, farmers have started using new technologies such as precision agriculture to manage their fertilizer consumption. Reduced tillage has become a common practice across the U.S. farms, reduces soil emissions during the farming stage (Figure 3.2). Nitrogen inhibitors reduce the requirement for nitrogen and also reduce the formation of N_2O. Precision farming and guidance methods also allow for the more efficient application of nitrogen. The combination of all of these methods results in increased yield per acre and reduced nitrogen per bushel.

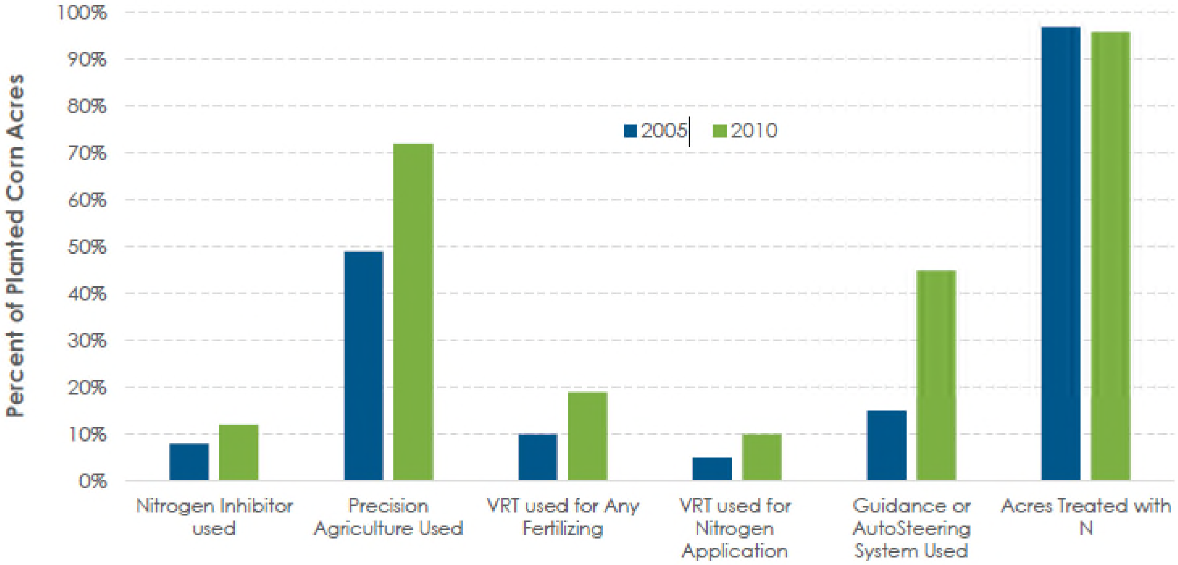


Figure 3.2. Changes in Corn Production Practices from 2005 to 2010. (Rosenfeld et al., 2018)

The leading corn farming states in the U.S. produce most of the ethanol in the country as shown in Figure 3.3. The location of ethanol plants is not surprisingly coincident with corn production. This co-location reduces corn transport distance and growth in corn production is occurring in the states with the highest yield per acre, which is shown in Figure 3.4.

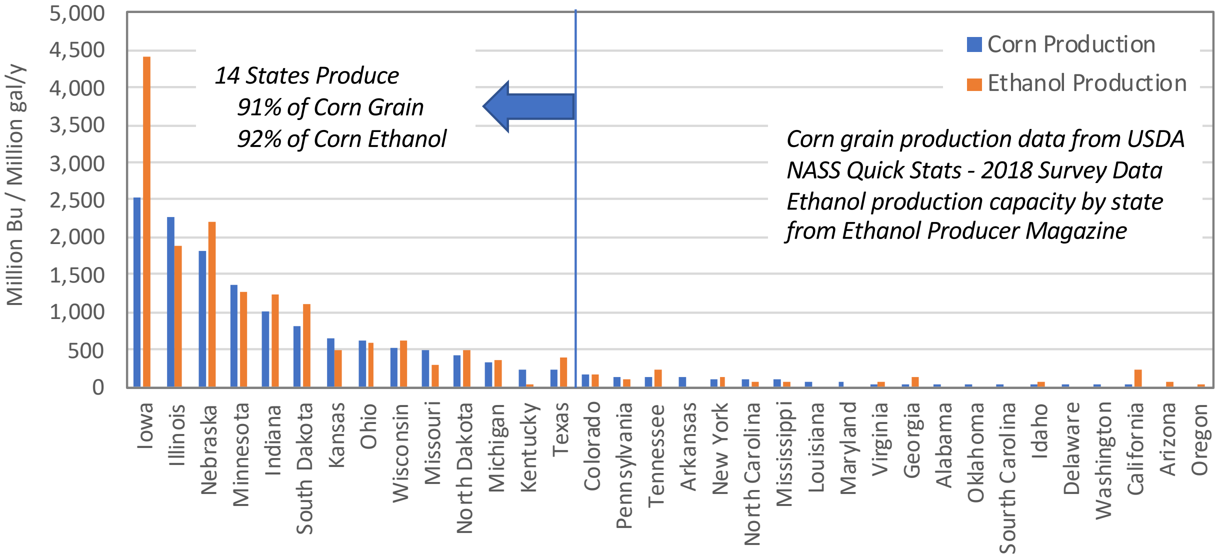


Figure 3.3. Corn Ethanol Production by State. (USDA NASS, 2018)

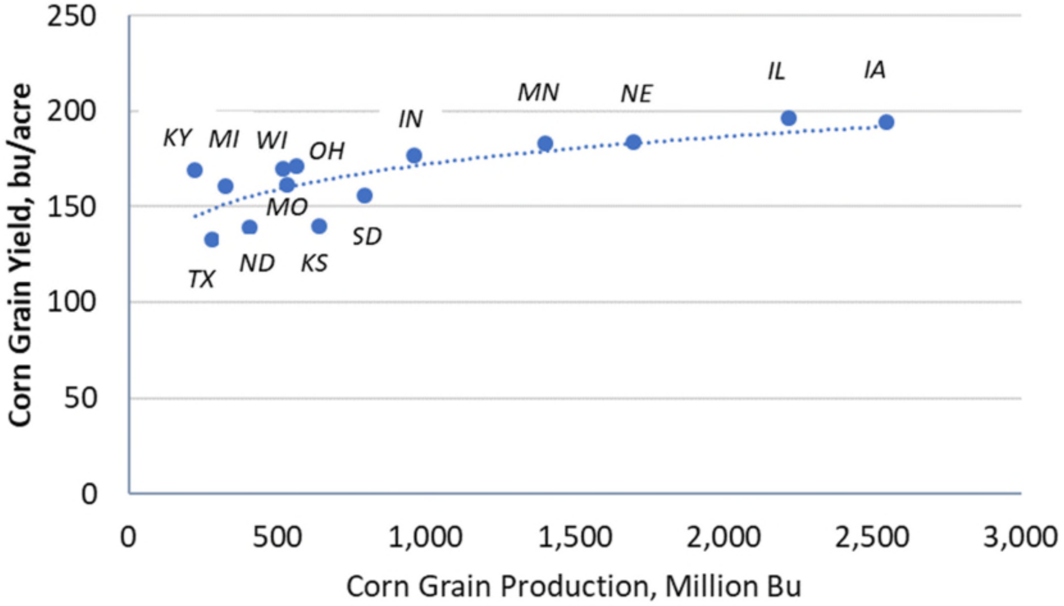


Figure 3.4. Average Corn Grain Yield vs. Production for 14 States.
(2014-2018 Weighted Average) (USDA NASS, 2018)

Iowa, Illinois, and Nebraska are the three states with the highest corn production in the U.S. An analysis of NASS data for applied nitrogen and corn yield shows consistent reduction in the nitrogen application rate per bushel of corn (Figure 3.5). The reduction in nitrogen application rate is consistent with the 2010 RIA estimate discussed below.

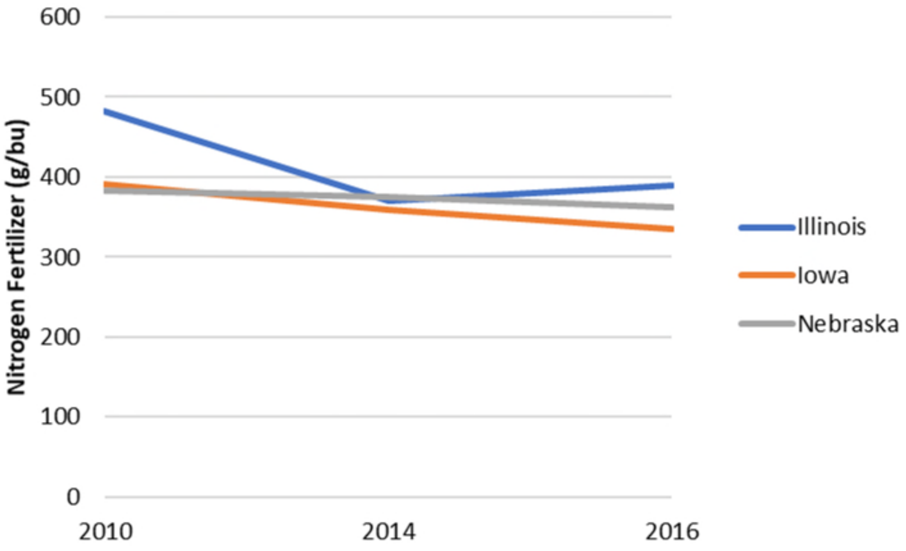


Figure 3.5. Nitrogen Fertilizer Use Rate in the Three Largest Corn Producer States.
(USDA NASS, 2018)

Domestic agricultural use of fertilizers, pesticides, and energy was projected by FASOM in the 2010 RIA. The 2022 projections are compared to several evaluations of NASS data in Table 3.1. The 2010 RIA used the GREET interim emission results to calculate the upstream emissions associated with agricultural inputs. The 2022 projections for farming inputs in the RIA reflect improved yields and advancements in farming techniques, which, in some cases, may not have yet been achieved. Overall, this comprises a small portion of ethanol's CI relative to the LUC portion discussed above.

Table 3.1. Farming Inputs of Corn in the U.S.

Input	Unit	GREET (2021)	Rosenfeld et al. (2018)	USDA NASS (2018)	EPA RIA[d]
Analysis Year		2020	2015	2016	2022
N	g/bu	401.5	373	380	344
P_2O_5	g/bu	150.6	128	165	79
K_2O	g/bu	152.3	130	193	98
Lime	g/bu	1,457	1,150	N/A[c]	260
Herbicide	g/bu	6	6	3	5
Pesticide	g/bu	0.01	0.1	N/A	1
Diesel	Btu/bu	5,200	4,730[b]	6,388	9967
Gasoline	Btu/bu	802	1,413	774	1042
Electricity	Btu/bu	1,326	441	1,089	19
Natural Gas	Btu/bu	479	1,301	1,212	1283
LPG[a]	Btu/bu	1,026	1,723	1,297	-

[a] Liquified Petroleum Gas

[b] The energy usage of corn ethanol was not mentioned in Rosenfeld et al. (2018), however they mentioned that they obtained the data from GREET (2015). To make it comparable, the energy usage data for Rosenfeld et al. (2018) were obtained directly from GREET (2015).

[C] Data was not available.

[d] From EPA RIA, Table 2.4-5. The values are listed per MMBtu of ethanol which appear to incorrectly labeled and not possible. If for example, the N fertilizer of 138.8 lb/MMBtu are taken as lb/acre yield and combined with a corn yield of 183 bu/ac from the RIA the N rate is 344 g/bu.

GREET1_2021 is the study input

3.2 Sensitivity Analysis of Farm Inputs

A sensitivity analysis was conducted to investigate the impact of each input on overall CI of corn and the results are shown in Figure 3.6. Fertilizer application rates, farm yields, transport distances to ethanol plants, and N_2O production rates were examined for 12 corn farming states using the GNOC model,[5] which provides an easy-to-use assessment tool with global applicability. Uncertainty distribution functions were developed based on the standard deviation of historical data and other variability factors to provide inputs for a Crystal Ball™ simulation of the GHG intensity of corn. The analysis shows that nitrogen fertilizer and N_2O

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[5] http://gnoc.jrc.ec.europa.eu/

emission are the most sensitive inputs, implying that a reduction in nitrogen fertilizer application rate significantly decreases the GHG intensity of corn and the CI of corn ethanol.

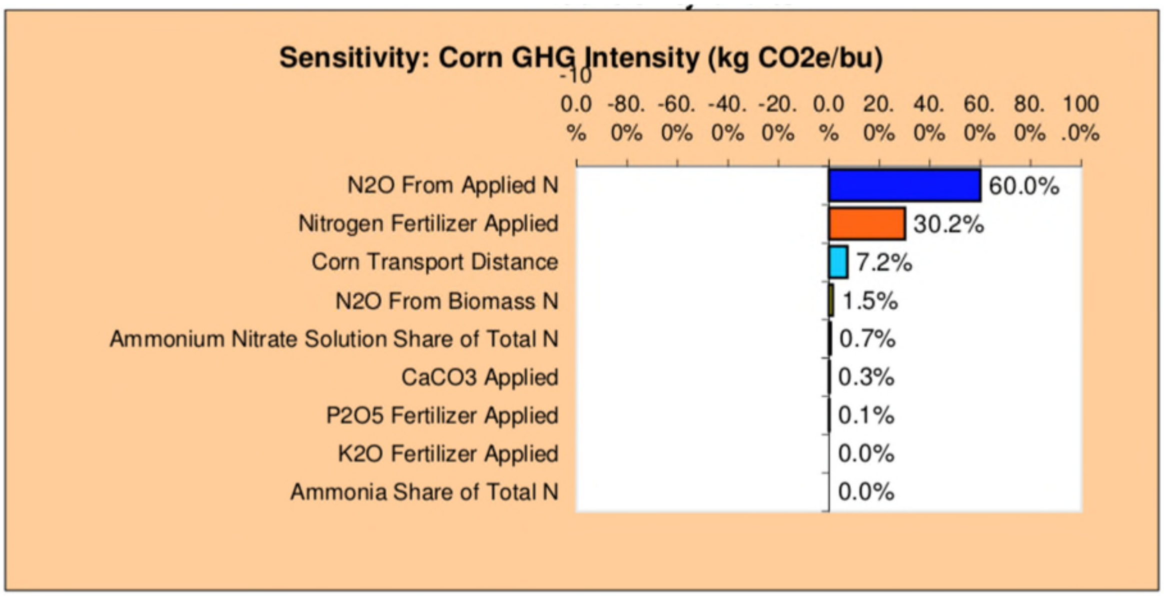

Figure 3.6. Sensitivity Analysis of Farm Inputs.

4. IMPACT OF CO-PRODUCTS ON CORN ETHANOL CI

The corn farming system and ethanol production generate several co-products that were considered in the 2010 RIA. These include DGS, Corn Distillers' Oil (CDO), and stover that is harvested with corn. Stover was considered as a fuel feedstock and not animal feed co-product. The effect of these co-products on GHG emissions is discussed in the following sections. Some ethanol plants also capture fermentation CO_2.

The 2010 RIA also used the study published by Argonne National Laboratory to estimate the DGS replacement rates for corn and soybean meal in animal feed. Production of DGS effectively results in a credit since DGS is a suitable source of animal feed and displaces agricultural crops like corn and soybean meal. However, since FASOM takes the production and use of DGS into account, no further allocation (displacement) was conducted in the 2010 RIA.

4.1 DGS Co-Product

Distiller's grains are the nutrient-rich co-product of the ethanol production process and provide an alternative to corn and soybean meal feed. Wet distiller's grains are sold to local markets due to their high moisture content and low shelf life. But generally, the distiller's grains are dried to increase the shelf life and facilitate transportation over longer distances. The product is referred to as Distiller's Dried Grains with Solubles (DDGS) (Iowa Corn, 2019). In the U.S., ethanol plants have the capacity to produce substantially more than 15 billion gallons of ethanol and 44 million metric tonnes of DDGS (U.S. Grain Council, 2018). This effect is significant since an acre of land producing ethanol for corn produces as much feed as an acre of soybeans. Due to its nutritional value, DDGS is considered a good substitute for soybean and canola meal. A recent study has investigated the effect of DDGS vs. soybean meal and canola cake on feed intake, milk production, and milk quality in dairy cows and concluded that DDGS can substitute for a soybean-canola mixture without affecting feed intake, milk yield, and quality, or sensory quality (Gaillard et al., 2017).

Figure 4.1 shows the prices of DDGS and soybean meal over time with a correlation in price activity. Rises in soybean meal prices are followed by rises with DDGS prices supporting the substitution effect. The replacement value of DGS was less well-understood in 2010 when corn ethanol was a less mature technology. While the overall substitution effects are more complicated, DDGS that displaces soybean meal results in the avoidance of emissions from soybean farming.

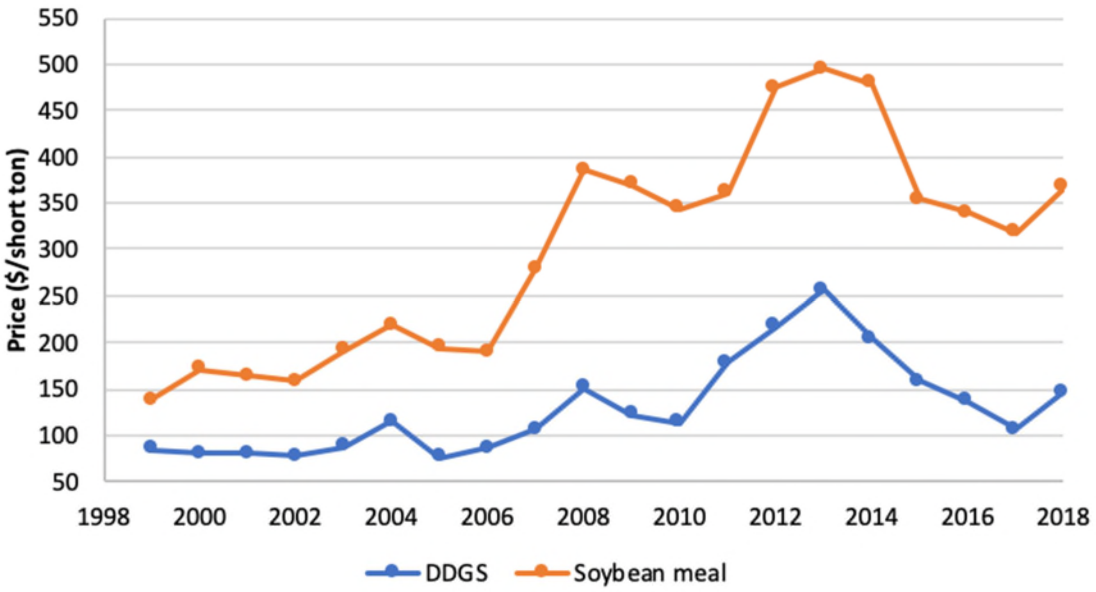

Figure 4.1. Historical Prices of DDGS and Soybean Meal. (USDA ERS, 2018; World Bank, 2018)

Soybeans as legumes fix nitrogen in the soil, which provides nitrogen for soybean crop and the following crop which is typically corn. Thus, the application of nitrogen fertilizer is not required for soybean farming. However, without N fertilizer, the soybean yield is limited to 50 to 60 bu/ac. In order to achieve higher yields, 30 to 60 lb/ac of nitrogen fertilizer is required (Schmidt, 2016). In recent years, more fertilizers, especially nitrogen fertilizer, have been used in soybean farming to increase yields (McGrath et al., 2013) (Schmidt, 2016). The GREET model input for soybean farming (ANL, 2018) is 48 g/bu of nitrogen fertilizer, which is based on a 2008 study (Huo et al., 2008). However, recent USDA data indicates that the consumption of nitrogen fertilizer in soybean is 18 lb/ac which translates to 166 g/bu (USDA NASS, 2018). The application of nitrogen fertilizer on soybean crop is triple the GREET input, which directly affects the emissions related to soybean production.

Since DDGS is a substitute for soybean meal, the avoided emissions are substantially higher than originally anticipated. Correcting the nitrogen fertilizer use for soybeans allows for a better estimate of the displacement value of DDGS with corn ethanol production. The FASOM model estimate for nitrogen usage in soybean farming in 2022 in the 2010 RIA appears to be less than 10 lb/ac (Figure A.**1**) with a projected soybean yield as 50 bu/ac in 2022. These parameters correspond to a nitrogen application rate of 64 g/bu, which is much lower than current nitrogen fertilizer use rate reported by USDA NASS (2018) (166 g/bu). (See Appendix A for a discussion of nitrogen application)

By comparing the nutritional value and moisture content, one lb of DGS is equivalent to 0.781 lb and 0.307 lb of feed corn and soybean meal, respectively. Therefore, one lb of DGS production results in the displacement of 118 g CO_2e plus 96 g CO_2e if replaced for soybean meal and corn (Table 4.1).

Table 4.1. The CI of DGS Using Displacement Method.

Feed Material	Soybean Meal[a]	Corn	Total
CI (g CO_2e/g)			
Production	0.53	0.24	
ILUC	0.32	0.03	
Total	0.85	0.27	
Displacement Ratio	0.307	0.781	
g CO_2e/lb DGS	118.4	95.7	214.1
g CO_2e/MMBtu EtOH	7,694	6,216	13,910

[a]The co-product credit for DGS depends on the crops that it displaces. In order to assess ILUC based on Figure 1.3, the displacement effect of corn to DGS is already taking into account in ILUC modeling in GREET with 5.0 lb DGS, dry basis per gal ethanol. However, the higher ILUC of soybean meal has not been fully taking into account due to the new market introduction of DGS. The displacement effect of urea feed is now shown here.

4.2 Corn Distillers Oil

Another important co-product of the ethanol plant is corn distillers' oil (CDO). Since 2010, corn oil extraction has become a common practice in bioethanol plants due to technological advancements, although it requires additional investment (Batres-Marquez, 2018). In the U.S., almost 85% of dry grind ethanol plants extracted corn oil in 2015, producing about 1.22 million metric tons of CDO (Veljković et al., 2018), and the extraction of CDO has continued to grow (Figure 4.2), which is consistent with the projections in the 2010 RIA. Several studies have shown that CDO has comparable properties to diesel and is used for biodiesel production (Balamurugan et al., 2018; Kumar and Kumar, 2013).

In the U.S., CDO represented the fastest expanding oily feedstock for biodiesel production in 2013 (Grooms, 2014). The California LCFS originally had a very favorable CI for biodiesel produced using CDO as feedstock.[6] This drove increased use of CDO as feedstock. In 2018, about 2,060 million lb of CDO, or 50% or production, was used from biodiesel production based on EIA statistics.

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[6] The LCFS CI was 4 g CO_2e/MJ of biodiesel for several years. This value has since been raised to about 22 g CO_2e/MJ, but the low initial value provided an incentive to use CDO as a biodiesel feedstock.

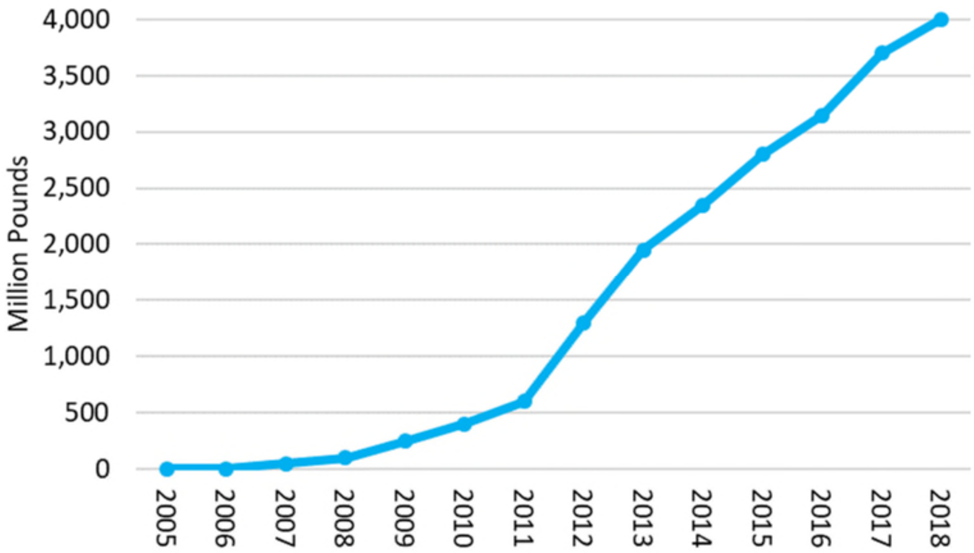

Figure 4.2. Corn Distillers' Oil Production in the U.S. (USDA NASS, 2018; RFA, 2019)

4.2.1 Corn Oil as Coproduct of Ethanol Production in EPA RIA

EPA estimated that by 2022, 70% of dry mill ethanol plants will conduct extraction, 20% will conduct fractionation, and 10% will not extract CDO. These estimates were incorporated into the FASOM and FAPRI/CARD models to account for extracted corn oil as biodiesel feedstock. The 2010 RIA projected that by 2022, 680 Mgal or 4000 million lb of CDO is produced as a by-product of corn ethanol production and used to produce biodiesel. The RIA analyzed the displacement of CDO with other agricultural products such as soy oil in the FASOM model. If CDO were treated as a fuel product, it would receive a greater share of the ethanol plant emissions and the ethanol plant emissions would be reduced. In practice, about half the CDO is used as biodiesel; which means that a corn ethanol biorefinery produces two energy products and the emissions and ILUC should be allocated between ethanol and CDO for biodiesel.

4.2.2 CDO Under Various Allocation Methods

Since CDO is a co-product of ethanol production, emissions from corn farming and ethanol production should be allocated to CDO or treated as a displacement credit. Several allocation methods allow for the treatment of CDO including displacement with soybean oil, and diesel, or energy allocation with ethanol and DGS. Each allocation method results in a different effect on the CI of corn ethanol shown in Table 4.2 as the estimated reduction in ethanol CI due to CDO production. Although the RIA accounted for CDO using the FASOM model, which focuses on the displacement of agricultural products, the energy allocation method is a better choice since corn oil us for biodiesel production has expanded in recent years. The effect of the different allocation approaches is shown in Table 4.2, energy allocation method results in more reduction in CI of corn ethanol than displacing with soybean oil. While displacing CDO with diesel is an extreme case, biodiesel from corn oil is an alternative for diesel fuel, so displacing with diesel is an option. EPA should factor into its analysis the fuel value of CDO. Energy inputs and emissions for ethanol plants as well as ILUC associated with corn usage should be assigned to both ethanol and CDO.

Table 4.2. The Effect of Displacement Method of CDO on CI of Corn Ethanol.

Modeling Approach	**CI (g CO_2e/MJ Ethanol)**
EPA RIA	~-1.14
CDO displacing with soybean oil[a]	-1.20
CDO displacing with diesel	- 4.94
Energy Allocation	-2.12

[a] Based on 166 g/bu of nitrogen fertilizer.

4.3 Replacement Feed

Corn stover (cobs and residue) is an important part of the life cycle of corn, either as fuel or as animal feed, but most LCA models treat them separately from starch ethanol (Welshans, 2014; Mueller, 2015). Corn stover is used as a cellulosic feedstock for ethanol production. Corn stover can also be used as a replacement for corn and hay or corn silage in animal feed. Mueller et al. (2015) conducted a study to investigate the effect of corn stover removal on overall emissions of ethanol. The analysis included a displacement credit for the 30% corn stover used as corn replacement feed (CRF) as well as the DGS produced from the grain corn. The displacement credit for CRF is based on a substitution ratio of 0.5 kg corn and 0.5 kg hay being equivalent to 1.0 kg of CRF on a dry matter basis. Although CRF is a suitable substitute for feed ingredients such as corn and hay, it requires pretreatment which involves consumption of chemicals such as calcium hydroxide. On the other hand, CRF has a feed and LUC credit. The results showed that using corn stover as animal feed has a co-product credit of -6.6 g CO_2e/MJ which potentially reduced the corn ethanol CI. The extent of CRF was not explicitly modeled by EPA in the 2010 RIA, but should be considered by EPA in reassessing the CI of corn ethanol.

5. BIOREFINERY TECHNOLOGIES

The performance of biorefineries affects life cycle GHG emissions due to the use of feedstock and fuel resources as well as chemical inputs. The key factors affecting GHG emissions for dry mill ethanol plants are shown in Table 5.1. The future energy inputs and yield for ethanol plants were examined in the 2010 RIA. Many of the technologies that affect dry mill ethanol plants were identified. The factors that affect energy inputs and yields, as well as the differences between the performance projected in the RIA and actual performance are examined here.

Table 5.1. Ethanol Plant Performance Parameters.

Performance Trend	Key Drivers	Effect on LCA
Increased Yield	Starch hydrolysis and fermentation efficiency Cellulosic conversion	Higher yield reduces corn upstream emissions and ILUC as well as DGS mass and co-product credit.
Reduced Natural Gas Consumption	Reduced drying energy, plant heat integration, corn oil extraction, advanced separation processes	Natural gas combustion and upstream emissions are proportional to use rate.
Reduced Electric Power Consumption	Ongoing improvements in efficiency and yield and cogeneration reduce power requirement. Corn oil separation requires additional electrical power.	Power generation and upstream emissions are proportional to use rate.
Increased Corn Oil Production	Corn oil in DGS is extracted by centrifuge or with solvents.	Several approaches. Substitution for agricultural products or allocation.
Reduced DGS Mass	Increased ethanol and corn oil yield reduce starch and oil component of DGS without changing protein output.	Affects co-product credit. Protein content is not affected. Only carbohydrate and fat fractions are affected by yield improvements.
Reduced Chemical Consumption	Increased yield and improved monitoring.	Reduced upstream life cycle for chemical production.
CO_2 Capture	Growth in CO_2 capture from ethanol plants which have a pure CO_2 stream. Avoids CO_2 production from other sources.	Several possible approaches, none used in RIA. Credit or allocation for CO_2 storage/ productive use.

The efficiency of corn ethanol biorefineries has improved (see following sections) in the past decade resulting in the use of less corn per gallon of ethanol and lower energy inputs. Corn ethanol plants also produce about 5% of their energy output as corn oil.[7] The primary factors affecting ethanol plant performance are discussed below.

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[7] 0.25 lb/gal ethanol × 15,993 Btu/lb (GREET soy and canola LHV) /77,000 Btu/gal denatured ethanol = 5.2%.

5.1 Corn Ethanol Yield

Several technologies have contributed to improvements in the ethanol yield per bushel of corn. Increased ethanol yield results in less corn used per gallon of ethanol which results in lower farming emissions, lower land use, and LUC per gallon of ethanol. Figure 5.1 shows trends in historical yield data as well as projections. Data from the GREET model that was available at the time of the 2010 RIA (Version 1.8c) is compared with industry data. These values are consistent with EPA's projections in the RIA with the trend line from the industry data slightly under the 2022 RIA projection. However, the input to the FASOM and FAPRI modeling system is 5% lower than the yield projected by EPA[8] for dry mill ethanol plants.

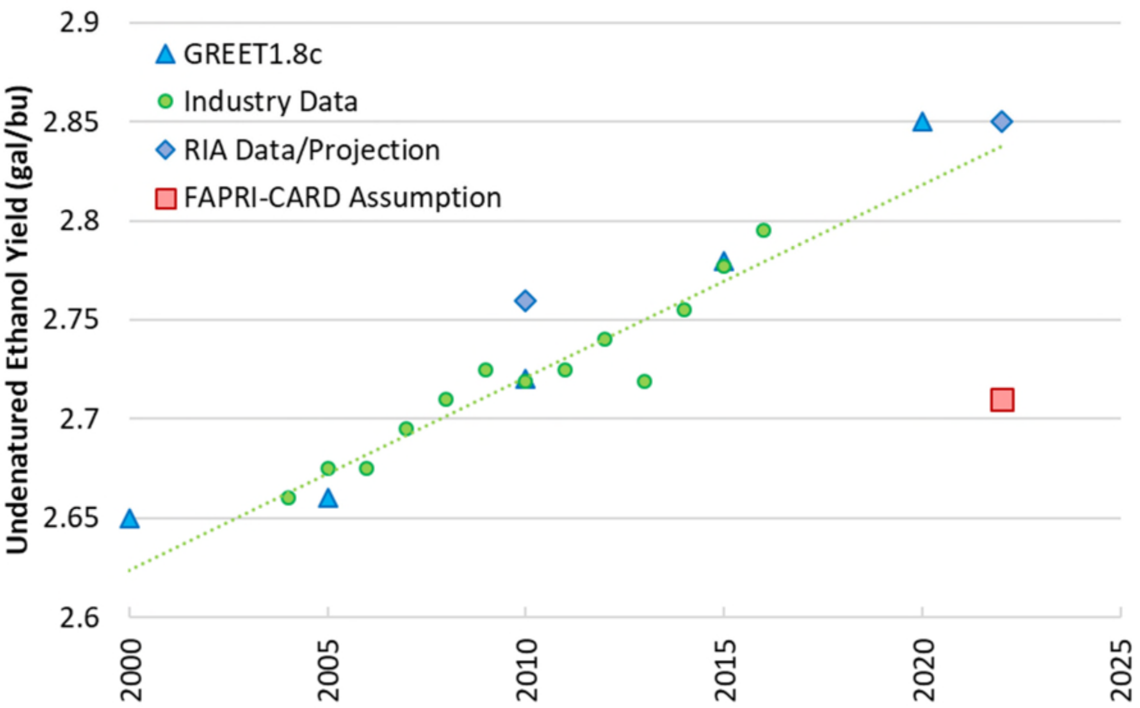

Figure 5.1. Dry Mill Corn Ethanol Yield Data and Projections.

5.1.1 Ethanol Yield in EPA 2010 RIA

EPA assumed ethanol yields of 2.71 gallons per bushel for dry mill plants and 2.5 gallons per bushel for wet mill plants and FASOM and FAPRI-CARD models used these yield assumptions. With the growth of dry mill plants, the aggregate yield should be higher than the values in the 2010 RIA. A higher yield would result in lower fertilizer use and ILUC. A first-order approximation is that corn farming and LUC related emissions should be 10% lower than those predicted by EPA due to actual yield improvements.

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[8] 2010 RIA Section 2.4.7.1 EPA states the FASOM assumption

EPA identified yield projections that are consistent with industry data.[9] The discrepancy may be due to the use of the modeling systems for other programs or challenges associated with changing a modeling assumption. In any event, the lower corn ethanol yield overestimates the corn feedstock requirement for ethanol production. An offsetting factor would be that the model predicted higher production of DGS and greater co-product displacement but the net effect would still be an overestimate of corn farming emission and land use effects.

5.1.2 Plant Debottlenecking

The debottlenecking process helps to increase the yield and reduce energy consumption in corn ethanol plants. New technologies and reviews of material and steam flows optimize the utilization of critical processes to boost overall throughput, increase yield from base throughput, or both. Membrane dehydration technology is one such technology which helps in energy reduction, purity flexibility, and debottlenecking distillation capacity and dehydration. These improvements have contributed to the overall improvement in U.S. ethanol plants.

5.1.3 Enzymes and Chemicals

Enzymes are among energy-intensive inputs for corn ethanol production. Companies like Syngenta and DuPont are providing enzymes that are more efficient in terms of increasing the ethanol yield and simultaneously reducing the enzyme consumption. In a new study by Kumar and Singh (2016) that investigates using amylase corn and superior yeast in corn ethanol production, the authors concluded that use of amylase corn and superior yeast in the dry-grind processing industry can reduce the total external enzyme usage by more than 80%. Combining their use with in situ removal of ethanol during fermentation allows efficient high-solid fermentation. Also, their study showed that the ethanol yield in their process is 4.1% higher than the conventional process of corn ethanol production.

5.2 Energy Consumption

Ethanol plants have reduced natural gas and power consumption through numerous factors such as heat integration, combined heat and power technologies, variable frequency drives, advanced grinding technologies, various combinations of front and back end oil separation, and innovative ethanol and dried distillers' grains (DDG) recovery (Mueller, 2016). These technologies directly affect the CI of corn ethanol. These energy-saving technologies were identified in the 2010 RIA and EPA modeled the natural gas and electric power consumption for corn ethanol plants that EPA projected would be built with wet and dry DGS (Figure 5.4).

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[9] RIA Section 1.1.1.1

Plant configurations modeled by EPA.

- Baseline plant
- Combined heat and power (CHP)
- CHP with corn oil fractionation
- CHP with corn oil fractionation and membrane separation
- CHP with corn oil fractionation, membrane separation, and raw starch hydrolysis

EPA placed considerable emphasis on modeling CHP. This technology has proven borderline economical with the lower costs of natural gas as well as lower costs of electric power. EPA projected that 70% of dry mill plants would adopt corn oil fractionation and this adoption rate has been exceeded.

Ten years of experience has provided insight on the actual energy use for dry mill ethanol plants. Data from ethanol plant operation has become available from industry surveys as well as pathway registrations under the California LCFS (Cooper, 2008; ACE, 2018; CARB, 2018 list of plants).

The GHG intensity of dry mill ethanol plants that were registered under the LCFS in 2016 is shown in Figure 5.2. These data are based on the CA-GREET2 model and the current CI values for these facilities with the CA-GREET3 model would be lower. However, the broader data set was available for more facilities in 2016. These ethanol plants that register under the LCFS tend to be closer to California and the lower CI ethanol plants are also represented here. The lower CI of advanced corn ethanol is attributed to the use of biomass or biogas from anaerobic digester as sources of energy. The CI values combined with LCFS applications allows for an estimation of the distribution of natural gas usage among these facilities. The range of natural gas usage was distributed equally among six bins and the range of each bin is shown in Figure 5.3. The average natural gas usage is 20,706 Btu/gal, LHV. These energy use rates and trend in reduced energy consumption over time are consistent with a survey of dry mill ethanol plants shown in Figure 5.4. These data are consistent with an industry average natural gas use rate of 22,500 Btu/gal by 2022, which is used in the assessment of GHG emissions in Section 8.

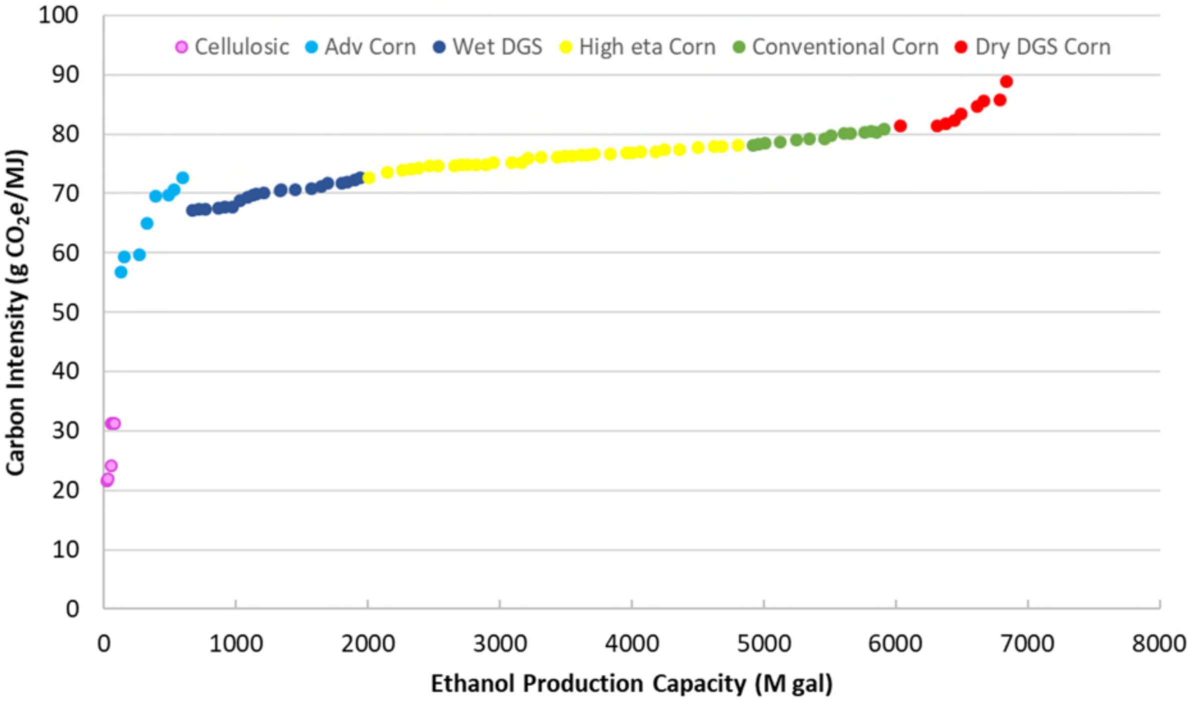

Figure 5.2. CI of Corn Ethanol with Various Technologies Registered under CARB (CA-GREET2 model) (CARB LCFS Pathway List)

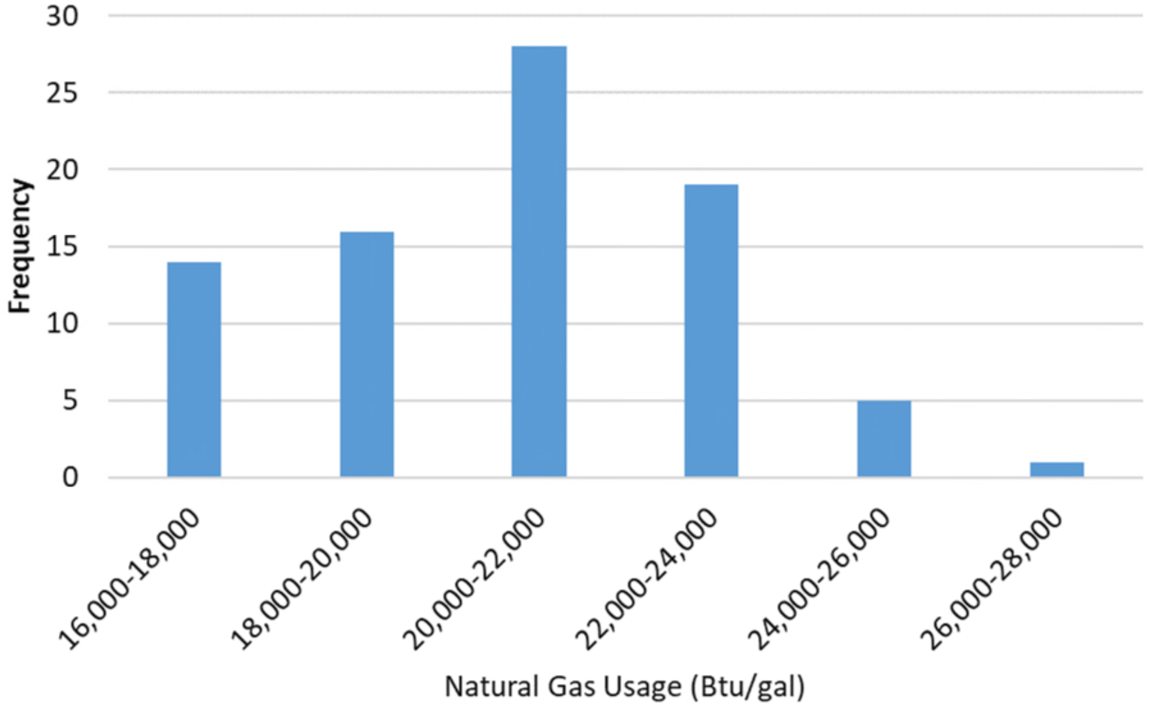

Figure 5.3. Distribution of Natural Gas Usage Among Ethanol Production Facilities.

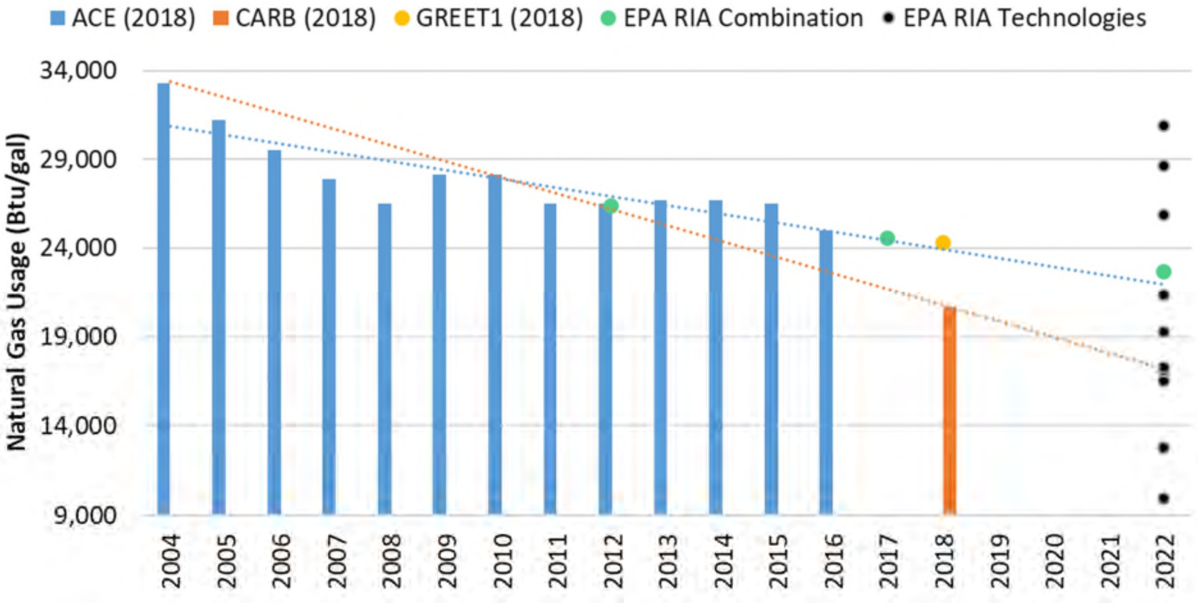

Figure 5.4. Decrease in Natural Gas Usage Since 2004 (EPA RIA combination denotes dry mill plant with only natural gas which produces 63% dry DGD and 37% wet DGS).

While the electricity consumption has not decreased significantly since 2010 (Figure 5.5), it has a decreasing trendline which implies lower electricity is being consumed by ethanol plant due to employing newer technologies. The overall impact of electric power should be examined as described in Section 6.6.

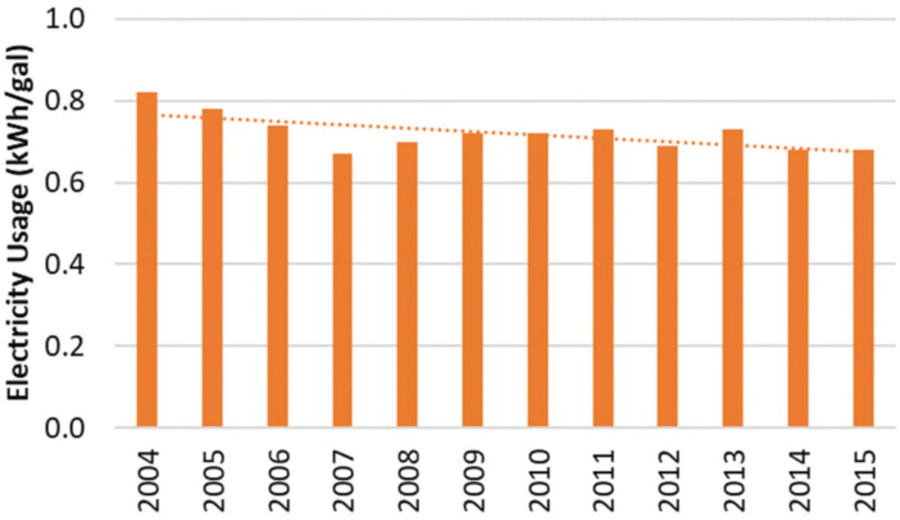

Figure 5.5. Electricity Conusmption in Corn Ethanol. (ACE, 2018)

5.3 CO_2 from Corn Ethanol

Many corn ethanol plants provide CO_2 for beverage and industrial purposes. The CO_2 generated in the fermentation process of corn-ethanol plants has a high market share such that it is the largest single-sector CO_2 source for the U.S. merchant gas markets. As a valuable product for the food industry, not only is the CO_2 not a waste product, but it also generates GHG savings credit which lowers the final CI of corn ethanol (Mueller, 2017). Absent ethanol plants, other sources of CO_2 would need to be utilized for refrigeration, beverages, and other applications (Mueller, 2019). Carbon in the fermentation CO_2 corresponds to half of the carbon in ethanol or about 37,000 g CO_2/MMBtu. After electric power for capture and liquefaction the GHG savings are over 30,000 g CO_2/MMBtu for ethanol plants that capture CO_2. In addition, at least 4 different ethanol plants are deploying carbon capture and EPA did not take into account the benefits of CO_2 capture or utilization in the 2010 RIA. The effect of these technologies is not included in the analysis in Section 8.

6. PROCESS FUELS

6.1 EPA RIA Fuel Production

In 2010, EPA considered several process fuels and different ethanol production practices (dry mill and wet mill) and came up with a combination of use rates for process fuels. EPA used the ASPEN models developed by the USDA to estimate the energy use at dry mill plants. The use rates are for a new dry mill corn ethanol refinery in 2022 that uses natural gas as its process fuel. The plant has a fractionation technology to extract corn oil and will produce a composite DGS coproduct that is 63% dry and 37% wet. Fuel Production emissions for this refinery were estimated as ~28,000 g CO_2e/MMBtu in 2022. The 2010 RIA used the GREET model to estimate the GHG CI of natural gas and electricity. These data have evolved and more recent estimates are included in the analysis in Section 8.

6.2 Phase Out of Coal

The use of coal as a fuel for ethanol plants has declined since 2010. The majority of ethanol plants are using natural gas as process fuel and only a small portion of the energy used in ethanol plants is coming from coal. According to corn ethanol pathways in the 2015 GREET model, on average, only 8 percent of the energy for steam production at U.S. ethanol plants comes from coal (ANL, 2018). EPA's projection of reduction in coal use were consistent with actual experience.

6.3 Natural Gas Production and Methane Emissions

Further refinements of the LCA of natural gas have led to many publications addressing the issue of energy inputs and methane emissions from natural gas production and distribution. GHG emissions associated with natural gas extraction have resulted in an increase in the GHG intensity of natural gas process fuel, which is taken into account in this study. As can be seen from Figure 6.1, the CI used for natural gas in this study was slightly higher than the CI used in the 2010 RIA.

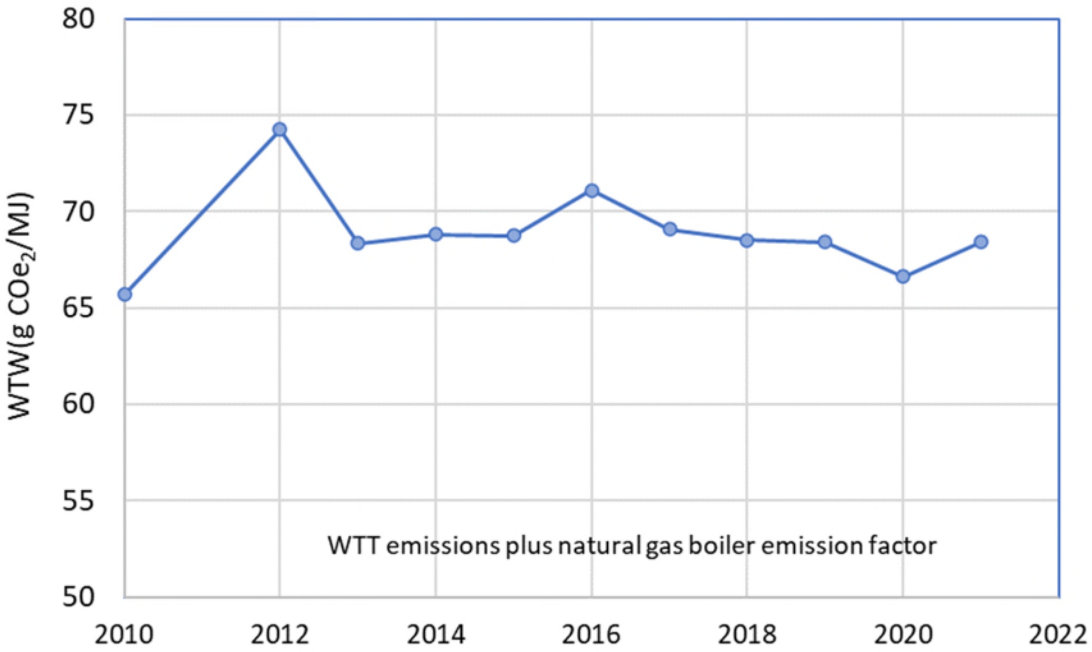

Figure 6.1. Well to Wheel (WTW) Carbon Intensity of Natural Gas plus Boiler Emission Factor in GREET. (ANL, 2018, GREET versions from 1.8b to 2021)

6.4 Biogas and Biomass Process Fuel

Landfill gas and biogas are potential process fuels for biorefineries which help to reduce the CI of biofuel (Table 6.1). The introduction of low GHG process fuel at biorefineries has been motivated by the RFS2 as well as the California LCFS. Below are several strategies employed by biorefineries to reduce the CI. All of these technology improvements lead to low CI ethanol that could be analyzed by EPA in the current rulemaking.

- Landfills collocated with ethanol plants;
- On-site anaerobic digestions of manure with avoided methane emissions;
- Anaerobic digestion of stillage;
- Electricity cogeneration;
- Solid fuel biomass combustion.

Table 6.1. Effect of Biogas on Carbon Intensity of Corn Ethanol.

Process Fuel	Biogas Fraction	CI (g CO_2/MJ), LHV	
		NG/Biogas	Ethanol
Natural Gas	100%	69	50
On-site Landfill	50%	1	40
Dairy Anaerobic Digester	15 to 25%	-250	0

6.5 Electric Power

Corn ethanol plants use electric pumps, hammer mills, and other electrical equipment. The electrical load has steadily declined over time from over 1 kWh per gallon of ethanol to an average of 0.65 kWh per gallon (ACE, 2018) over a 10-year period. Over the same time period, the GHG intensity of the U.S. grid has declined from 750 to 505 g CO_2e/kWh on a life cycle basis. On the other hand, the 2010 RIA projected power use of 1.09 kWh/gal with projects of reduced power consumption. Actual power use had dropped to about 30% less than the projected value.

6.5.1 Grid Carbon Intensity

The carbon intensity of electric power has declined with the expansion of natural gas production and the declining price of natural gas (Figure 6.2). Carbon intensity of electric power based on GREET has declined by 34% from 2010 to 2021 due to reduction in coal use and growth in renewable power generation. The decrease in grid electricity CI directionally reduces the corn ethanol CI since electricity is used in different stages of corn ethanol production, which was not anticipated in the 2010 RIA with an overstatement of about 1000 g CO_2e/MJ ethanol.

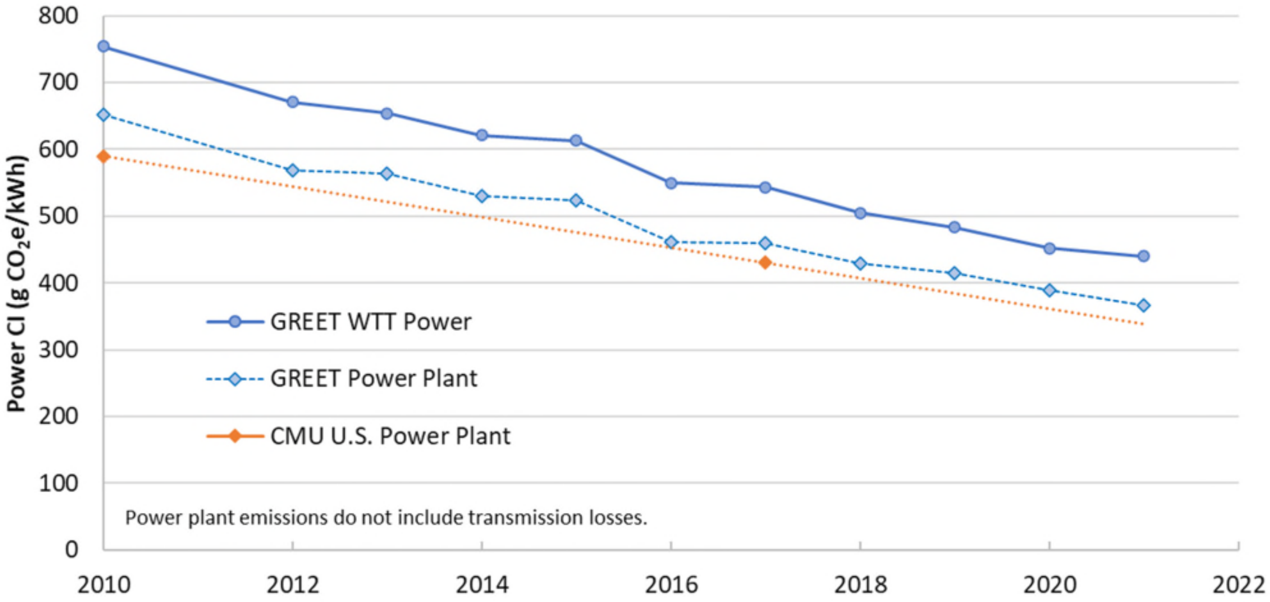

Figure 6.2. Carbon Intensity of Electric Power (U.S. Average).
(Power plant emissions do not include transmission losses, Source GREET)

A study at Carnegie Mellon University (CMU) examined the direct GHG emissions from the power sector in the U.S. and found that between 2001 and 2017 the average annual carbon intensity of electricity production in the U.S. decreased by 30%, from 630 g CO_2e/kWh to 439 gCO_2e/kWh (Schivley et al., 2018; EIA 2021). A similar proportional reduction in emissions occurred for power plants in the corn belt states where most ethanol plants are located (Figure 6.3). Schivley et al. (2018) used the U.S. Energy Information Administration (EIA) database to calculate aggregate GHG emissions and reports only power plant emissions[10]. The power plant emissions are consistent with the power plant component GREET. Based on both EIA and GREET, the CI of electricity is dropping. Note that the more recent EIA data shows a continuous downtrend in the GHG intensity of U.S. electric power.

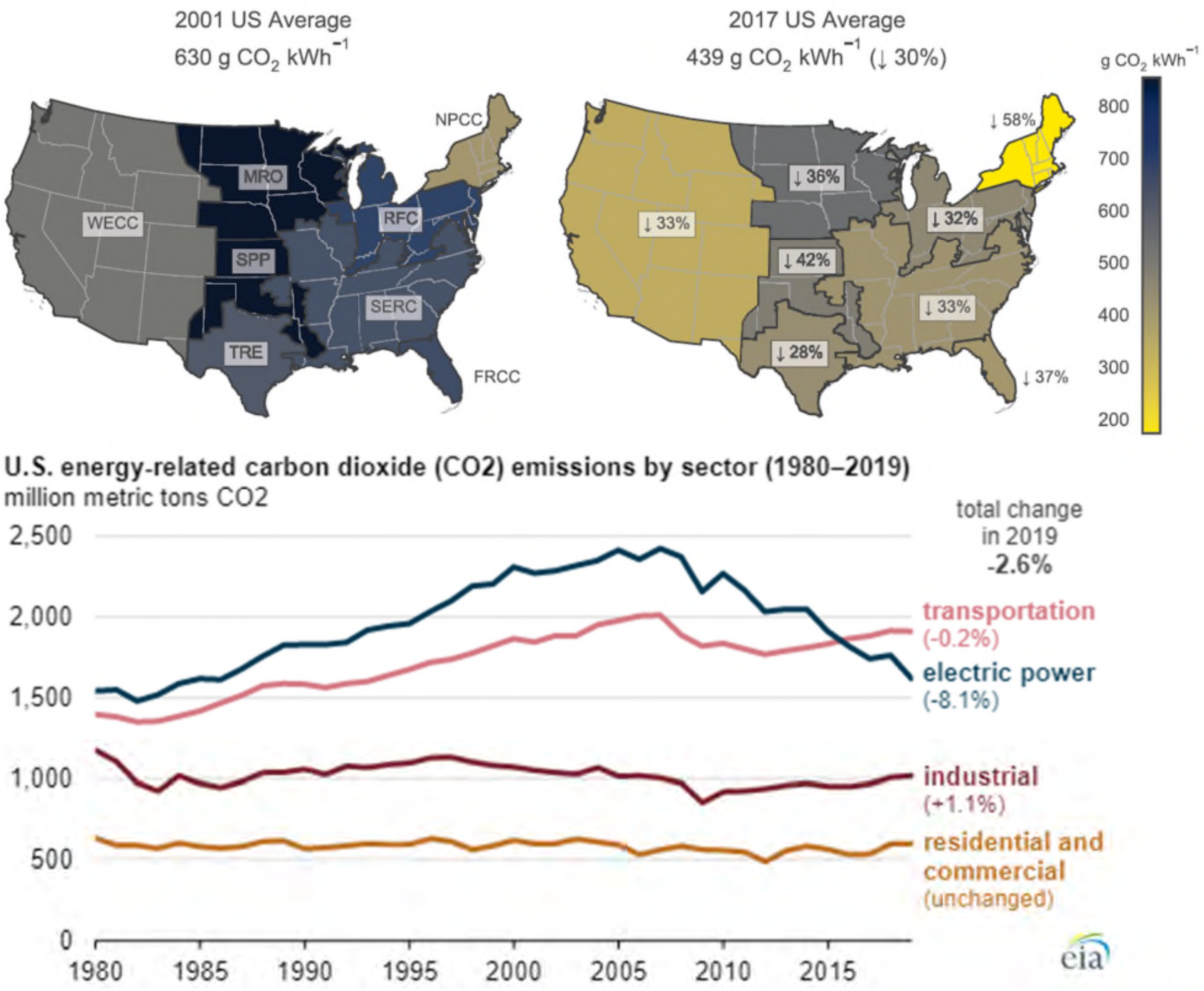

Figure 6.3. Change in Carbon Intensity of Electricity. (Schivley et al., 2018; EIA, 2021)

6.5.2 Renewable Power

Ethanol plants also have the opportunity to obtain lower GHG sources of electric power. Under current fuel policies, such as California's Low Carbon Fuel Standard, ethanol plants must use renewable power that is directly connected to the generation source. However, renewable power had contributed to the overall reduction in GHG emissions from the grid in the U.S.

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[10] Power plant emissions at the plant from GREET correspond to the "fuel" phase × (1 – loss factor)

6.6 Summary of Ethanol GHG Analysis Issues

Many factors affect the CI of corn ethanol. A summary of the issues and recommended analysis method is shown in Table 6.2.

Table 6.2. Evaluation Issues related to GHG Analysis.

LCA parameter	Analysis Issue	Recommendation
Ethanol refinery energy efficiency has increased.	The energy efficiency has increased in a few refineries and it does not reflect the average.	Based on our analysis, the current energy usage at the fuel production stage is close to EPA RIA's estimate, however, both electricity and natural gas consumption have a declining trend which should be considered.
Electric power GHG intensity.	The GHG intensity of electric power has dropped faster than projected in the 2010 RIA.	Update electricity mix for electric power generation.
Emissions associated with gasoline is under estimated.	EISA requires that the EPA compare biofuel emissions to a 2005 petroleum baseline.	The 2005 petroleum bassline analysis excluded methane leakage and the thermal cracking of petroleum which has lead to underestimation of emissions associated with gasoline.
Co-product allocation method	EPA RIA used the replacement method which results in lower co-product credit.	Since corn oil is used as biodiesel feedstock (energy source) energy allocation is a better option which results in more reduction in corn ethanol CI.
Fertilizer use rate for soybean	EPA RIA used lower fertilizer use rate for soybean.	According to recent USDA statistics, the N fertilizer use rate in soybean is almost three times more than what EPA used. Higher fertilizer rate for soybean results in more co-product credit for DGS which replaces the soybean meal.

7. PETROLEUM BASELINE EMISSIONS FOR 2005 ARE LARGER THAN PROJECTED.

7.1 EPA 2010 RIA Approach in Estimation of Petroleum Baseline

EPA estimated the lifecycle GHG emissions associated with baseline gasoline transportation fuel using the 2009 analysis performed by the National Energy Technology Laboratory (NETL). The NETL analysis considers the GHG emissions associated with crude oil extraction both in the U.S. refineries and refineries in other countries from which the U.S. imported oil. The emissions from the 2010 RIA for 2005 gasoline fuel are shown in Table 7.1.

Table 7.1. Carbon Intensity of 2005 Gasoline from Well to Wheel (WTW).

	GHG Emissions (g /MMBtu)			
Life Cycle Step	CO_2	CH_4	N_2O	CO_2e
Fuel production	16,816	2,282	103	19,200
Tailpipe	77,278	3	5	78,891

EPA established the baseline RBOB (Reformulated gasoline Blendstock for Oxygen Blending) CI for gasoline at 93.08 g CO_2 e/MJ in the year 2005.[11] EPA has not re-examined the CI of petroleum since the 2010 RIA; however recent studies have shown that EPA underestimated the emissions associated with 2005 gasoline. The key factors analyzed by these studies include:

- Fugitive methane;
- Flaring of associated gas;
- Enhanced production methods including water flooding and thermal oil recovery;
- Mix of oil sands;
- Refinery complexity.

The key findings of recent studies which have more accurate data are discussed below.

7.2 New Findings on Petroleum Baseline

Researchers have studied the life cycle GHG emissions of petroleum fuels for several decades. Many of these studies follow the process for LCA defined by International standards (ISO 14040, 2006). Initial studies examined the national inventory of GHG emissions from crude oil production and refining with calculations of crude oil and fuel transport (Wang, 1999). Even though GHG emissions from oil refineries are reported as part of most national GHG reporting systems, the distribution of emissions among refined products has remained a challenge since multiple refinery units produce a range of products.

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[11] California, in 2006, established a baseline CARBOB (California Reformulated gasoline Blendstock for Oxygen Blending) CI of 95.86 g CO_2 e/MJ. However, this value was updated to the 2012 value of 99.18 g CO_2 e/MJ to reflect the steady shift to higher intensity crude oils fed into U.S. refineries.

Aspects of crude oil production including flaring, indirect effects of road building, thermal enhanced oil recovery, and crude production methods were identified as key aspects of the life cycle of petroleum fuels (Unnasch et al., 2009; Keesom et al., 2009). Subsequent studies expanded the modeling methods and detail for crude oil production in regions such as the EU (Keesom et al., 2012; ICCT, 2014; COWI, 2015). More detailed models of crude oil production have also been developed by Jacobs Consultancy (Keesom et al., 2012) and Stanford University (El-Houjeiri et al., 2014). The California Air Resources Board (ARB) also publishes annual estimates of the CI of crude oil (CARB, 2019b). Regional studies of crude oil for the U.S., China, and globally are also part of the scientific literature (Cooney et al., 2016; Masnadi et al., 2018a; Masnadi et al., 2018b; Gordon et al., 2015).

The GHG LCA emissions associated with gasoline have been examined in numerous studies conducted by Jacobs Consultancy, Argonne National Laboratory, MathPro, and the University of Calgary (Keesom et al., 2012; Elgowainy et al., 2014; Kwasniewski et al., 2016; Rosenfeld et al., 2009, Abella and Bergerson, 2012). These studies show that a CI of 97 g/MJ would be more accurate than the 93 g/MJ for the 2005 baseline value estimated in the EPA 2010 RIA due to emissions associated with a range of crude oil production practices including oil sands upgrading, venting and flaring or produced gas, and enhanced oil recovery technologies.

The quality and consistency of the raw crude fed into refineries determines the complexity of processing required such that lower quality crude oil is more difficult to refine into transportation fuels, thus resulting in higher CI. The total energy expended to recover crude oil and the resulting GHG emissions vary depending upon the crude characteristics and the recovery methods used. The carbon intensities per production method were analyzed in a study that examined the CI of fuels under the RFS2 (Boland & Unnasch, 2014). The results for different petroleum fuels are shown in Table 7.2.

Table 7.2. Petroleum Gasoline Carbon Intensity.

Petroleum Source	**Gasoline Carbon Intensity (g CO_2 e/MJ)**		
	Low	**High**	**Average**
Primary	84.50	94.6	89.55
Secondary	93.58	98.18	95.88
TEOR	100.58	120.00	110.29
Stripper Wells	101.95	116.44	109.20
Mining Upgrader	100.42	104.91	102.67
SAGD, Dilbit	105.00	115.36	110.18
Fracking	97.48	111.54	104.51
Oil Shale	113.00	159.00	136.00

Conventional oil includes primary and secondary sources of oil and these are the most well defined and accessible sources of crude and hence the most drawn upon, the carbon intensity for gasoline from these crude oils ranges from approximately 84 to 98 g CO_2 e/MJ. TEOR (Thermally Enhanced Oil Recovery) methods are generally implemented where the crude characteristics (viscosity, API gravity) dictate and also to extend the life of a production well. Heating water to produce the steam or other *in-situ* TEOR techniques require additional energy inputs and can increase emissions by an additional 8 to 9% over conventional production. Compared to conventional oil deposits, oil sands require production techniques that are associated with greater environmental impacts. Shallow deposits are typically accessed using strip-mining techniques, while deeper deposits are generally accessed using in situ techniques whereby steam is injected into the reservoir to heat the bitumen until its viscosity decreases sufficiently to allow it to flow out of the reservoir. On a WTW basis, the GHG emissions from oil sands are generally between 5 to 15% higher than from most conventional oils. Heating water to produce the steam used for in situ techniques and bitumen-sand separation uses large amounts of energy, typically natural gas, and produces correspondingly large amounts of emissions. In addition, bitumen produced from tar sands must go through more extensive refining than conventional oil, producing additional emissions. Upgraded mining techniques have led to advances in emissions reductions by approximately 2% over other oil sands ranges. The emission ranges shown in Figure 7.1 show a range of crude oil types that were in production in 2005 and are higher than the baseline in the 2010 RIA.

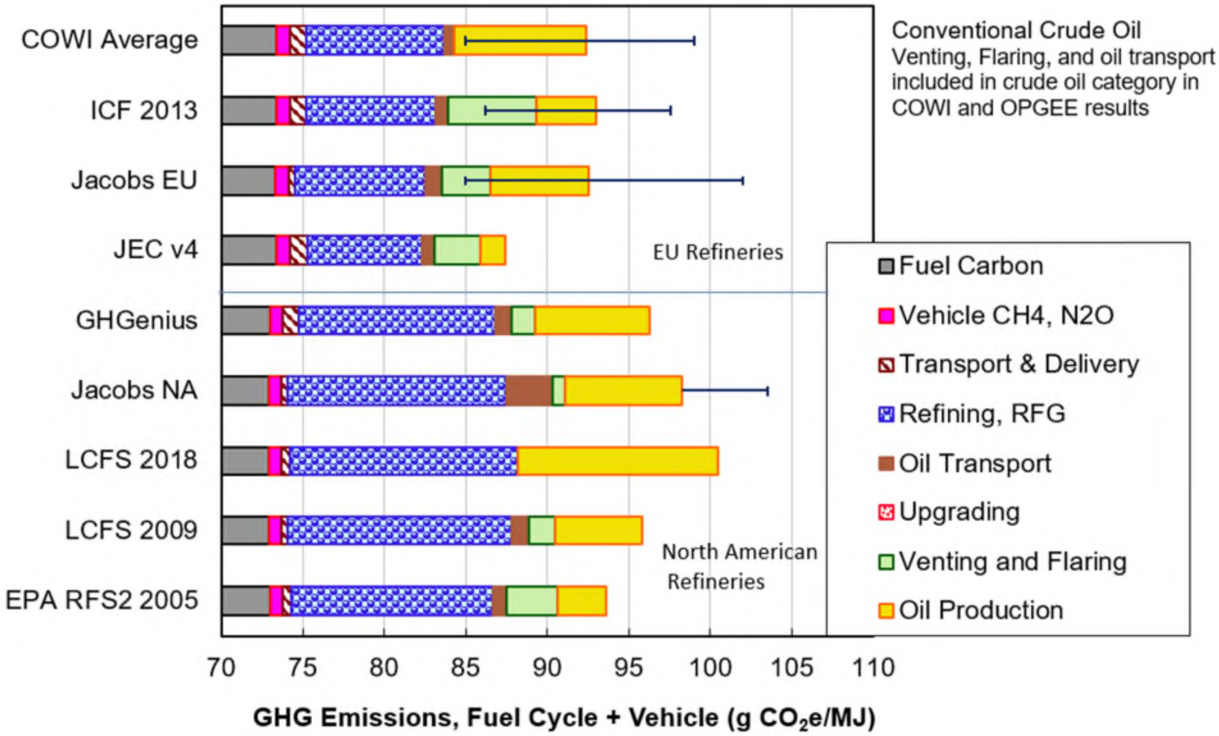

Figure 7.1. CI of Gasoline Estimated by Several Studies. (Unnasch et al., 2018)[12]

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[12] The Jacobs EU, JCE v4, GHGenuis, Jacobs NA, LCFS 2018, LCFS 2009, and EPA RFS2 2005 were presented in Keesom et al. (2012), Edwards et al. (2012), S&T (2013), Keesom et al (2012), CARB (2018), CARB (2009), and EPA (2010), respectively.

8. ESTIMATED GHG EMISSIONS FROM CORN ETHANOL

This study evaluated EPA's 2010 LCA of corn ethanol and specifically focused on the emission categories with the highest impacts. Since 2010 when the RIA was conducted, more data have become available, LUC models have been revised several times and more realistic assumptions have been made. Ten years of research provides a better understanding of the impact of biofuel expansion on LUC both in the U.S. and across the globe. Also, the energy consumption in the fuel production stage has been improved continuously since 2010 which should be accounted for in EPA's GHG LCA. Another important factor are the co-product credits where the role of corn oil as biodiesel and the substitute value of soybean meal displacement was not fully reflected in the 2010 RIA. The main factors analyzed in this study are discussed below.

1. International LUC has the highest share from total emissions of corn ethanol in the RIA. Recent studies have estimated much lower values for international LUC compared to EPA RIA. In this study, uses the GREET (2021)/CCLUB, to calculate both domestic and international LUC. GREET uses the GTAP model which has undergone several rounds of revision since 2010 and GTAP's estimate of international LUC due to corn ethanol production is almost five times lower than what EPA RIA estimated. GTAP includes refinements in pasture utilization and projections of yield improvement reflected by elasticities (Taheripour, 2017).
2. Corn ethanol yield affects both domestic and international LUC. EPA projected a yield of 2.71 gal/bu, however, recent data shows that the ethanol yield in dry mill process is 2.88 gal/bu and continues to improve (GREET, 2021).
3. Energy consumption in the fuel production stage has improved due to the application of new technologies. EPA projected the natural gas consumption as the main source of energy for dry mill process with corn oil fractionation as 25,854 Btu/gal. Data from LCFS applications show a trend below 20,000 Btu/gal by 2022. Also, the CI of electricity used as a source of energy in biorefining has a declining trend due to the consumption of cleaner fuels in the production stage.
4. DGS, a byproduct of corn ethanol, is a partial substitute for soybean meal. Nitrogen fertilizer use in soybean farming has increased recently and reached 166 g/bu (USDA NASS, 2018). The RIA assumed a nitrogen fertilizer use rate for soybean of approximately 64 g/bu. Higher nitrogen fertilizer use rates increases the GHG intensity of soybean meal which results in a higher credit for the DGS co-product.
5. Corn oil is a co-product of corn ethanol that has achieved a high adoption rate. The 2010 RIA used the displacement method; however, the evolving use of corn oil is biomass-based diesel production (2021 Draft RIA, Figure 5.2.3-1). Therefore, energy allocation is an appropriate option since the growing use of corn oil is as an energy product. The net effect is a lower CI when both ethanol and biodiesel are treated as energy products.

This study uses the GREET (2021) model to calculate the CI of corn ethanol configured with current ethanol plant and crop data. Since GREET lacks some consequential aspects of corn ethanol LCA such as international rice methane emission and international livestock emissions, the analysis in the ICF study (Rosenfeld et al., 2018) provides the basis for these parameters in order to be consistent with the emissions categories in the 2010 RIA. The allocation treatment of corn oil biodiesel is factored into the analysis also as shown in Table 8.1.

The estimated GHG emissions represent a hybrid between the GREET and consequential LCA approach in the 2010 RIA. The allocation effect of corn oil as a biodiesel feedstock is taken into account with emissions allocated between ethanol and corn oil-based diesel. Note that the substitute value of corn oil is a small fraction of the DGS co-product and an acre of land that produces corn for ethanol makes as much animal feed as an acre of soy beans.

Table 8.1. CI of Corn Ethanol for Dry Mill, Natural Gas Operation with Corn Oil Extraction.

Emission Category	**2005 Gasoline Revised**	**2005 Gasoline RIA**	**GREET 1999**	**EPA 2010 RIA**	**GREET 2021**	**This Study[a]**	**ICF**
Domestic Livestock				-3,746	**-2,202**	-2,463	**-2,340**
Domestic Farm Inputs and Fertilizer N_2O			16,000	8,281	**11,548**	9,065	**11,023**
International Farm Inputs and Fertilizer N_2O				6,601	**-987**	**-1,013**	-1,013
Domestic Rice Methane				-209	578	578	578
Tailpipe	79,004	79,004	880	880	**2,420**	**2,483**	**2,359**
International Rice Methane				2,089	**3,795**	**3,894**	**3,700**
International Livestock				3,458	**-2,255**	-2,038	**-2,199**
Domestic Land Use Change				-4,033	**1,374**	3,432	**1,374**
Fuel and feedstock transport			5,000	4,265	**2,160**	**2,217**	**2,217**
International Land Use Change			30,000	31,797	**6,139**	9,082	**5,986**
Fuel Production	21,100	19,200	48,000	27,851	29,527	34,518	28,792
Net Emissions	**100,104**	**98,204**	**99,880**	**77,233**	**47,468**	**52,096**	**59,755**

[a] 95.2% allocation factor (fraction of ethanol output/ ethanol plus corn oil) applied to either **GREET** or **ICF** results as indicated in bold.

Natural gas consumption of 24,305 Btu/gal, LHV. International farming inputs are based on the ICF analysis even though the full burden of domestic corn farming is represented with the GREET inputs. Domestic and international rice methane and livestock emissions are based on the ICF values combined with the allocation factor. International and domestics land use change are based on the GREET result combined with the allocation factor. This study does not investigate categories including international farm inputs and fertilizer N2O, domestic and international rice methane emissions and international livestock emissions and relies on the ICF study estimates for these emission categories and are combined with the allocation factor for corn oil. Livestock emissions include two major factors, enteric fermentation, and manure management. It has been shown by several studies that replacing DGS with soybean meal reduces the enteric fermentation. The manure management emissions refer to emissions during collection, storage, transfer, and treatment of manure. While the replacement of DGS reduced the enteric fermentation in domestic livestock, it was not included in estimating the international livestock emissions in RIA analysis. Inclusion of reduction in enteric fermentation for international livestock would decrease the emissions associated with international livestock.

Figure 8.1 shows the estimated CI is 50,417 g CO_2e/MMBtu while 2010 RIA estimated the CI of corn ethanol as 77,233 g CO_2e/MMBtu. The GREET (2021) estimation of corn ethanol CI is the lowest since it does not account for international livestock and rice emissions. The emission estimates from the ICF analysis provide the basis for the analysis presented here. While in GREET (2021) a small percentage (~7%) of energy for fuel production is coming from burning coal, this analysis represents natural gas dry mill facilities, which are the new facilities incentivized by the RFS2 and does not attempt to examine the entire range of ethanol production technologies.

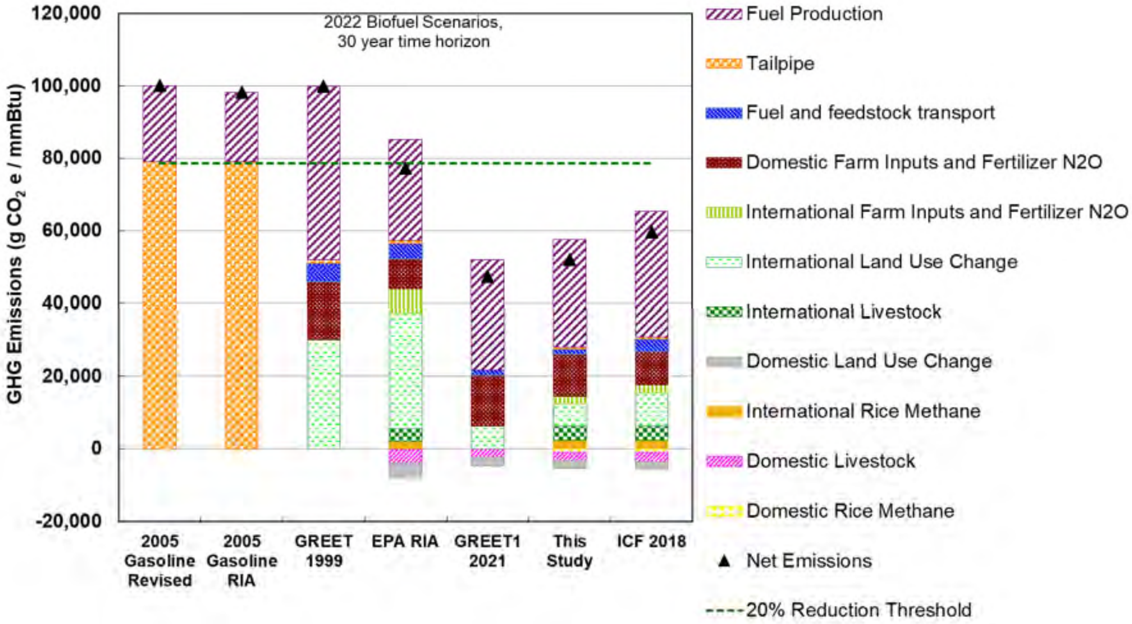

Figure 8.1. CI of Corn Ethanol for Dry Mill, Natural Gas Operation with Corn Oil Extraction.

Under the current situation and in the year 2022, Rosenfeld et al. (2018) calculated the CI of corn ethanol as 59,755 g CO_2e/MMBtu and 54,588 g CO_2e/MMBtu, respectively. Rosenfeld et al. (2018) also defined a scenario in which new technologies and better practices are employed to reduce the emissions in corn and fuel production. They concluded that by employing advanced technologies and introducing new co-products in the fuel production stage, and efficient management practices such as reduced tillage, nutrient management and cover crops in the farming stage the GHG emissions can be reduced to 27,852 g CO_2e/MMBtu. These estimates are consistent with ongoing trends in regenerative agriculture.

9. CONCLUSIONS

Life cycle GHG emission from the corn ethanol was analyzed over a range of production technologies and analysis methods. The data in this study show that life cycle GHG emissions for corn ethanol plants can range from 26 to 57 g CO_2e/MJ. Typical dry mill facilities have a CI in the 40 to 55 g CO_2e/MJ range. The CI for the 2005 petroleum baseline is also higher than originally projected; so, most of the ethanol plants in the U.S. produce fuel with a 45 to 55% reduction in GHG emissions. The key factors that result in GHG emissions that are lower than projected in the 2010 RIA include the following:

- Reduced energy consumption;
- Reduced GHG intensity for electric power;
- Shift from coal to natural gas fuel;
- Adoption of corn oil extraction with energy allocation;
- Reduced rates of deforestation;
- Improved rates of DGS use as animal feed;
- Displacement of ILUC and N_2O emissions from soy beans;
    - Higher nitrogen application rates to soybeans than originally modelled;
- Use of corn replacement feed from crop residue;
- Introduction of lower CI process fuels for ethanol plants;
- Higher GHG emissions from 2005 petroleum baseline fuels.

EPA overestimated international land use conversion in the 2010 RIA and has not updated the analysis in the draft 2021 RIA. New ILUC studies that take into account pasture intensification show a lower level of international ILUC and are represented in the CCLUB model from Argonne National Laboratory (ANL). The CCLUB model incorporates the most recent modeling from Purdue University's GTAP program. EPA also analyzed negative direct and indirect land use conversion emissions in the 2010 RIA. These results are confirmed in the CCLUB model from ANL and are consistent with the basic factors affecting the growth of corn ethanol production. Total agricultural land has not increased significantly in the U.S.

In addition, much of the growth in corn ethanol has come from a reduction in soybean production. Corn farming increases soil carbon relative to soy farming with no till practices and due to the fact that corn builds up soil carbon from its root mass. Criticisms of the CCLUB model based on the choice of the CENTURY emission factors associated with crop activity are misplaced as the emission factors based on Winrock and Woods Hole are simple approximations that are unsubstantiated. The CENTURY approach is used in the development of the U.S. emission inventory and is also consistent with regenerative agriculture practices that generate voluntary carbon credits.

In addition, EPA did not sufficiently document advancements in corn ethanol technology. Numerous ethanol plants are starting to use biogas and biomass fuel as well as implementing carbon capture and sequestration.

Finally, EPA understated the 2005 petroleum baseline and has not acknowledged the revised estimates of emissions in the 2021 draft RIA for this rulemaking. The refining of heavy oil as well as flaring emissions from many international sources of crude oil, which occurred in 2005 contribute to higher GHG emissions associated with gasoline than those in the 2010 RIA.

10. APPENDIX A – NITROGEN APPLICATION RATES

Nitrogen application rates affect the GHG intensity of corn production. In addition, ethanol plant DGS provides a replacement for crops with nitrogen application rates that are higher than anticipated in the 2010 RIA.

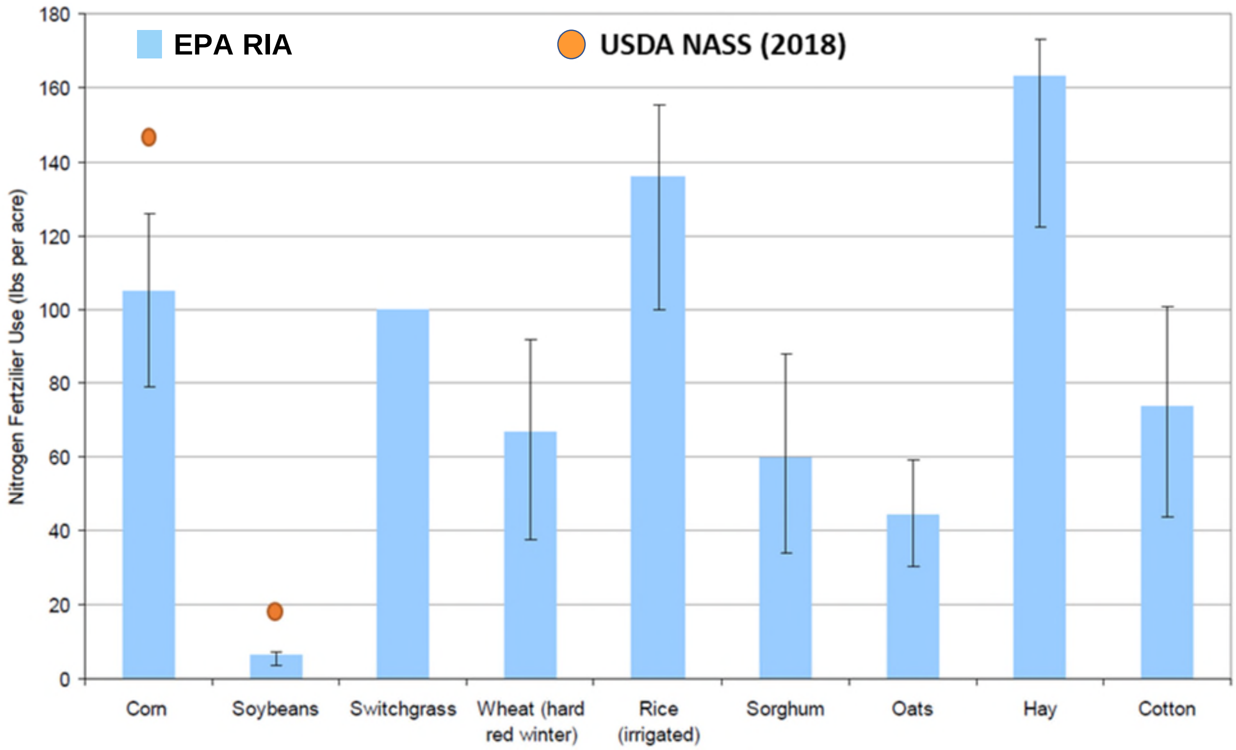

Figure A.1. FASOM Average Nitrogen Fertilizer Use by Crop. (EPA, 2010, not updated in EPA 2021)

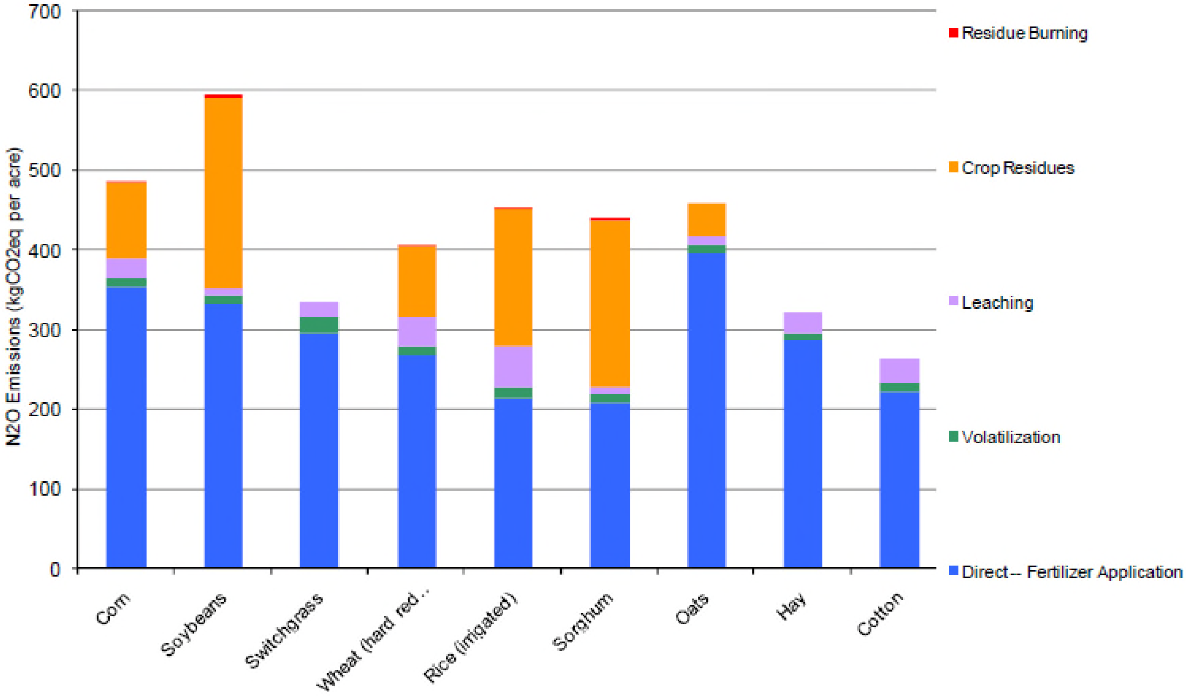

Figure A.2. N_2O emissions per acre from crop production.

Correcting the actual N fertilizer use in soybean farming, i.e., 166 g/bu, results in about a 460 g CO_2e/MMBtu of ethanol reduction in carbon intensity (CI) of corn ethanol with the soybean meal substitution rates in the GREET model.[13]

In summary: EPA attributed a certain amount of N fertilizer to soy production. DGS displaces soybeans that would otherwise be used as animal feed. Soybeans are more energy intense to grow than considered in the 2010 RIA and this displacement credit should be taken into account. The displacement value of DGS may be understated in the 2010 RIA also.

The literature review presented below examines the discrepancy between USDA NASS database and GREET on nitrogen fertilizer use in soybean farming. Soybean, which is an annual legume, requires a high amount of nitrogen (~5 lb of N per each bushel). However, 50 to 60% of the required nitrogen is supplied through the N-fixation process, which is a result of a symbiotic relationship between the plant and soil bacteria (Nafziger, 2014). The nitrogen fixation process consumes about 10% of the soybean's energy in the form of sugars produced by photosynthesis. According to Nafziger (2014), "at high yield levels, the crop might not be able to produce enough sugars to go around, and that either yield will suffer, or N fixation will be reduced." One of the methods to overcome this issue is to add nitrogen fertilizer in the growing season of soybean. Several studies have investigated the impact of nitrogen fertilizer application rate on soybean yield (Mourtzinis et al., 2018; La Menza et al., 2017; Schmidt, 2016. Mourtzinis et al. (2018) conducted one of the most comprehensive studies on soybean yield

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[13] (166 – 48) lb/bu ÷60 lb/bu. 0.307 lb SBM displaced per lb DDGS, 3.78 g CO_2e/g N fertilizer, 0.0153 g N_2O/g N.

response to N fertilizer in the U.S. which included 207 environments (experiment × year combinations) for a total of 5991 N-treated soybean yields. While this study reported that the soybean yield increased by an increase in N fertilizer application, in most individual environments, the effect of a greater N-rate on soybean yield was not significant.

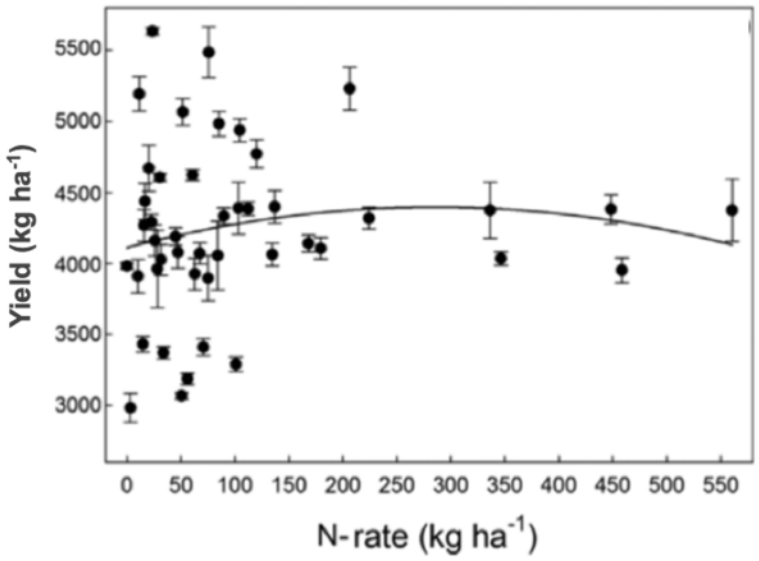

Figure A.3. Effect of Nitrogen Application Rate on Soybean Yield. (Mourtzinis et al., 2018)

While there was a large yield variability among environments within the same N rates, Mourtzinis et al. (2018) generated a second-degree N polynomial function that was significant ($p = 0.0297$), and it estimated the nitrogen rate of 340 kg ha^{-1} for maximization of soybean yield. This rate translates to 1.8 kg N per bushel of soybean (Figure A.**3**). Similarly, Nafziger (2014) studied the impact of nitrogen fertilizer on soybean yield over several years and concluded that soybean yields response to N fertilizer ranged widely among the trials.

In another study, La Menza et al. (2017) tested the hypothesis that indigenous nitrogen sources (N fixation and soil mineralization) are insufficient to meet crop N requirements for high yields. For this purpose, they developed a protocol to ensure an ample N supply during the entire crop season. They reported that soybean yield under ample N was 11% higher than the zero-N condition. Based on the literature review, we can conclude that adding N fertilizer to soybeans to achieve higher yields is gaining more attention, however, there is no clear trend between N application rate and soybean yields. There are several other factors which can affect the soybean yield such as planting date, N application timing, irrigation, etc. which need further studies. The higher emissions associated with soybean meal have been included in the more recent versions of GREET.

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Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 3

Net Gain
ECOLOGICAL SERVICES

ANALYSIS OF **EPA'S PROPOSED RULEMAKING FOR** 2020, 2021, and 2022 RVOs REGARDING LAND USE CHANGE, WETLANDS, ECOSYSTEMS, WILDLIFE HABITAT, WATER RESOURCE AVAILABILITY, and WATER QUALITY

Prepared For: Growth Energy
Date: February 3, 2022
Author: Pieter Booth, Principal[1]
Net Gain Ecological Services

This memorandum provides Net Gain's comments and observations regarding selected technical issues associated with EPA's Proposed Rule for the Renewable Fuel Standard (RFS) Program Rules for 2020, 2021, and 2022 Renewable Volume Obligations (RVOs) (the Proposed Rule; EPA 2021a) and the associated Draft Regulatory Impact Analysis (RIA; EPA 2021b). The Proposed Rule and the RIA rely heavily on EPA's Second Triennial Report (EPA 2018). Therefore, this memo updates and builds upon previous findings and conclusions presented in the following reports[2] attached as exhibits:

- Ramboll. August 18, 2019. The RFS and ethanol production: Lack of proven impacts to land and water. Prepared for Growth Energy. Ramboll, Seattle, WA. (Exhibit 1).
- Ramboll. November 29, 2019. Memorandum: Supplemental analysis regarding allegations of potential impacts of the RFS on species listed under the Endangered Species Act. Prepared for Growth Energy. Ramboll, Seattle WA. (Exhibit 2).[3]

These prior analyses addressed the absence of a demonstrated causal nexus between the RFS and land use change (LUC); adverse impacts to wetlands, ecosystems, and wildlife habitat; and adverse impacts to water resource availability and water quality. Our analyses refuted claims by other investigators that the RFS causes quantifiable adverse impacts to environmental media. We have evaluated more recent scientific literature on this topic and continue to find that there is no evidence the RFS program causes these adverse environmental impacts. Based on this finding, there is no evidence that the Proposed Rule will result in land conversion or cause adverse impacts to wetlands, ecosystems, wildlife habitat, water availability and water quality. We encourage EPA to update its analysis in the RIA to address these findings and correct its potentially misleading discussion of environmental impacts of the program.

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[1] Mr. Booth has over 30 years of experience as an environmental scientist specializing in environmental risk assessment and restoration, natural resource damage assessment, environmental due diligence, and policy analysis. He has published 19 articles and presented his work 43 times at national and international conferences. He has acted as consulting expert on over a dozen environmental damages cases in the U.S. and has been retained as a testifying expert on three international environmental damages cases.

[2] Mr. Booth was lead author on both referenced reports.

[3] Submitted by Growth Energy as "ESA Comments – Attachment B," Docket # EPA-HQ-OAR-2019-0136 Supplemental Notice of Proposed Rulemaking; Renewable Fuel Standards Program: Standards for 2020 and Biomass-Based Diesel Volume for 2021, and Response to the Remand of the 2016 Standards.

EXECUTIVE SUMMARY

The RIA presents only a generalized discussion of the drivers for and nature of potential impacts of biofuel feedstock production and biofuel refining on LUC; wetlands, ecosystems, and wildlife habitat; and water availability and water quality. It fails to recognize the complex causal links between drivers of impacts and the potential impacts described to land and water, which in turn creates the misleading impression that there is a causal relationship between the RFS and impacts to land and water, where no such relationship has been established.

Conversion of Wetlands, Ecosystems, and Wildlife Habitats: The Role of Land Use Change

Crop extensification resulting in LUC is the factor that has garnered the most attention in assessing the potential impacts to land and water from the RFS. The causal chain linking the RFS and LUC consists of a myriad of complex interactions among economic, biophysical, and social factors that are very challenging to model. In its Second Triennial Report and its Endangered Species Act No Effect Finding for the 2020 Final Rule (No Effects Finding) (EPA 2019), EPA has recognized this complexity and the large amount of uncertainty in establishing causation between the RFS and LUC, but EPA fails to adequately consider the implications of this uncertainty and absence of evidence in its conclusions in the RIA. The RIA cites studies such as Lark et al. (2015) and Wright et al. (2017) in its discussion of the RFS and LUC. More recent publications have concluded the findings of Wright et al. (2017) and Lark et al. (2015) were flawed and based on inaccurate data. In addition, EPA does not adequately consider that these studies fail to establish a causal link between the RFS and their reported results. Other recent publications similarly do not find a quantitative causal relationship between the RFS and LUC, with studies confirming our prior findings that the work of Lark et al. (2015) and Wright et al. (2017) is unreliable. The RIA should be updated to acknowledge the shortcoming of such studies and address the more recent literature.

Further, EPA largely ignores several important factors in play that negate or mitigate potential impacts of the RFS on land and water; these include:

- Continued improvement in crop yield satisfies increased demand for corn without the need for extensification and LUC.
- Cropping practices and other practices at the farm level such as conservation tilling, and vegetative buffers minimize impacts to soil, surface water, and groundwater.
- Production of Distillers Dried Grains with Solubles (DDGS) offsets a considerable amount of demand for corn and soy as animal feed.
- Adoption of more efficient irrigation methods and advanced farming technologies minimize use of irrigation water, pesticides, and fertilizers.

EPA should update the RIA to address the complex economic and biophysical links in the causal chain associating the RFS with impacts to land and water. EPA should address each important link in the causal chain, including data gaps and lack of any evidence substantiating one or more of the causal links in the chain. EPA should also address the mitigating factors set forth above.

EPA's consideration of impacts to wetlands, ecosystems, and wildlife habitat in the Second Triennial Report and the RIA consists almost entirely of general descriptions of data on nationwide wetlands losses, conversion of grassland habitat, discussions of waterfowl habitat loss, potential impacts to aquatic habitats, and potential impacts of grassland conversion to agriculture on insect pollinators. In both the Second Triennial Report and in the RIA, EPA acknowledges the uncertainty of efforts to quantify a relationship between the RFS and wetland and grassland habitat losses, yet this is not adequately reflected in its conclusions. For example, the RIA includes the following statements relative to the proposed volumes for 2022:

- There is a possibility that the proposed volumes for 2022 may "inspire" an increase in feedstock production which in turn may affect wetlands (page 91).
- There is a potential to "incent" additional production of biofuels that in turn, may affect grasslands and other ecosystems (page 96).

Given the magnitude of the uncertainties described by EPA and others in establishing causation between the RFS and such impacts, and considering the myriad of economic, biophysical, and social links in the causal chain, the "possibility to inspire" feedstock production or "incent" biofuel production appears to be vanishingly small. This should be given due consideration in the RIA.

Water Quantity and Water Quality

As with the discussion of LUC, the RIA presents lengthy discussions of impacts associated with agriculture in general (including biofuel feedstocks) and water quantity and water quality; however, the RIA fails to adequately describe the complex economic and biophysical links in the causal chain associating these impacts with the RFS. EPA should reevaluate the discussions of generic impacts as well as address the causal chain as set forth above. In addition, to the extent EPA discusses the hypoxic zones in western Lake Erie and the Gulf of Mexico it must explain that there has been no quantitative attribution of these water quality impacts to the RFS and that any such attribution is conjecture. We also recommend that EPA enhance the discussion of technological improvements in agriculture that reduce water and agrichemical use.

THE RFS AND LAND USE CHANGE

The Draft RIA has three critical failings in its discussion of the potential role of the RFS on LUC:

- It relies on flawed studies that underlie the Second Triennial Report without due consideration of more recent work that shows there is no demonstrated causal link between the RFS and LUC, as EPA itself has acknowledged since it prepared the Second Triennial Report.
- It fails to consider the high degree of uncertainty in the causal relationship between the RFS and biofuels prices, which is a fundamental assumption underlying assessments of the RFS, and it fails to acknowledge that such a relationship has not been adequately quantified.
- It fails to address important mitigating factors including the continuing increase in crop yield, adoption of conservation farming practices and modern farming technology, and production of DDGS.

These shortcomings are discussed below.

Reliance on Flawed Research and No Established Causal Relationship

Some investigators have asserted that the RFS has resulted in extensive conversion of non-agricultural land to agriculture due to increased demand for corn for ethanol. Our findings indicate that these claims are not borne out, in part because the studies use unreliable databases, present flawed data analysis, and/or do not attempt to establish a causal link between the RFS, increased ethanol production, and LUC. Indeed, EPA (2019) repeatedly asserts that no causal connection has been established between LUC associated with corn production and the RFS.

As background, in the discussion of potential impacts of the RFS on LUC in its Second Triennial Report, EPA repeatedly cites geospatial analysis conducted by the following researchers who used the Crop Data Layer (CDL)[4] dataset:

- Lark et al. (2015) analyzed LUC nationwide during the period 2008-2012 using CDL calibrated with ground-based data from USDA’s Farm Service Agency (FSA), and data from the National Land Cover Database (https://www.mrlc.gov/national-land-cover-database-nlcd-2016). The authors reported that 7.34 million acres of previously uncultivated lands became utilized in crop production and of those 1.94 million acres (785,000 ha.) of converted lands were planted in corn as a first crop.
- Wright et al. (2017) assessed quantitative spatial relationships between the loss of grasslands and the locations of ethanol refineries with the intent of associating this LUC with demand for ethanol. Wright et al. (2017) note that approximately 2 million acres of grassland was converted to row crops within 50 miles of an ethanol refinery between 2008 and 2012.

Several investigators have shown that reliance on inadequately corrected and verified CDL data leads to an unacceptable level of uncertainty in geospatial analysis and potentially misleading results and conclusions from such analysis. For example, Dunn et al. (2017) examined data for 2006-2014 in 20 counties in the prairie potholes region using the CDL, a modified CDL dataset, data from the National Agricultural Imagery Program, and ground-truthing. Dunn et al. (2017) concluded that analyses

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[4] The CDL data set is developed by the U.S. Department of Agriculture National Agricultural Statistics Service (https://www.nass.usda.gov/Research_and_Science/Cropland/SARS1a.php).

relying on CDL data returned the largest amount of LUC by a wide margin. They further concluded that errors associated with CDL-based analyses resulted in estimates where "the number of hectares in the potential error associated with CDL-derived results is generally greater than the number of hectares the CDL-based analysis determined had undergone a transition from grassland, forested land, or wetland to agricultural land." This suggests that errors in classification inherent in the CDL can result in uncertainty bounds that are larger than the estimates themselves (thereby even predicting negative land conversion to agriculture).

Specifically, Dunn et al. (2017) pointed out that the findings reported by Lark et al. (2015) contradict USDA data indicating that cropland area has remained almost constant during the period 2008-2012. Similar critiques have been published of the findings reported by Wright et al. (2017) using the CDL data set. The RIA does not acknowledge a major shortcoming of the study by Wright et al. (2017), namely, the authors' admission that their study "did not consider potential effects of other explanatory variables." The paper also discussed the errors in the data itself, stating that the "conversion of non-cropland to cropland was mapped correctly over 70% of the time," which means that it was mapped incorrectly 30% of the time, a considerable percentage.

Several other recent papers challenge the findings of previous authors who have implicated the RFS in LUC. Of note are papers by Pates and Hendricks (2019), Pristola and Pearson (2019), and Shrestha et al. (2019). Pates and Hendricks (2019) assessed the local impact of ethanol plants on cropland transitions and concluded that ethanol plant expansions *reduce* the probability of cropland conversion by 0.5% on average and that fields near ethanol plants were 10% *less* likely to convert non-agricultural land into cropland than fields farther away. The authors acknowledge that this result contradicts their underlying premise that ethanol plants induce LUC through local effect on corn prices. They speculate (without providing evidence) that this contradiction may result from bias due to concurrent changes in Crop Reserve Program (CRP) policy that disproportionately affected areas near ethanol plants.

Pristola and Pearson (2019) performed a critical review of literature that was relied on by EPA in its Second Triennial Report (and again in the RIA) regarding the RFS and LUC and concluded that major flaws in the work by Wright and Wimberly (2013), Lark et al. (2015), and Wright et al. (2017) render the work by these authors unreliable. Their major findings are as follows:

- All three studies reviewed relied on data from the CDL which has several shortcomings including the inability to differentiate between native prairie, CRP, grass/hay, grass/pasture, and fallow/idle grassland types, especially in earlier years.
- Improvements in the CDL over time make it problematic to compare land cover and land use over relatively long time periods. Thus, results reported in the three studies might be biased due to the CDL's ability to better identify cropland in later years than earlier years. This bias would give the appearance that cropland expanded, as these authors assert.
- All three studies reported cropland expansion over the conterminous United States, but this is contradicted by data from the NASS that show a contraction of cropland from 2008 to 2012, and that by 2017, cropland acres were below 2007 levels.

Both Lark et al. (2015) and Wright et al. (2017) relied on CDL data for Iowa for 2008 and 2012. Data from NASS revealed that during the period 2008-2012 in Iowa there was a net increase of cropland of

38,000 acres as compared to an increase of 263,468 acres as reported by Lark et al. (2015) and 295,100 acres as reported by Wright et al. (2017).

Shrestha et al. (2019) studied the relationship between biofuel demand, food prices, and LUC. One of the authors' objectives was to assess the accuracy of automated land use classification as performed by previous investigators (including Lark et al. 2015) as compared to manual land use classification techniques. For this analysis, the authors selected study areas within three counties near Moscow, Idaho with a total land area of 664 km^2. The areas were selected to represent a range of climates and proportions of land cover types. Their work revealed that 10.90% of non-agricultural land was misclassified as agriculture, whereas only 2.23% of agricultural land was misclassified as non-agricultural. The automated classification showed an 8.53% increase in agricultural land from 2011 to 2015, while the manual classification showed only a 0.31% (±1.92%) increase. The result derived via manual classification was within the margin of error suggesting that there was no significant LUC during the period.

These recent findings further call into question EPA's continued reliance on flawed studies in its discussion of the RFS and LUC, and indeed call into question whether there is any quantifiable causal link between RFS and LUC.[5]

Inadequate Consideration of the Drivers of Biofuels Feedstock Prices

Studies that attempt to link the RFS with impacts to land and water (especially those studies focusing on LUC) include a foundational presumption that there is a causal link between the RFS and biofuel feedstock prices. Econometric models used to quantify the relationship have a high degree of uncertainty, partly because agricultural commodities are traded on international markets and their production is affected by highly uncertain and seasonally variable weather conditions. The RIA acknowledges this uncertainty by stating that "…models that attempt to project prices at specific times in the future, or in reaction to specific demand perturbations, necessarily contain high levels of uncertainty" (page 209). The RIA goes on to discuss the relationship between grain stores and futures prices and how annual volumes of grain stores depend on current year harvests and future year harvest projections. The RIA provides no discussion of the relationship, if any, between grain stores and the RFS. The RIA acknowledges that, in a general sense, grain prices are influenced by "an array of factors from worldwide weather patterns to biofuel policies to international tariffs and trade wars" (page 209). Finally, the RIA presents results from a meta-analysis of the impact of increased biofuel production on corn prices.[6] Based on the results of the single meta-analysis by Condon et al. (2013) conducted almost a decade ago the RIA projects that the proposed ethanol volumes for 2021-2022 will increase the price of corn 3% per billion gallons, or $0.11per bushel.

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[5] In addition, several publications released since August 2019 reported on LUC such as conversion of grassland to corn and soy (e.g., Zhang et al. 2021; Lark et al. 2019b; and Arora and Wolter 2018) and cropland expansion and potential wildlife impacts (Lark et al. 2020); however, these studies do not attempt to establish causal linkages between increased demand for ethanol from the RFS and LUC. Rather, these articles and others reveal a trend among researchers toward improving the accuracy of geospatial modeling to discern specific LUC which appears to be a shift from previous efforts to associate LUC with the RFS. In addition, several authors focused on assessing the environmental benefits of improved agricultural practices, conservation, and restoration, and policy actions to reduce grassland losses (e.g., Fargione et al. 2018; Lark 2020; and Runge et al. 2017).

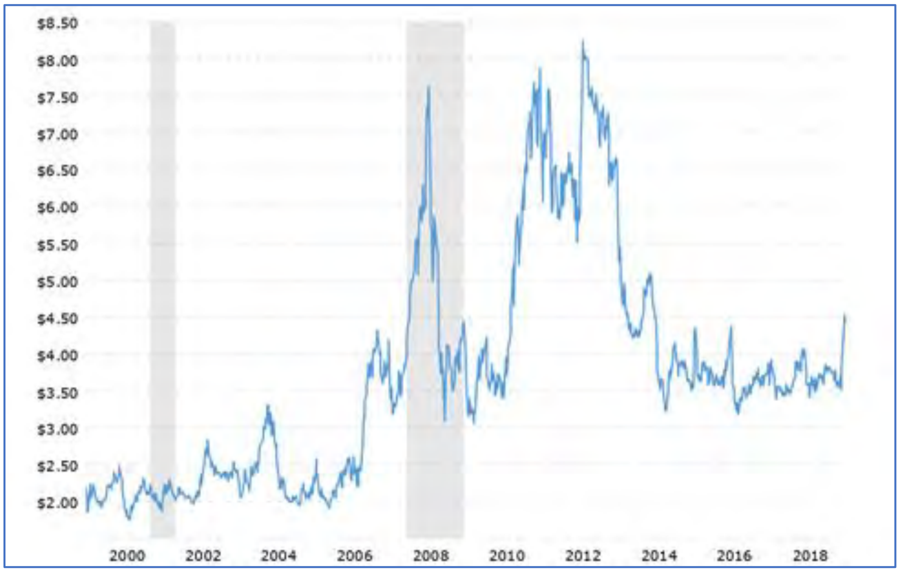
[6] EPA states that Condon et al. reviewed published papers in 2015, when in fact, the working paper was released in 2013 and reviewed papers published between 2008 and 2013.

Despite the acknowledgment of the high degree of uncertainty in econometric models attempting to link the RFS to biofuel feedstock prices, the RIA presents no discussion of such uncertainty and rather proposes the projected price increases estimated by Condon et al. (2013) as fact. For example, the RIA presents no information on whether the meta-analysis conducted by Condon et al. (2013) controlled for how and to what extent corn prices were affected by rapid economic growth in developing countries leading to growing food demand or how corn prices were affected by a dietary transition from cereals toward more animal protein. As a result of these market factors alone, global consumption of agricultural commodities has been growing rapidly. Further, the temporal fluctuation in corn prices is highly influenced by the effect of the price of oil on production inputs such as agrichemicals and fuel for farm equipment, and this relationship is not mentioned by EPA in either the Second Triennial Report or the RIA. Also significant is a study by Shrestha et al. (2019) that analyzed food price inflation and land use classification and concluded that food price inflation since 1973 was lowest during the biofuel boom years of 1991-2016 and was most highly correlated with the price of oil.

Figures 1 and 2 show nominal prices of West Texas Intermediate crude and corn for the latest 20-year period (the shaded areas on the graphs show period of US recessions) and demonstrates that corn prices track very closely to the price of oil.

Figure 1. West Texas Intermediate Crude Price ($/barrel).

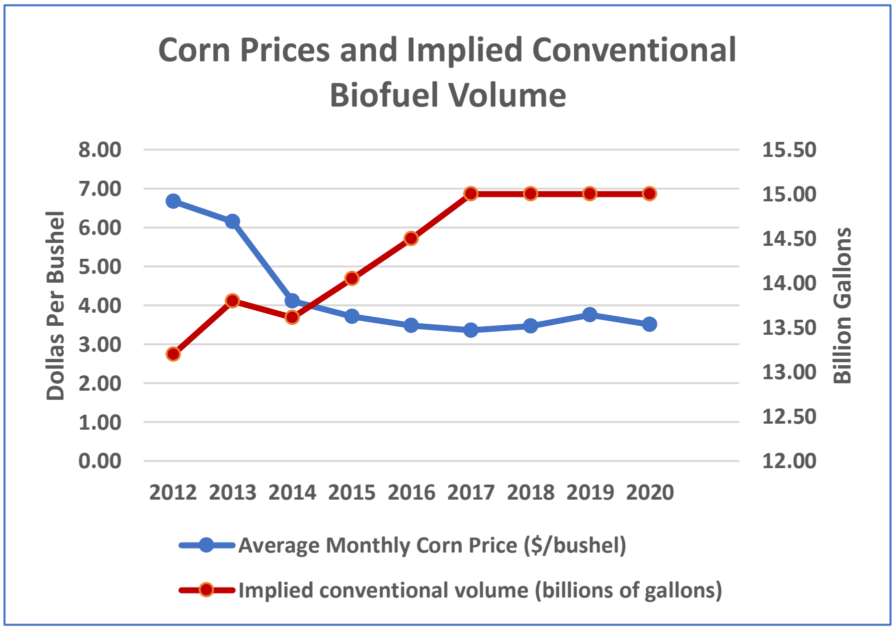
Figure 2. U.S. Corn Price ($/bushel).



SOURCE: Macrotrends n.d.

By contrast to the close relationship between U.S. corn prices and the price of crude oil, Figure 3 shows a plot of U.S. average annual corn prices and the implied ethanol volumes 2012-2020 showing no apparent relationship.

Figure 3. Corn prices versus implied conventional ethanol volumes 2012-2020.



SOURCES: https://www.nass.usda.gov/Charts_and_Maps/graphics/data/pricecn.txt and Congressional Research Service (2020).

Inadequate Consideration of Mitigating Factors

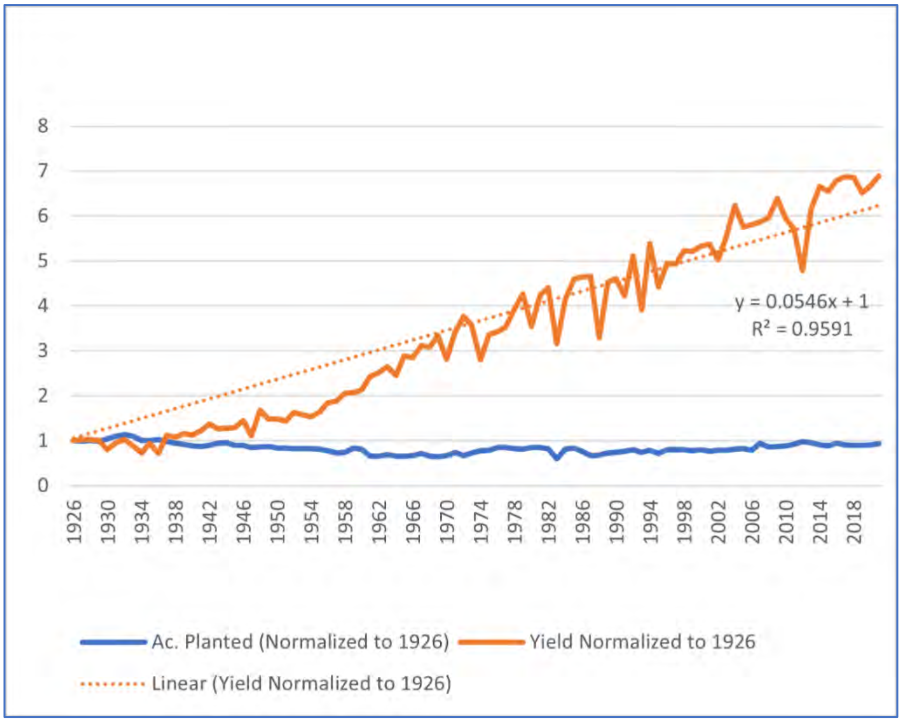
The RIA, like the Second Triennial Report, fails to adequately consider important factors that act to dampen any effect of the RFS on converting non-agricultural land to agriculture for ethanol feedstock, including:

- Increased demand for corn for all uses has mostly, if not fully been met by increased yields.
- Cropping practices such as double cropping increase production with no additional need for land in cultivation.
- Production of dried distillers' grains with solubles (DDGS) by ethanol refineries offset a considerable amount of demand for land to grow corn and soy for animal feed.

Increases in Corn Crop Yield

EPA has not adequately accounted for the fact that increased demand for corn for ethanol and the effect of this increased demand on land conversion, if any, has been offset by increases in yield over time. In fact, the number of acres planted in corn across the United States in the last couple of decades has remained close to or below the total acres planted in the 1930s, despite increases in demand for corn as human food, animal feed, and biofuels over this nearly 90-year period. The increase in demand has largely been met by an approximately 7-fold increase in yield (bushels per acre) (Figure 4). The USDA further anticipates that changes in corn production will result in an increase of approximately 16.1 more bushels per acre by 2028 without a substantial increase in farmed acreage.

Figure 4. Relative Change in Acres of Corn Planted and Yield (1926-2021)



Cropping Practices

Intensification refers to increasing the production of a crop on the same acreage of land and does not directly result in LUC. Extensification refers to increasing production of a crop by planting on land not previously in agriculture. A farmer can intensify production of a crop by switching crop types to a more desired crop or by double planting a single crop (double-cropping) instead of seasonally rotating crops. EPA's Second Triennial Report acknowledges the potential significance of cropping practices in meeting any increased demand for corn due to the RFS. By contrast, the RIA does not mention cropping practices in this context, rather it discusses double cropping only briefly and only as it relates to potential effects on water quality. In its Second Triennial Report, EPA cites a study by Ren et al. (2016) in Iowa (the state with the largest corn production) that examined changes in corn and soybean rotations around 2017 and found that 59% of the area that had been in corn/soy rotation prior to 2007 was in two or more years of continuous corn after 2007. However, EPA fails to acknowledge the most important conclusion related to LUC from this study: "… it is clear that the expansion of corn production after 2007 was realized by altering crop rotation patterns" (Ren et al. 2016).

Further, the RIA mentions the findings reported by Plourde at al. (2013) regarding farmers switching from corn/soy rotation to double cropping of corn as a means of increasing corn production but fails to acknowledge its significance in the context of intensification in lieu of extensification to meet demand. Rather, Plourde et al. (2013) is mentioned in terms of potential effects on nitrogen and phosphorous loads to surface waters.

Use of Distillers Grains and Solubles as a substitute for Corn and Soy in Animal Feed

EPA has not adequately accounted for the fact that the ethanol industry produces large amounts of distiller's grains with solubles (DDGS) and that this biproduct is used as animal feed where it substitutes for traditional grains such as corn and soy. EPA's Second Triennial Report acknowledges the role of DDGS in offsetting overall demand for corn and soy; however, this fact is ignored in the RIA.[7] Production of DDGS and its use as a substitute for corn and soy in animal feed likely has a very important mitigating effect on any potential contribution of the RFS to LUC. This effect can be estimated based on the annual volume of corn grown for ethanol (bushels), the annual figures for yield (bushels per acre) and the following assumptions:

- 17 lbs of DGGS are produced per bushel of corn processed[8]
- 1 lb of DGGS is equivalent to 1.22 lbs of corn/soy (Hoffman and Baker 2021)
- One bushel of corn/soy weighs on average 58 lbs

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[7] The Second Triennial Report states that approximately 12% of the total corn production from 2014-2016 was returned to the feed market in the form of DDGS. The Report also acknowledges a study by Mumm et al. (2014) that concludes that 40% of corn grown in 2011 was estimated to be utilized in ethanol production; however, when the offsetting effect of DDGS is accounted for, the acreage devoted to corn for ethanol goes down to 25%. The report also does not acknowledge that these same authors estimate that the percentage of land devoted to corn for ethanol will drop further to 13% by 2026 due to technological advances increasing crop yield as well as increasing the efficiency of the ethanol distillation process. It is curious that the RIA mentions this study as well, but only in the context of water quality.

[8] Explaining Fluctuations in DDG Prices - Center for Commercial Agriculture (purdue.edu) (accessed 1/5/2022).

Applying these assumptions to the annual amount of corn grown for ethanol and annual yield during the period 2008 to 2020, production of DDGS is estimated to have offset corn/soy equivalent acreage ranging from 8.7 million acres in 2008 to 13.5 million acres in 2012 with an annual average of 11.2 million acres over the period[9].

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[9] Figures on corn displaced by DDGS 2010-2020 from World of Corn 2021. By comparison, the U.S. Corn Growers Association estimates 6.0-8.6 million acres per year over the period 2010-2020 with an average of 6.9 million acres per year but it is not clear how its estimate was calculated.

The RFS AND CONVERSION OF WETLANDS, ECOSYSTEMS, AND WILDLIFE HABITAT

The introduction to this section in the RIA simply repeats information presented and conclusions made in the Second Triennial Report regarding land use change. Without providing any supporting information, the introductory paragraph to this section wrongly concludes that "Evidence from observations of land use change suggests that some of this increase in acreage and crop use is a consequence of increased biofuel production."

In the discussion of wetlands, the RIA presents information in reports from several federal agencies that describe the status and trends of U.S. wetlands. These reports and sources of data merely record changes in wetland types nationwide and do not provide any analysis of the cause of the changes that would be useful in the context of the RIA. The RIA goes on to discuss "several regional studies" of changes in wetland area but highlights only one study: Wright et al. (2017). The RIA concludes that this study demonstrated a causal connection between the proximity of an ethanol refinery and loss of wetlands. The RIA also relies on Wright et al. (2017) in its discussion of losses of shrubland and forest ecosystems. As described above, the study by Wright et al. (2017) has been shown to be unreliable.

The RIA also discusses loss of land in the CRP and references a single study by Morefield et al. (2016) who conclude that CRP land lost between 2010 and 2013 largely went to conversion to row crops for corn and soy. The authors of the study do not try to attribute the loss of CRP to increased demand for biofuels, rather they acknowledge that important drivers of extensification at the expense of grassland and wetlands include a combination of "commodity prices, reduced land retirement options, and diminishing interest in land retirement programs…"

In its discussion of wildlife impacts, the RIA mentions loss of wetlands and impacts to ducks, and loss of grasslands and impacts to grassland birds and insects. The RIA acknowledges that the effects of the RFS on wildlife have not been studied, yet presents results from a study of grassland bird diversity and cropland that implicates LUC in reduced species diversity, and studies of impacts to pollinators, including a discussion of the potential role of exposure to agrichemicals.[10] The RIA does not infer a causal relationship between the RFS or crops grown for biofuel feedstock as a driver for effects to wildlife and concludes that "[a]t present it is not possible to confidently estimate the fraction of wildlife habitat loss or of corn or soy production that is attributable to biofuel production or use. Thus, we cannot confidently estimate the impacts to date on wildlife from biofuels generally nor from the annual volume requirements, specifically" (pages 98-99).

The discussion of potential impacts to wetlands ecosystems, and wildlife habitat presented in the RIA (as well as in the Second Triennial Report) is unbalanced and creates a false impression that the generic impacts described are attributable to the RFS. EPA should reevaluate this discussion to present a balanced perspective that accurately presents the current state of knowledge regarding the lack of a quantitative relationship between biofuel feedstock grown specifically to meet the RFS requirements and potential impacts.

An expanded review of literature on this topic since our work on Exhibits 1 and 2 concludes that no publications establish a quantitative or qualitative causal link between impacts from biofuel feedstock

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[10] This includes a discussion of neonicotinoids which concludes that the risk of these chemicals to pollinators is poorly understood, and EPA's preliminary determination is that the risk is low.

production and impacts to wetlands, ecosystems, or wildlife habitat.[11] Wiens et al. (2011) suggests a linkage between biofuels and potential biodiversity impacts by implicating demand for ethanol in the loss of CRP lands but provides no analysis of causation. Wimberly et al. (2018) implicate corn and soy extensification in increases in grassland habitat fragmentation in eastern South Dakota and western Minnesota. These authors state that the LUC was driven by higher corn prices driven by increasing demand for ethanol, and they cite Lark et al. (2015), Wright et al. (2017), and Wright and Wimberly (2013)—all studies that have been largely discredited, as described above. Hoekman and Broch (2018) describes benefits and "dis-benefits" of LUC ostensibly driven by higher ethanol prices but provide no quantitative or qualitative causal links to the RFS or corn grown for ethanol.

In sum, the RIA should reflect that the latest scientific literature does not establish any causal relationship between the RFS and impacts to wetlands, ecosystems, or wildlife habitat.

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[11] For many publications on this topic, that is not the goal. For example, Pleasants (2017) quantifies milkweed stem abundance in soy and corn fields in the U.S. Midwest and develops estimates of the restoration required to increase monarch butterfly populations but does not mention the RFS or biofuels. A paper by Landis et al. (2018) models biodiversity and ecosystem services under different biofuels cropping systems, but makes no mention of the RFS or corn grown for ethanol.

THE RFS AND WATER RESOURCE AVAILABILITY AND WATER QUALITY

Both the Second Triennial Report and the RIA present detailed discussions of water use to grow corn as well as potential adverse effects to water quality from agriculture in general due to soil loss and transport of pesticides and fertilizers to surface water bodies. However, EPA provides no causal nexus between these potential impacts and agriculture to produce biofuels in general, or more to the point, production of biofuels for the RFS.

Further, existing studies suggest that environmentally protective goals for biofuel production are achievable as best management practices and technological advances in farming continue to be adopted by the farming community.

Water Resource Availability

Water Used for Growing Corn

As is true for LUC, the relationship between corn production and water resource availability and water quality varies geographically and temporally, and studies have failed to demonstrate a quantitative causal link between corn grown for ethanol or the RFS and impacts to water availability. The RIA, EPA's Second Triennial Report, and studies cited therein provide information regarding the geographical distribution of irrigated agriculture in general and biofuel crops relative to known stressed aquifers, but there is no evidence or analysis provided regarding the relative impact of corn grown for ethanol production in response to RFS mandates.

In its discussion of life cycle water use for biofuel feedstock production, the RIA relies on information and analysis presented in the Second Triennial Report, including specific reference to Lark et al. (2015) and Wright et al. (2017) regarding these authors' now refuted conclusions about cropland expansion associated with biofuels and the RFS. The RIA does not present any assessment of the actual water intensity of corn grown for ethanol, rather it presents some general statistics regarding use of water to grow corn and soy. For example, the RIA makes the following statements:

- 90% of corn is grown in areas where corn is non-irrigated.
- If 20% of corn production was used to produce 12 billion gallons per year of ethanol, this would represent only 4.4% of all irrigation withdrawals (citing a study by Dominguez-Faus et al. 2013).
- Nebraska is one of the states with the largest water withdrawals for irrigation and recent increases in irrigation withdrawals have been largely driven by the need to irrigate corn for ethanol (citing a report by the National Academy of Sciences; NAS 2011).

These statements are of little value without providing specific context relative to corn grown for ethanol, and this context is highly geographically variable. In particular, the statement by NAS (2011) regarding irrigation withdrawals in Nebraska and corn grown for ethanol is unsubstantiated by the authors of the report and should not have been cited in the RIA. Moreover, it is outdated by over a decade. However, the RIA acknowledges that "…there have been no comprehensive studies of the changes in irrigated acres, rates of irrigation, or changes in surface and groundwater supplies attributed specifically to the increased production of corn grain-based ethanol and soybean-based biodiesel" (page 123).

A review of literature not previously presented by EPA did not reveal any studies attempting to quantify water use specifically for growing corn that was destined to produce ethanol required to meet RFS requirements. Xie et al. (2019a), Xie and Lark (2021), and Xie et al. (2021) present findings related to mapping of irrigated land in the U.S., but they present no nexus between water use and the RFS or water use and corn grown for ethanol. Xie et al. (2019b) present a method for mapping annual irrigation distribution over the period 2000-2017 and conclude that irrigation over the period 2009-2017 was greater than over the period 2000-2008 and that the greatest increase was in Nebraska and was associated with corn and soy. However, the paper contains no mention of the RFS, biofuels, or ethanol and therefore does not attempt to link the increase in annual irrigation to renewable fuels policy and its conclusion regarding association of increased irrigation with corn and soy is unfounded.

The impacts of irrigation withdrawals to grow corn for ethanol are dependent on the existing condition of available water resources, the use of irrigation water to produce corn relative to other crops, and the proportion of irrigated corn grown that is used in the production of ethanol. Although the RIA acknowledges these complexities, it fails to explicitly relate them to the RFS or to corn grown for ethanol. The RIA postulates three approaches for estimating the change in water demand that may result from increased ethanol volumes: life cycle water requirements for ethanol as compared to gasoline, projected LUC and crop management, and changes in crop prices and associated economic value of irrigation. The RIA acknowledges EPA's inability to perform such analyses yet concludes that there is likely to be some increased irrigation pressure on water resources due to the proposed ethanol volumes. The RIA fails to acknowledge that "increased irrigation pressure," to the extent such a thing may occur, does not necessarily translate to increased overall water use or strain on existing water resources. Moreover, the RIA asserts that the changes in irrigation may result from the proposed volumes impact on crop prices without first establishing that any such impact on crop prices has occurred historically or is likely to occur as the result of the proposed volumes, which are similar to the volumes in 2019.

Water Use for Ethanol Production

Ethanol refineries have made great strides in reducing water consumption. In a 2007 Renewable Fuels Association survey of 22 ethanol production facilities (representing 37% of the 2006 volume produced), dry mills used an average of 3.45 gallons of water per gallon of ethanol produced and wet mills used an average of 3.92 gallons of water per gallon of ethanol produced. Muller (2008) reported declines in water requirements at ethanol dry mills from 5.8 gallons of water per gallon of ethanol (gal/gal) in 1998 to 2.7 gal/gal in 2012. Wu and Chiu (2011) noted that water consumption in existing dry mill plants had, on a production-weighted average basis, dropped 48% in less than 10 years, a reduction that is similar to that reported by Muller (2008). These previously reported improvements in efficiency are confirmed by the latest scientific literature. For example, Wu (2019) reports a 54% decrease in water intensity for the ethanol industry over the period 1998-2017 and a 12% decrease over the period 2011-2017 illustrating the gains in water use efficiency at ethanol plants. Improvements in water use efficiency at ethanol refineries are largely ignored by EPA.

Advancements in Farming Practices Reduce Agriculture's Impacts on Water Resource Availability

What is clear but not adequately recognized by EPA in the RIA or Second Triennial Report is that advancements in farming practices and technology have reduced the negative impact of farming on water resource availability. Over the past decade, there has been increased use of precision agriculture methods as well as standard best practices which retain soil moisture. This trend is expected to continue and is expected to reduce the need for irrigation. As an indication of the trend in irrigation reduction, the University of Nebraska (2018) reports that in Nebraska (as a bell-weather of other dry western states), the percentage of all corn acreage that is irrigated has declined from a high of 72% in 1981 to 56% in 2017.

Farms are increasingly moving away from traditional, less-efficient irrigation systems and adopting water saving irrigation systems. In 2018, 67% of cropland acres irrigated used pressurized systems including sprinklers and low-flow micro systems (Hrozencik and Aillery 2021). The number of farms using inefficient gravity irrigation systems decreased from 62% in 1984 to 34% in 2013, converting mostly to pressure-sprinkler irrigation which is more efficient than gravity irrigation. Water savings associated with advanced irrigation systems relative to typical gravity systems are summarized below[12]:

- Subsurface Drip: 25-35%
- Rainwater Harvesting: 50%
- Precision Agriculture: 13%
- Conservation Structures: 18%

In terms of the adoption of precision agriculture, almost 10% of farms use soil-moisture or plant-moisture sensing devices or commercial irrigation scheduling services. Sensor technology can optimize irrigation scheduling and hence increase water use efficiency. It is also anticipated that additional large industrial farms (which make up a large volume of total production) will employ water use simulation models that are based on corn growth patterns and weather conditions. Adoption of these technologies will continue to grow in the U.S., and particularly in the west, where 72% of water irrigation takes place and farmers have recent experience with low water supply following the 2012-2016 drought. In addition to changes in irrigation technologies, agricultural practices regarding the timing of irrigation have helped reduce the amount of water applied to corn. For example, Xue et al. (2017) have shown that corn crops can forego initial irrigation without significant adverse effects to yield.

Genetic engineering and selection for improved drought tolerant corn cultivars has resulted in corn strains that can tolerate a 25% reduction in water application without affecting yield. The use of drought-tolerant corn, which was commercially introduced in 2011, increased to over 22% of the total U.S. planted corn acreage by 2016 (Mcfadden et al. 2019). More importantly, this percent of use was greatest in the driest corn-producing states of Nebraska (42%) and Kansas (39%). Other states that

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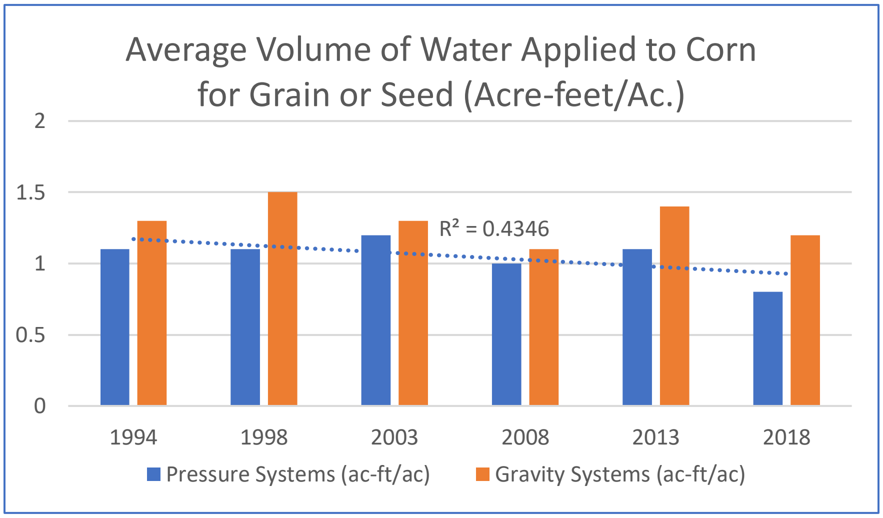
[12] See for example Ailen 2013, Barton and Clark 2014, Biazin et al. 2012, Center for Urban Education about Sustainable Agriculture (CUESA) 2014, Gowing et al. 1999, Shangguan et al. 2002, National Research Council 2008, Netafim n.d., and Qin et al. 2015.

are not as drought prone (e.g., Minnesota, Wisconsin, and Michigan) saw drought-tolerant corn planting ranging between 14% and 20% of total acreage in 2016. Figure 5 illustrates the downward trend in the volume of water applied to corn over the period 1994-2018.

Figure 5. Average volume of water applied to corn over the period 1994-2018.



SOURCE of Data:
ttps://www.nass.usda.gov/Publications/AgCensus/2017/Online_Resources/Farm_and_Ranch_Irrigation_Survey/fris_2_0036_0036.pdf Accessed 1/5/2022

Water Quality

The RIA discussion of potential water quality impacts, like the Second Triennial Report, fails to establish a causal link between corn grown for the RFS and water quality impacts. The RIA discusses several studies addressing impacts to soil and surface water from corn and soy, including erosion, soil carbon depletion, and nutrient runoff. These impacts are inextricably linked to LUC as well as crop intensification, but the results of these studies are relevant only to the extent the RFS-LUC or RFS-intensification link can be demonstrated and quantified. The RIA at page 101 presents a simplistic example calculation of the increased nitrogen applied to farm fields nationwide due to corn extensification, but this calculation is based on the work of Lark et al. (2015) which has been shown to be unreliable. This example calculation should be removed from the text of the RIA because it is erroneous and misleading. Similarly, the RIA discusses data from USDA NASS for percentages of planted corn acres that received treatment using herbicides, insecticides, and fungicides, but such information is irrelevant to an analysis of the water quality impacts of the RFS unless it can be quantitatively tied to the program. Finally, the RIA cites work by Garcia et al. (2017) who estimate that corn production between 2002 and 2022 would result in nitrate groundwater contamination > 5 mg/L in areas with sandy or loamy soils. Although Garcia et al. (2017) mention the RFS as a potential driver for increased corn production, the study does not derive a quantitative causal relationship between their conclusions and the RFS, nor is that a stated goal of the research. It is inappropriate for EPA to present this work without adequate context.

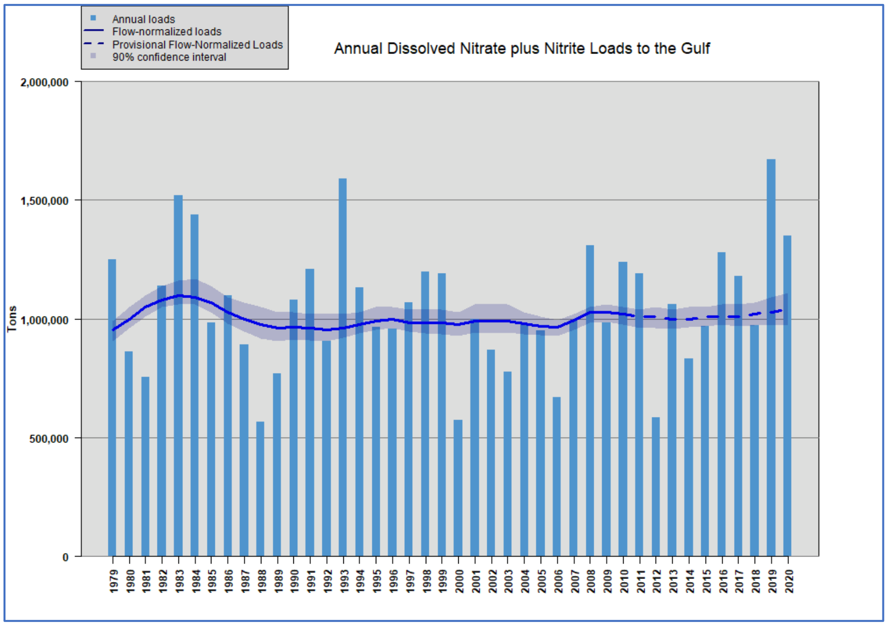
In the absence of evidence of a quantitative causal relationship, the discussion in the RIA of the relationship between agriculture (and corn growing in particular), and proximal water quality is unbalanced and creates the unfounded impression of a direct causal relationship.

Similarly, the RIA presents a discussion of the potential downstream effects of corn and soy cultivation. In terms of aquatic life, the RIA presents a discussion of the biological condition of the nation’s rivers and streams and the causative factors contributing to poor conditions. As with its Second Triennial Report, the RIA mentions large scale hypoxia in western Lake Erie and the Gulf of Mexico and the nexus to nutrient enrichment. The RIA also discusses the potential for downstream impacts from herbicides and pesticides applied to corn and soy. Throughout these discussions, the RIA provides no nexus to the RFS.

Like the Second Triennial Report, the RIA fails to acknowledge that there is no established causal connection between corn grown for ethanol and the formation, persistence, or severity of hypoxic events in western Lake Erie or the Gulf of Mexico. The RIA ignores a rich literature describing the complexity of these phenomena as well as characterization and modeling of nutrient loading to these systems from various sources, but such studies fail to establish a causal relationship between the formation and severity of the GoM dead zone and the RFS. For example, econometric modeling by Secchi et al. (2011) predicts an increase in corn acreage due to corn intensification spurred by increasing corn prices and extends that prediction to estimate increased nutrient loading to the Upper Mississippi River basin; however, these authors did not attempt to assert a causal connection between increased corn prices (the variable that drives their analysis) and the RFS.

As illustrated in Figure 6, the RIA fails to acknowledge that nitrogen loading to the Gulf of Mexico has remained fairly stable over the past 40 years.

Figure 6. Annual Nitrate and Nitrite Loading to the Gulf of Mexico 1980-2020.



Source: USGS n.d.

There may be no dispute that excess nutrient loading from the key watersheds that discharge into western Lake Erie and the northern Gulf of Mexico contribute to eutrophication and hypoxia; however, these watersheds contain a complex mix of urban and rural uses that present important sources of nutrients as well as toxic contaminants. In any case, the direct causal link to the RFS or corn grown for ethanol production (compared to all other uses and compared to all other agricultural activities) is not substantiated by the Second Triennial Report or the literature cited therein and should be qualified as such to the extent discussed in the RIA. Regional hypoxic conditions in western Lake Erie and the Gulf of Mexico were increasing in frequency and severity, long before ethanol production increased, and this fact should also be acknowledged by EPA.

The RIA also fails to acknowledge the importance of regional weather on the occurrence and severity of large-scale hypoxia events. The National Oceanic and Atmospheric Administration (NOAA) states that a major factor contributing to the large Gulf of Mexico "dead zone" in 2019 was the abnormally high amount of spring rainfall that resulted in flows in the Mississippi and Atchafalaya Rivers that were 67% above the average flows over the previous 38 years[13]. Data collected by the United States Geological Survey (USGS) indicate that because of these high flows, nitrate loads were about 18% above the long-term average, and phosphorus loads were approximately 49% above the long-term average (USGS 2019).

Notwithstanding the misleading discussions presented in the RIA, the RIA correctly acknowledges 1) that the important determinants of impacts to water and soil quality are not directly determined by the RFS; 2) there are many effective management practices that can act to counterbalance any negative impacts from corn for ethanol; and 3) the magnitude of potential impacts due to the RFS cannot be estimated at this time. The RIA should be edited to present a more balanced discussion of potential water quality impacts from biofuel feedstock agriculture within the specific context of crops grown for biofuels to meet the goals of the RFS program.

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[13] Courtney and Courtney (no date) reported that predictions made by NOAA and Louisiana University's Marine Consortium of the areal extent of the GoM dead zone were 31% higher than the actual measured hypoxic areas from 2006 to 2014. The authors of this paper hypothesize that GoM waters are becoming less susceptible to low dissolved oxygen over time.

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EXHIBIT 1

RAMBOLL. AUGUST 18, 2019. THE RFS AND ETHANOL PRODUCTION: LACK OF PROVEN IMPACTS TO LAND AND WATER. PREPARED FOR GROWTH ENERGY. RAMBOLL, SEATTLE, WA.

THE RFS AND ETHANOL PRODUCTION: LACK OF PROVEN IMPACTS TO LAND AND WATER

Prepared at the Request of
Growth Energy

Prepared by
Ramboll

Date
August 18, 2019

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TABLES

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ACRONYMS AND ABBREVIATIONS

API	American Petroleum Institute
CDL	cropland data layer
CGF	corn gluten feed
CRP	Conservation Reserve Program
DDGS	distiller’s dried grains with solubles
EISA	Energy Independence and Security Act
EPA	U.S. Environmental Protection Agency
FSA	Farm Service Agency
ha	hectare
ITRC	Interstate Technology & Regulatory Council
LUC	land use change
NOx	nitrogen oxide
NASS	National Agricultural Statistics Service
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	National Resources Conservation Service
NWI	National Wetlands Inventory
RFM	Reduced form model
RFS	Renewable Fuel Standard
SOA	secondary organic aerosols
SOx	Sulphur oxide
TPH	total petroleum hydrocarbons
UOG	unconventional oil and gas
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
USEIA	U.S. Energy Information Administration
VOC	volatile organic compound

1. EXECUTIVE SUMMARY

This report was prepared by Ramboll for Growth Energy in anticipation of the United States Environmental Protection Agency (EPA) issuing proposed rulemaking on the Renewable Fuel Standard (RFS), commonly referred to as the "RFS Reset." One of the factors that EPA must consider in resetting renewable fuel volumes in the program is potential environmental impacts.

The key conclusion of this report is that there are no proven adverse impacts to land and water associated with increased corn ethanol production under the RFS. Accordingly, EPA could decide to reset renewable volumes in a manner that would incentivize greater production and consumption of conventional corn ethanol in US transportation fuel without discernible adverse environmental impacts to land and water, to the extent any exist. The major factors supporting this conclusion are that continued improvements in agricultural practices and technology indicate that increased demand for corn grown for ethanol in the United States can be met without the need for additional acres of corn planted, while at the same time, reducing potential impacts to water quality or water supplies.

Our review focused on analyses concerning water quantity and quality; as well as ecosystems, wetlands, and wildlife. Analyses concerning ecosystems, wetlands, and wildlife were presented primarily as part of the body of literature addressing land use change (LUC) and conversion of land from non-agricultural to agricultural uses in the United States. We focused particular attention on EPA's recent environmental review of the RFS, *Biofuels and the Environment: Second Triennial Report to Congress* (EPA 2018a), and studies relied upon by the agency therein. Ramboll also reviewed other key publications pre- and post-dating EPA (2018a). A full list of refences cited in this report is presented in Section 8.

We also reviewed a recent paper by Hill et al. (2019) investigating the air quality-related health impacts of growing corn. Finally, we provide a brief overview of certain environmental impacts of oil and gas exploration and production and gasoline refining, in response to EPA's (2018a) acknowledgement that its assessment is not fully comprehensive because it does not consider a comparative assessment of the impacts of biofuels relative to petroleum-derived fuels.

The principal findings of our review by topic include, but are not limited to:

- Land use change—Some investigators have asserted that the RFS has resulted in extensive conversion of non-agricultural land to agriculture due to increased demand for corn for ethanol. Our findings indicate that these claims are not borne out, in part because the studies do not establish a causal link between the RFS, increased ethanol production, and LUC. Indeed, in a follow-up analysis to its Triennial Report EPA (2018b) reached the same conclusion—that no causal connection has been established between LUC associated with corn production and the RFS.
    - The number of acres planted in corn has remained effectively constant despite significant increases in production. Acres planted in corn across the United States has remained close to or below the total acres planted in the early 1930s, despite increases in demand for corn as human food, animal feed, and biofuels over this nearly 90-year period. The increase in demand has largely been met by an approximately 7-fold increase in yield (bushels per acre).
    - Most studies asserting a connection between the RFS and LUC fail to adequately account for the myriad factors that drive farmers' choices to

plant a given crop or to convert non-agricultural land to cropland. The price of corn is only one of many such factors, and the literature does not support that the RFS is the predominant driver of pricing of this global commodity. Moreover, assertions that the RFS drives LUC, fail to adequately recognize the increased efficiency in corn production per acre as well as the diminished demand for corn crop acreage due to co-products of the ethanol refining process, such as distiller's dried grains with solubles (DDGS). Assessments of LUC and the RFS generally fail to recognize external factors that might be driving expansion of farmland, such as the loss of farmland near urban areas.

- Water use and water quality—EPA (2018a) and other authors raise concerns that increased corn grown for ethanol may be overstressing water sources and resulting in regional water quality impacts. Our findings indicate that these concerns are not borne out primarily due to research that fails to establish a causal relationship between corn grown for ethanol and impacts to water use and water quality. We further find that EPA (2018a) does not adequately acknowledge the role of advances in agricultural practices in mitigating potential water use and water quality impacts.
  - A quantitative or causal relationship between the RFS and concerns over water use has not been established. From a geographical standpoint, much of the corn that is used for ethanol production is grown on non-irrigated land where impacts to water availability are minimal, and while noted, this is not quantitatively considered by EPA (2018a). In addition, the increased adoption of modern farming practices and precision agriculture (Vuran et al. 2018) is reducing the potential impact of agriculture in general, including increased corn production, on water availability. EPA (2018a), in fact, noted that the increased use of these best management practices should substantially limit impacts to water resources. While some investigators have claimed that growth in corn production has resulted in greater stress to water resources, those studies that focus on negative impacts fail to acknowledge, or do not appear to emphasize, that the current focus on best management practices and resource protection is being widely adopted by the corn growing community and incentives to adopt such practices continue. The technical publications we have reviewed do not establish that the RFS drives corn planting decisions and potential associated water impacts.
  - A quantitative or causal link between corn production associated with the RFS and adverse water quality impacts has not been established. While observed environmental impacts, such as excessive algae blooms in western Lake Erie and low oxygen levels in the Gulf of Mexico have been documented, we found that the literature on this issue fails to quantitatively link these regional water quality problems to increases in corn production for ethanol. Indeed, nutrient loading to the Gulf of Mexico, as measured by nitrates and nitrites, has remained relatively constant since at least 1980 despite increases in corn production. In addition, very few investigators have looked closely at agriculture trends over the past decade that show the implementation of modern farming practices are helping to reduce potential watershed impacts; modern farming practices include improved products such as slow-release fertilizers, and improved practices such as precision agriculture and better water and stormwater management. This trend is expected to continue well into the future and provide additional benefits to other agricultural products in addition to corn. Finally, expected future gains in corn yield (bushels produced per acre per year) in combination with steady or even declining fertilizer and pesticide

use (in pounds per acre per year), will naturally result in a decrease in the potential for water quality impacts.

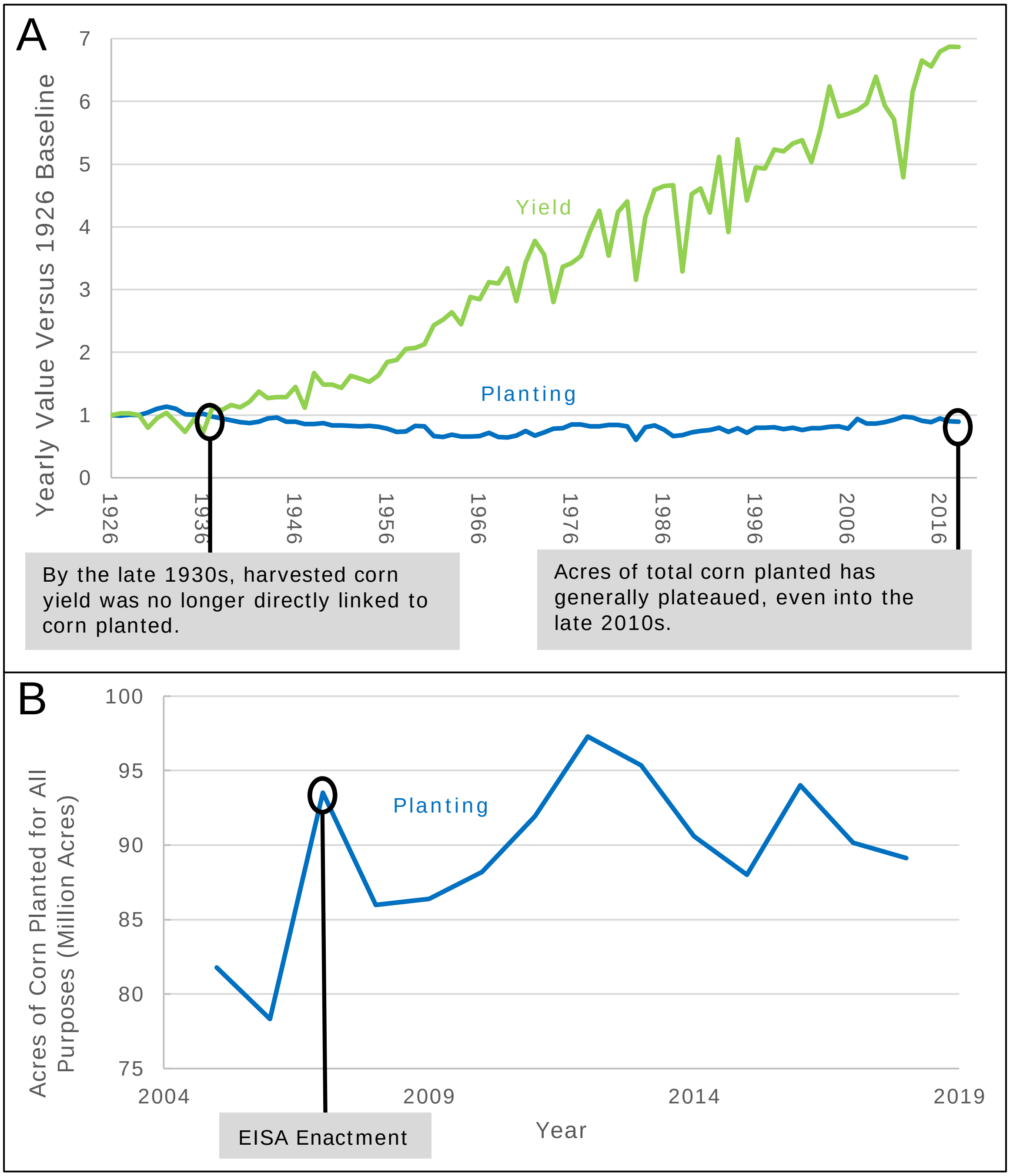
- The RFS Reset is well-timed to coincide with ongoing improvements in agricultural practices—Nearly all published investigations Ramboll has reviewed that focus on the potential impact of increased corn growth for biofuel production have focused on past practices with only passing mention of future expectations. EPA (2018a) acknowledges the benefits of the increased use of best management practices on the environment. Modern agricultural practices are economically beneficial to corn producers when they result in reduced input costs associated with water and agricultural chemicals. The timing for increasing corn production and reduced potential environmental impacts due to precision agriculture coincides with increased biofuel demand, and the coincidence of these trends will benefit both producers and the environment into the future.

1.1 Total Acres Planted in Corn Has Remained at or Below Levels in the Early 1930s While Total Production Increased 7-Fold

The United States Department of Agriculture (USDA) has maintained annual statistics on domestic crop production for decades. Corn production in the United States annually exceeds 10 billion bushels, with approximately 50% of corn currently grown for ethanol production and 50% for grain use. Accordingly, corn is documented to be the most widely produced feed grain in the United States (U.S.), accounting for more than 95 percent of total production and use followed by sorghum, barley, and oats (USDA 2019). Most of the corn crop for feed grain is used for livestock feed. Other food and industrial products include cereal, alcohol, sweeteners, and byproduct feeds.

While the approximate share of U.S. corn (in bushels) dedicated to production of ethanol has increased from 4% in 1986, to 38% in 2015 (USDA-ERS 2019b), and to approximately 50% in 2018, the total corn planting (in acres) has remained relatively stable since the 1930s (Figure 1). On a shorter time-scale, acres of corn planted each year does vary, but when examining data between 2007 and 2018, there is no long-term upward trend. In fact, acres of corn decreased 8.07% in 2008, the year after the enactment of the Energy Independence and Security Act (*EISA*), then rebounded through 2012, then decreased again such that in 2018, acres of corn were 4.7 % lower than in 2007. These data, from the USDA Crop Production Historical Track Record (updated in USDA, 2019) demonstrates the increased efficiency, planting and production of the corn crop without a need to secure appreciable additional acreage for production. Efforts in better crop management, improved fertilizer use, and precision agriculture are all likely contributors to improved yields. The USDA further anticipates changes in corn production to result in an increase of approximately 16.1 more bushels per acre by 2028 without a substantial increase in farmed acres (and with a corresponding reduction in the use of water resources and fertilizer).

Figure 1: A) Annual Yield in Bushels of Corn Per Acre and Annual Acres Planted in Corn Versus 1926. B) Annual Acres of Corn Planted 2004-2018.



By the late 1930s, harvested corn yield was no longer directly linked to corn planted.

Acres of total corn planted has generally plateaued, even into the late 2010s.

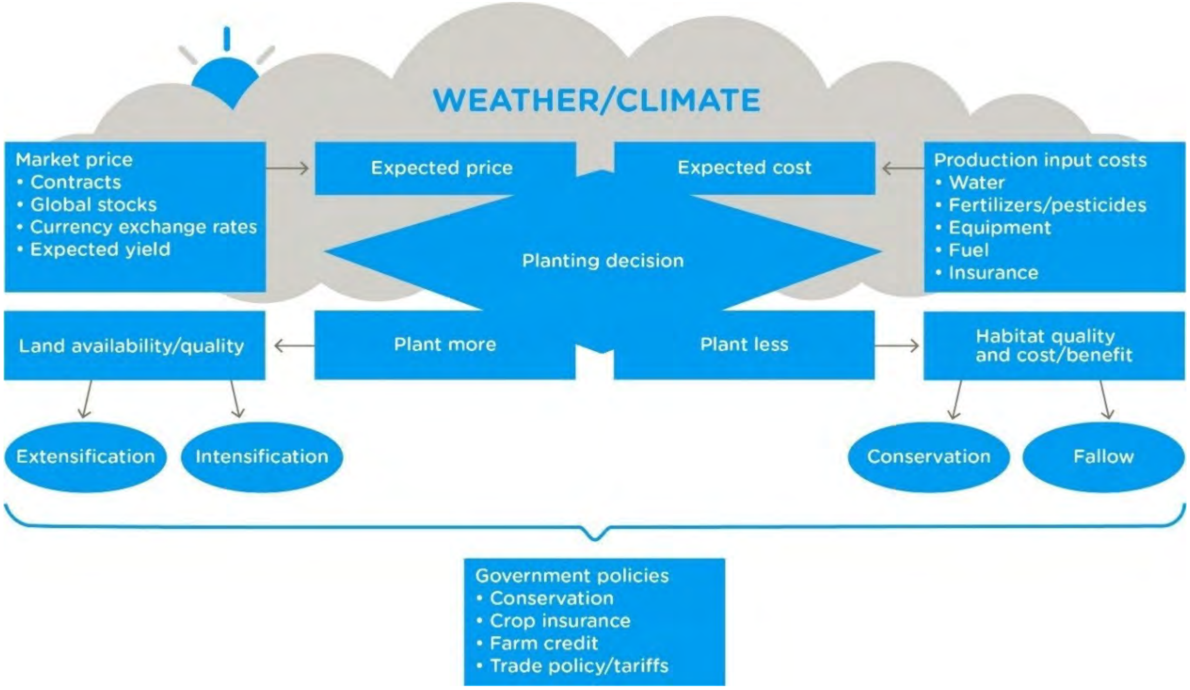
EISA Enactment

Source: USDA Crop Production Historical Track Records, 2019

1.2 Studies Have Failed to Establish a Quantitative Link Between the RFS and Land Use Change

The decision by farmers and landholders on whether to plant a bioenergy crop such as corn reflects complex relationships between biophysical, economic, and social factors (Figure 2).

Figure 2: Illustration of the Complexity of Biophysical, Economic, and Social Factors Affecting Planting Decisions.



One factor that is of paramount importance is weather and climate. Regional weather patterns largely dictate crop patterns across the country, but this is also influenced by the availability (and price) of water for irrigation in areas with relatively low annual precipitation or highly variable precipitation. The probability of severe weather such as drought and flood as well as severe storm events in any given year, may also influence planting decisions. Government policy is another overarching factor affecting planting decisions, and these include potential monetary incentives associated with the U.S. Department of Agriculture Conservation Reserve Program (USDA CRP), other conservation programs such as local conservation easements, the availability of crop insurance, and market incentives that might affect commodity prices. Other factors include market price and the price of production inputs, which can be strongly influenced by the price of oil, exchange rates and trade policies. Local market prices are influenced by a wide range of factors including status of commodity stores, distance to markets, and competition from regional and even global markets. Input prices are also highly variable due to market prices, and volume requirements for some inputs such as irrigation water are weather and climate dependent. Finally, all of the above factors, plus the availability and quality of land and ecosystem characteristics and ecological value play into decisions regarding land use—whether to plant new acreage (extensification) or plant more of a given crop on existing acreage (intensification).

The influence of the RFS on LUC is poorly understood and likely weak. To the extent it suggests otherwise, EPA (2018a) inadequately assesses the range of market and nonmarket factors influencing land use change and does not consider key studies that suggest that the RFS likely had a small, and perhaps negligible effect on LUC, especially changes in land use from non-agriculture to biofuels feedstock (corn and soy). In particular, EPA (2018a) does not adequately consider the role of farm policy such as crop insurance, land characteristics, input and output prices, and technology on growing decisions by farmers.

Studies relied upon by EPA (2018a) to quantify LUC around the time of enactment of the RFS are based on unreliable data and likely overestimate LUC. In particular, EPA (2018a) cites work by several authors who report findings of considerable LUC, including LUC in ecologically sensitive areas such as the Prairie Pothole Region, but do not sufficiently acknowledge or discuss findings by more recent research that indicates that many of the earlier studies were flawed or substantially overstated the extent of LUC in and around the enactment of the RFS. EPA (2018a) also does not sufficiently acknowledge that the studies it relied on do not establish a causal relationship between the RFS and LUC. In addition, EPA (2018a) makes no attempt to quantify, or even describe in any detail, the potential ecological impacts of the alleged LUC, so the actual environmental harm, if any, associated with the RFS remains nebulous. Notwithstanding these shortcomings of the report, EPA clarifies in a subsequent discussion of environmental impacts of the RFS that it *does not* view the literature it identified in the Triennial Report as supportive of a causal link between LUC and the RFS; rather, there is a myriad of "complex regulatory and market factors that are relevant to such a relationship" (EPA 2018b).

A recent effort by Lark et al. (2019) to develop a quantitative link between the RFS and LUC may be the most exhaustive effort to date, but their reliance on an uncertain "business as usual" baseline and on estimating price increases attributable to the RFS are major weakness of the work. Most important, the entire analysis presented by Lark et al. (2019) rests on estimating price increases attributable to RFS, yet the authors fail to adequately acknowledge the role of important factors such as the dietary transition from cereals toward more animal protein in developing countries resulting in rapid growth in the consumption of agricultural commodities. Other important factors affecting corn prices over the period include higher oil prices and the link between the U.S. dollar exchange rate and commodity prices. In addition, the data sets and models used in their analysis are not made explicit, and some data are not in the public domain, precluding a thorough independent review of their work.

EPA (2018a) also failed to adequately account for the role of cropping practices and production of DDGS at ethanol refineries as important LUC offsetting factors. Several studies indicate that a substantial portion of increase corn production following the introduction of the RFS was met via farmers' cropping practices, including switching from other row crops to corn or double cropping corn instead of rotating between corn and soy (or other crops). These studies are not given adequate consideration by EPA (2018a). Although EPA (2018a) acknowledges that production of DDGS may offset some demand for corn as livestock feed, key studies estimate this offsetting effect is considerable. In addition, EPA (2018a) does not discuss whether and to what extent this offset for demand for corn is a market driver that provides downward pressure for LUC to corn.

1.3 Changes in Agricultural Practices Broadly Reduce the Likelihood of Environmental Impacts to Water Resource Availability and Quality

Advancements in technology and water management techniques have continued to increase the efficiency in water resource management by stabilizing, and potentially reducing, the overall volume of water necessary for corn growth. Agriculture accounts for an estimated 80 percent of national consumptive water use in the US according to the USDA's Economic Research Service (2018) and reaffirmed by the National Academy of Science (2019). According to the 2012 statistics from the USDA, irrigated corn acreage represented about 25% of all irrigated acreage in western states, and about 24% of all irrigated acreage in the eastern states (USDA-ERS 2018a). Additionally, the USDA has shown that irrigation for all crops, including corn, has decreased even as the farming acreage has essentially been stable over the past 35 years. The USDA attributes this trend to improvements in physical irrigation systems and water management. The USDA also notes that significant capital investments in on-farm irrigation is continuing, particularly in the western states, where most of the irrigated farm-land is concentrated. As an indication of a positive trend in irrigation reduction, the University of Nebraska, Lincoln reports that in Nebraska (as a bell-weather of other dry western states), the percentage of all corn acreage that is irrigated has declined from a high of 72% in 1981 to 56% in 2017 (University of Nebraska 2018).

Increasing crop yield per area of farmed land is taking place on both irrigated and unirrigated corn crops, suggesting that changes in yield are not attributed to irrigation alone. In certain areas, more corn is now being grown on the same number of acres, which has resulted in increases in irrigation. However, watersheds where most intensification has occurred are mostly in Western states which account for less ethanol feedstock than the less- or non-irrigated Midwest and Eastern States.

Trends and expectations in the biofuel refining process also show increasing water use efficiency and lower water demand over time (upwards of 50% reductions in recent years). This trend is anticipated to continue as ethanol refining technology advances.

Advances in sustainable farm management, including substantial improvements in nutrient formulation and use, and technological improvements in pesticide and fertilizer application, will continue to reduce the potential for impacts to water quality in regional watersheds near corn growing areas regardless of the cause of historical water quality impacts. Additionally, the EPA acknowledges that corn production for ethanol has not been reliably linked to large scale degradation of water quality. The hypothesized causal relationship between the hypoxic zones in the northern Gulf of Mexico and eutrophication in Western Lake Erie with corn grown specifically for ethanol production is weak and lacks supporting data. It is recognized that urban and agricultural runoff in the subject watersheds have likely contributed to the conditions; but EPA (2018a) notes that attributing these water quality issues to ethanol production is speculative and not based on specific data.

1.4 Recent Estimates of Health Damages from Corn Production are Unreliable and Misleading

Although the primary focus of this report is on studies assessing the implications of the RFS program and corn ethanol production for land and water, a recent report that attempts to link corn production to adverse public health impacts from air emissions merits a brief response. A recent publication in Nature Sustainability (Hill et al. 2019) purports to estimate US annual health damages caused by particulate air quality degradation from all direct farm and indirect supply chain activities and sectors associated with maize (corn) production. Although the authors do not reference the RFS, they do mention corn grown for ethanol, and the publication has been referenced by third parties in a manner suggesting that corn grown for ethanol may be associated with adverse health outcomes. Ramboll's review indicates that the conclusions presented by Hill et al. (2019) are unsubstantiated and likely overestimate adverse health impacts, where it is not clear any health impacts exist.

The direct and indirect activities explored by Hill et al. (2019) include air emissions from farms and upstream processes that produce the chemical and energy inputs used in corn crop production: fuel, electricity, agrichemical production, transportation, and distribution. The paper focuses on particulate matter smaller than 2.5 microns in diameter ($PM_{2.5}$), which is a concern for human health because particles of this size can penetrate deep into the lungs and enter the bloodstream, and potentially result in both acute and chronic effects to the respiratory and cardiovascular systems. Ramboll reviewed the underlying models and assumptions employed in the Hill et al. (2019) analysis and we present the following findings:

- The model relied upon by the authors uses annual-average data for emissions, meteorology, and chemical/removal rates to estimate annual-average $PM_{2.5}$ impacts. Use of annual averages is inappropriate for representing processes that operate over shorter time scales ranging from minutes to several months (e.g., atmospheric dispersion and chemical formation of $PM_{2.5}$) and results in a high level of uncertainty. The authors acknowledge that this weakness in their approach results in spatial errors in annual average $PM_{2.5}$ calculations. These spatial errors can significantly impact the resulting exposure and mortality estimates. The authors, however, do not present sensitivity analyses to assess the impact of the model assumptions, nor do they include any plausible range of uncertainty or variability with their modeled $PM_{2.5}$ concentration or mortality estimates.
- The 2005 modeling year upon which modeling is based is not representative of more recent chemical conditions of the atmosphere in the U.S., which may lead to an overestimate of the $PM_{2.5}$ contributions from corn production by more than a factor of 2, and this overestimate results in overestimates of health and economic damages.
- Several major sources of uncertainty in the modeling are not acknowledged or accounted for by the authors, including the following key uncertainties:
  - Ammonia emission estimates, which are the largest driver of mortality in the Hill et al. (2019) modeling analysis, are also the most uncertain aspects in any $PM_{2.5}$ air quality modeling, because: (1) emissions are largely from agricultural sources that vary both spatially and temporally due to weather and farming practices; (2) many different methods are used to estimate ammonia emissions, and each can yield very different emission rates and exhibit a high degree of error; (3) annual average ammonia emission inventories used in the modeling fail to account for important seasonal variations and related complex interactions with sulfate and nitrate chemistry; and (4) ignoring diurnal and intra-daily ammonia emission variations have been shown in the literature to overestimate ambient ammonia concentrations by as much as a factor of 2.
  - The health impact assessment is based on a single epidemiological study that found associations between $PM_{2.5}$ concentrations and mortality, but a clear causal link has not been established in the scientific community. In fact, the components of $PM_{2.5}$ that may be associated with adverse health effects are yet unknown, but evidence suggests that carbonaceous particles are more toxic than inorganic particles such as those derived from ammonia and nitrate or sulfate.

Based on our review of literature documenting the development and testing of the simplistic model employed by Hill et al. (2019), we conclude that the model is not able to faithfully reproduce $PM_{2.5}$ impacts estimated by more complex state-of-the-science air quality models. In fact, its performance is at its worst for the very $PM_{2.5}$ component (ammonium) that the Hill et al. (2019) model indicates is the largest contributor to PM mortality from corn production. This renders the modeling especially unreliable for this key PM component. Overall, the uncertainties enumerated above result in unreliable estimates of $PM_{2.5}$ exposure, mortality and related costs associated with corn production, each associated with a large range of variability.

1.5 Environmental Impacts Associated with Ethanol Production Cannot be Viewed in a Vacuum, Without Consideration of Such Impacts Associated with Gasoline Production

EPA (2018a) acknowledges its Triennial Report fails to address environmental impacts associated with gasoline production, but it is important not to view environmental impacts of ethanol in a vacuum given the biased view this presents.

Land use for oil and gas production is extensive. In 2011, the direct footprint of oil and gas production was approximately 1,430,000 acres (Trainor et al. 2016). By 2040, Trainor et al. (2016) estimate the direct footprint of oil and gas production will be approximately 15,890,000 acres.

Habitat fragmentation from oil and gas production is also high and is known to decrease biodiversity (Butt et al. 2013). For example, the fragmentation caused by the dense placement of over 55 pads per square mile in Texas is known to cause a reduction in habitat quality for lizards in the short term (Hibbitts et al. 2013), while in the long term, habitat restoration after the removal of oil and gas infrastructure does not eliminate adverse effects to biodiversity (Butt et al. 2013).

Figure 3: Illustration of Habitat Fragmentation in Jonah Field, Wyoming from Oil and Gas Production.

SOURCE: EcoFlight (USDA 2012)

Oil and gas products, production fluids, and refinery effluent have negative impacts on soil and water quality and flora and fauna when released in the environment (EPA 1999, Wake 2005, Pichtel 2016). The toxicity of crude oil and its individual components has been well studied and these products are known to have negative impacts on wildlife depending on the exposure and dose received (Interstate Technology & Regulatory Council [ITRC] 2018).

Production water, fracking fluids, and refinery effluent, though less well-studied, have also been found to have adverse effects on plants and wildlife, resulting in decreased populations and biodiversity (Wake 2005, Pichtel 2016).

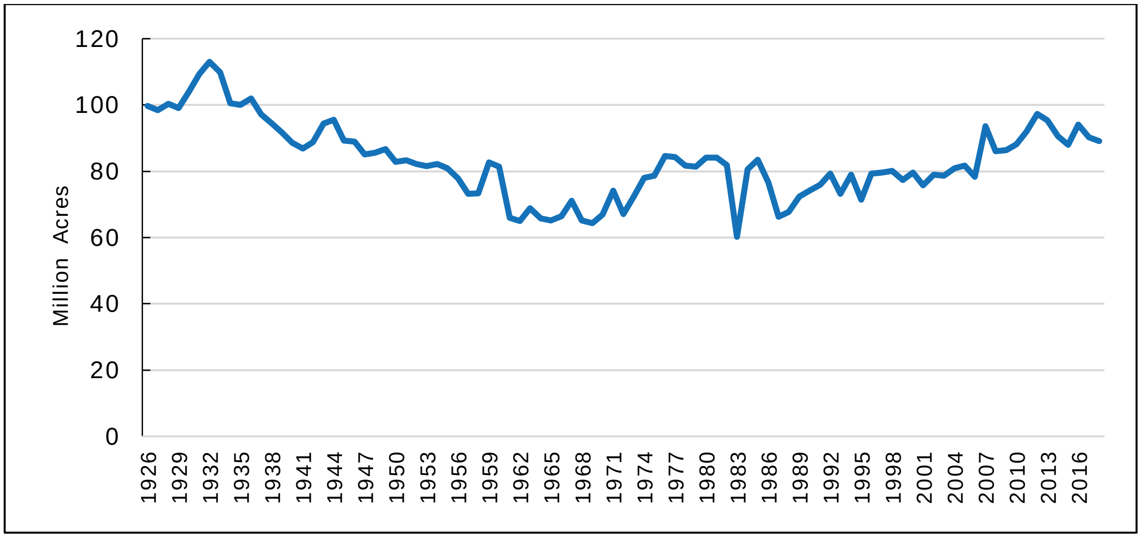
American Petroleum Institute (API) reported approximately 10.8 million gallons of oil were spilled into U.S. Navigable Waters from 1997-2006 with the amount spilled per year varying from 466,000 (2005) to 2.7 million (2004). This figure clearly does not include the Exxon Valdez spill in Alaska in 1989 or the Deepwater Horizon spill in 2010. National data suggest that spills from unconventional oil and gas may amount to one million gallons each year (Patterson et al. 2017). These data are exclusive of major offshore releases and incidents.

The findings and conclusions summarized above and set forth in the remainder of this report are subject to the limitations stated in Section 7.

2. ACRES PLANTED IN CORN HAVE REMAINED AT OR BELOW LEVELS IN THE EARLY 1930s WHILE TOTAL PRODUCTION INCREASED 7-FOLD

The total acres of corn planted in the U.S. has remained relatively stable and in fact has decreased slightly since the 1930s as shown in Figure 4, while the approximate share of U.S. corn (in bushels) dedicated to production of ethanol has increased from 4% in 1986 to 38% in 2015 and currently to approximately 50% in 2018 (USDA-ERS 2019b).

Figure 4: Total U.S. Planted Acres of Corn Per Year (million acres).

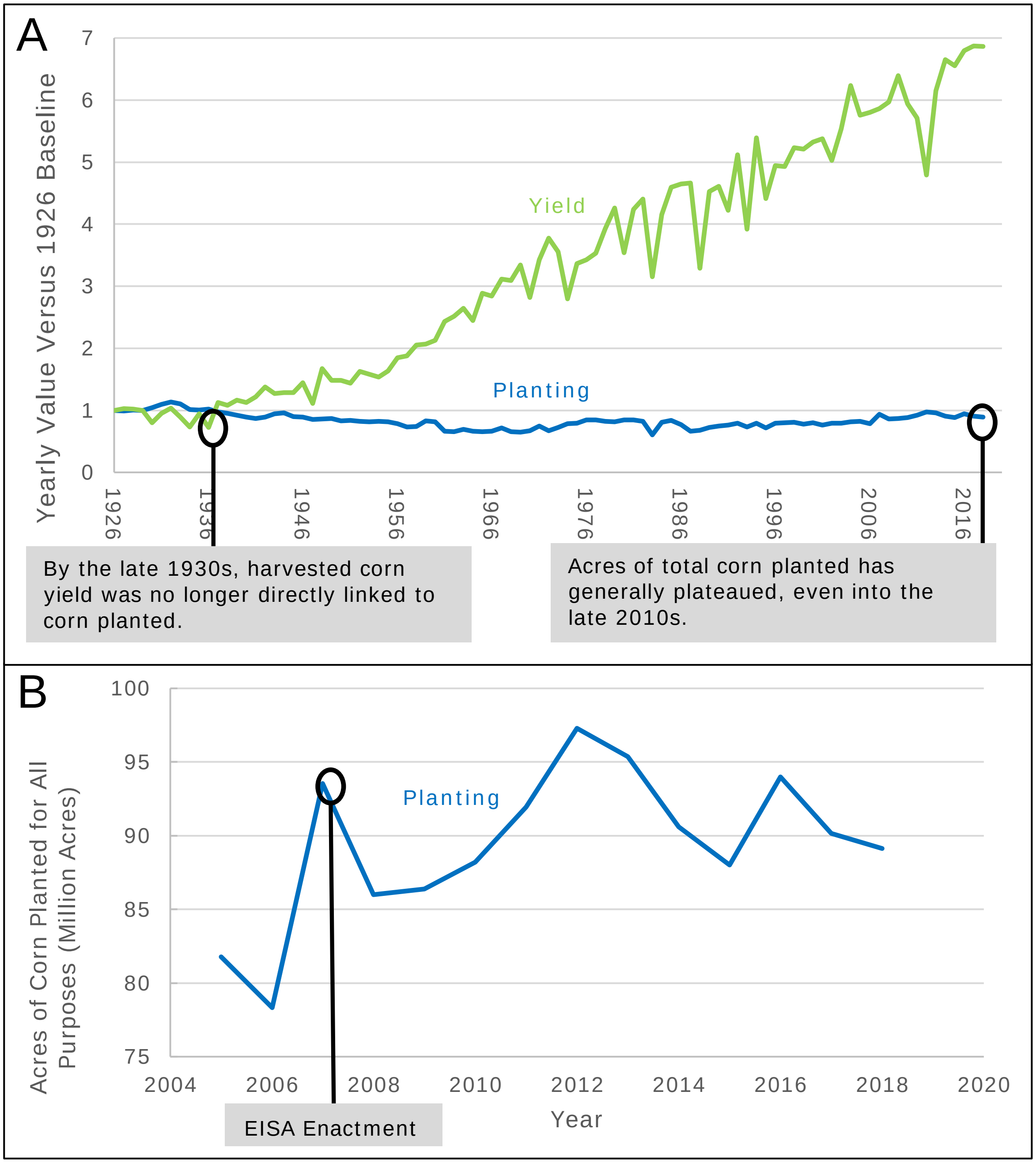


(Source: USDA 2019)

Even as the total corn acreage has been relatively stable or has slightly decreased since the early 1930s, the yield in bushels per acre during this same approximate period has increased dramatically as illustrated by Figure 5: A) Annual Yield in Bushels of Corn Per Acre and Annual Acres Planted in Corn Versus 1926. B) Annual Acres of Corn Planted 2004-2018.

These statistics reported by the U.S. Department of Agriculture (USDA) are a positive sign of the ability of farming practices to become more efficient and optimized to generate more yield without adding additional acreage. Also noticeable is that the stability of farming acreage and continued increase in yield extends into the last decade, following the enactment of the EISA. In 2018, 4.7% fewer acres of corn were planted for all purposes in the U.S. as compared with 2007, even though the approximate percentage of corn for ethanol versus other uses has increased. There was regional variation in changes in corn planting; for example, comparing data from 2017 with 2007, approximately two million fewer acres of corn were planted for all purposes in Illinois, with approximately 860,000 additional acres in North Dakota. Regional changes are driven by a wide range of competing macroeconomic conditions, mostly unrelated to ethanol production, including the relative value of crops like spring wheat and cotton, or changes in corn outputs from other countries. Indeed, the EPA confirmed that, for a variety of reasons, even the proposed 2019 RFS renewable volume obligation standards would not be expected to result in an increase in farming acreage (EPA 2018b).

Figure 5: A) Annual Yield in Bushels of Corn Per Acre and Annual Acres Planted in Corn Versus 1926. B) Annual Acres of Corn Planted 2004-2018.



By the late 1930s, harvested corn yield was no longer directly linked to corn planted.

Acres of total corn planted has generally plateaued, even into the late 2010s.

EISA Enactment

(Source: USDA Crop Production Historical Track Records, 2019)

According to 2018 USDA projections, annual U.S. corn production is anticipated to surpass 15 billion bushels by 2025, while the USDA projects a 2.1-million acre decline in planted corn acres for 2018/19 (Capehart et al. 2018, USDA-ERS 2018b). Schnepf and Yacobucci (2013) cite the following projections by USDA and industry for future increases in corn yield: USDA predicts yields will reach about 240 bushels per acre by 2050 (overall increase of 55% over the 37-year period), whereas the outlook from biotechnology seed company Monsanto is an increase of 300 bushels per acre by 2030, (overall increase of 93% over the 17-year period).

The continued trend of decreases in farmable acres and increases in yield will likely continue to some stable equilibrium that will be controlled by economic and general land resource conditions. There appears to be little or no discussion in reports and documents, such as EPA (2018a), Lark et al (2019) and others, of the significance of these trends.

3. STUDIES HAVE FAILED TO ESTABLISH A QUANTITATIVE RELATIONSHIP BETWEEN THE RFS AND LUC

3.1 Overview of LUC and Environmental Impacts

In this section we first present a discussion of the lack of evidence for a quantitative causal link between increased demand for ethanol from the RFS and LUC. Second, we present a summary of some of the largest sources of uncertainty in studies that EPA (2018a) relies on to assert that the RFS may have resulted in considerable LUC. Third, we discuss the information presented by EPA (2018a) on the topics of cropping practices as well as the role of distiller's dried grains with solubles (DDGS) in offsetting LUC potentially associated with the RFS.

The literature attempting to relate LUC to ethanol production generally acknowledges shortcomings in some of the major data sets, and authors such as Lark et al. (2015) and Dunn et al. (2017) attempt to address these shortcomings by using advanced geospatial analysis techniques and data corrections (Lark et al. 2015, Dunn et al. 2017). Importantly, studies relied upon by EPA (2018a) to quantify LUC around the time of enactment of the RFS are based on unreliable data and likely overestimate LUC.

Assertions made by EPA (EPA 2010, 2018a) to link LUC (including land taken out of the CRP as well as non-agricultural land converted to agriculture) to increased demand for ethanol due to the RFS cannot be substantiated by the underlying literature for a variety of reasons, including, but not limited to the following:

- There are a myriad of complex, interrelated market and non-market factors affecting farmers' decisions on land use and a thorough assessment of the causative factors was not undertaken in the literature cited by EPA (2018a).
- Many studies do not differentiate among crop type (e.g., corn and soy) when looking at LUC and thus it is not possible to establish a causal linkage between LUC and demand for ethanol versus demand for biodiesel from those studies.
- Most studies of LUC are regional or state-specific and there is substantial inconsistency between studies regarding the geographical area of focus. This inconsistency precludes arriving at broad regional or national conclusions. For example, several studies focus on LUC in the Prairie Pothole Region due to this region's environmental fragility; whereas other studies assessed the "western corn belt", "lake states", or the entire continental United States.
- Many studies focus on specific land use types prior to conversion to agriculture (e.g., grassland, wetlands, or land in the CRP) and thus are not inter-comparable.
- Increased demand for all uses of corn may be met via either expansion of agricultural land onto previously uncultivated land (extensification) and by increased production from existing land (intensification). Intensification does not result in LUC and EPA (2018a) does not adequately represent the role of intensification in mitigating the propensity for extensification and LUC.
- Use of corn in ethanol refining produces substantial amount of DDGS and the use of DDGS as a substitute for corn as livestock feed reduces the demand for corn as livestock feed. This issue is not adequately accounted for in the assessment by EPA (2018a) of the potential role of RFS in LUC.

- The literature assessing LUC relative to the RFS generally fails to consider the considerable loss of agricultural land in urban areas and the role this loss may have in extensification elsewhere.

EPA (2018a) reviewed a wealth of information documenting LUC to biofuel crops and potential environmental impacts, but the report presents no coherent arguments or convincing lines of evidence of: (1) a quantitative relationship between ethanol production spurred by increase demand from the RFS and the documented LUC, or (2) quantitative impacts to ecosystems, wetlands, or wildlife. EPA (2010 and 2018a) reference numerous studies of LUC around the time of the enactment of the EISA. Many of these studies combine data over the period pre- and post-2007, making it difficult or impossible to confidently associate observed LUC to the time the RFS came into effect. Many authors also simply infer that there is a relationship between LUC and the RFS without any meaningful exploration of the market drivers for such change. In fact, EPA (2018b) asserts that historically the annual RFS requirements have not driven increased ethanol production and consumption. EPA asserts that this is due to the fact that consumption of ethanol has remained fairly steady since 2013 (when the 10% ethanol/gasoline blend became the predominant fuel), yet corn starch ethanol production has continued to rise well beyond the volumes required by the RFS standard, driven by favorable export markets. Ethanol exports more than doubled over the 2013-2017 period from about 0.62 billion gallons to 1.72 billion gallons (US EIA 2018).

Irrespective of market drivers, EPA (2018a) acknowledges that attributing the causes of land use change to any one factor, including the RFS, is difficult and speculative. Interestingly, EPA (2018a) acknowledges many of these shortcomings, especially in their concluding statement that "*we cannot quantify with precision the amount of land with increased intensity of cultivation nor confidently estimate the portion of crop land expansion associated with the market for biofuels*".[1] EPA (2018a) acknowledges that contributing factors to LUC include market dynamics such as crop prices and input prices (e.g., fuel, transportation costs, costs of equipment, etc.) and nonmarket costs such as those resulting from adverse weather and pests. EPA (2018a) further acknowledges that these and other factors influence land use change and that these factors may be "*coincident with the passage of EISA and therefore correlated in an empirical analysis*".[2] A fundamental problem with many of the studies cited by EPA (2018a) is that they focus on establishing correlations, or simply temporal associations between observed LUC and the RFS, and do not establish causation. EPA (2018b) succinctly summarizes the issue of relating LUC to the RFS as follows: "…*there is no scientific consensus about how to accurately and consistently attribute land use change in the context of biofuels*".[3]

3.2 The Impetus for LUC is Influenced by Complex Factors; and the Influence of the RFS is Poorly Understood and Likely Weak

EPA (2018a) identifies LUC as one of the primary drivers of potential environmental impacts from increased biofuels production, and they devote an entire section to the topic. However, EPA (2018a) also acknowledges the weakness and lack of certainty in many reports that attempt to establish a quantitative link between the RFS and LUC. For example, EPA (2018a) points out that the U.S. Department of Agriculture National Agricultural Statistics Service (USDA NASS) data indicate increases in corn crops but in the absence of comprehensive land classification "*it is impossible to know whether these increases came from existing*

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[1] EPA (2018a) at page xi

[2] EPA (2018a) at page 22

[3] EPA (2018b) at page 16

agricultural lands or new lands that were not recently in cultivation".[4] EPA (2018a) additionally notes weaknesses in empirical approaches in general, including difficulty in comparing observations and differences in how measured attributes are defined. Consequently, EPA (2018a) acknowledges that it is difficult to attribute the causes of land use changes, including where such changes are coincident with the passage of the EISA.

Several authors have examined LUC from the standpoint of decisions made at the individual farm level. Wang et al. (2017) conducted surveys of 3,000 randomly selected farmers in 37 counties in South Dakota and 20 counties in North Dakota to gain an understanding of the relative importance of different factors affecting land use decisions, and how that relative importance changes with operator and farm characteristics. The results of their survey indicated that the importance of crop output and input prices, innovations in cropping equipment, and weather patterns all increase closer to the economic margin. The authors also found that highly sloped areas are more sensitive to crop prices and crop insurance policies than less sloped land and that as farm size increases, farmers are more sensitive to policy issues and technological innovations (Wang et al. 2017).

Claassen et al. (2011) assessed the effect of farm policy on LUC and found that crop insurance, disaster assistance, and marketing loans contributed to a 2.9 percent increase in cropland acreage between 1998 and 2007 in the northern plains (Claassen et al. 2011). Miao et al. (2015) found that crop insurance reduced the effective cost of land conversion by stabilizing crop revenues (Miao et al. 2016).

Efroymson et al. (2016) use classical causal analysis to elucidate shortcomings of existing studies of the relationship between biofuels policy and LUC. The authors point out that such studies are often based on assumptions that the production of feedstock for biofuels results in the increase in demand for food crops, which in turn, results in an increase in crop prices and expansion of the total area devoted to agriculture; and that this cascading process results in the loss of areas of natural vegetation, including grasslands. EPA (2018a) acknowledges the general premise by Efroymson et al. (2016), describes the methods the authors used, but does not describe the authors' principal conclusion that for LUC, single lines of evidence considered individually are insufficient to demonstrate probable cause. Many of the studies cited by EPA (2018a) in describing a putative relationship between the RFS and LUC indeed focus on single lines of evidence such as the temporal association between LUC and the enactment of the RFS, correlations between LUC and farm proximity to ethanol plants, or LUC and increased production of corn.

Fausti (2015) explored the causal linkages among genetically modified corn, ethanol production, and corn production, hypothesizing that genetically modified corn allowed for the expansion of corn acreage, increased corn production incentivized increased ethanol production, and the RFS allowed this economic feedback mechanism to intensity (Fausti 2015). The author examined pre-RFS data (1996-2000) as well as post-RFS data (2009-2013) and found that the policy-induced [RFS] increase in ethanol production after 2006 had a statistically significant and positive effect on change in corn acres planted. However, although this relationship was statistically significant, Fausti (2015) found that the "policy-induced" change was responsible for only 0.69% to 0.88% percent of the change in corn acres planted.

One line of evidence for a link between RFS and LUC that has been explored by several authors is the relationship between increased acres in corn or LUC and proximity to ethanol

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[4] EPA (2018a) at page 21

plants. EPA (2018a) asserts that "*The finding of higher rates of conversion closer to the biorefineries is important and suggests a causal link*".[5] In support of this assertion, EPA (2018a) cites "Motamed and Williams (2016)".[6] EPA (2018a) also states that "*for instance* [Motamed et al. 2016]*, estimated that for every 1% increase in an area's ethanol refining capacity, its corn acreage and total agricultural acreage increased by 1.5% and 1.7%, respectively".*[7] *However, EPA (2018a) ignores the authors' own caveats about interpretation of this finding.* In particular, the authors implicate the observed spatial linkages to food and animal feed, as well as ethanol production, conceding that "*[t]hese outcomes may reflect the efficient response of different producers to new economic incentives, but any externalities associated with these evolving arrangements remain unknown*".[8] In other words, no causal link to the RFS was established.

Wright et al. (2017) is cited several times by EPA (2018a) to provide evidence of the association between land use change (loss of grasslands) and refinery location. In particular, Wright et al. (2017) note that approximately 2 million acres of grassland was converted to row crops within 50 miles of a refinery between 2008 and 2012. However, EPA (2018a) again does not acknowledge a major shortcoming of the study, namely, the authors' admission that their study "*did not consider potential effects of other explanatory variables".*[9] The paper also discussed the errors in the data itself, stating that the "*conversion of non-cropland to cropland was mapped correctly over 70% of the time* " which means that it was mapped incorrectly 30% of the time, a considerable percentage.[10]

Li et al. (2018) examine the determinants of change in corn acreage and aggregate crop acreage as a function of the establishment of ethanol plants and changes in crop prices in the United States between 2003 and 2014. In this nationwide study, the authors report that corn acreage is fairly inelastic with respect to both changes in nearby ethanol refining capacity as well as changes in crop prices (Li et al. 2018). Unlike previous studies of the relationship between LUC and ethanol refinery location that have regional focus, Li et al. (2018) base their findings on the analysis of data for 2,535 counties in the contiguous United States. Li et al. (2018) found that a 1% increase in ethanol capacity in a county was associated with approximately 0.03% to 0.1% increase in corn acreage in that county and a 1% increase in corn price was associated with an approximately 0.18% to 0.29% increase in corn acreage in a county. The authors conclude that previous studies may have overestimated the effect of the proximity of ethanol refineries on planting of corn. The authors did find that the expansion in corn ethanol alone, all else being equal, resulted in a 2.9-million-acre increase in acres planted in corn in 2012 relative to 2008. Critically, however, they noted that most of the increase came from conversion of other crops to corn rather than LUC to corn from a non-agricultural land use. Li et al. (2018) also refute previous studies that purported to show considerable and irreversible LUC to corn, and they recognize that the overall effect of corn ethanol production on total crop acreage was negligible (Stein 2018).

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[5] EPA (2018a) at page 35

[6] This study is mis-cited by EPA and should have been Motamed et al (2016). See Section 8 *References* of this report for full citation.

[7] EPA (2018a) Box 3 at page 53

[8] Motamed et al. (2016) at page 741

[9] Wright et al. (2017) at page 9

[10] Wright et al. (2017) at page 3

A review of the above studies indicates that a causal relationship between the RFS and LUC has not been definitively established, and to the extent there is a causal linkage, the relationship is likely weak. These studies as well as EPA (2018a) do not consider in a quantitative way, the potential role of agricultural land loss on extensification. Although EPA (2018a) present some information on agricultural land loss, these studies are not discussed in any detail nor is the potential relationship to extensification.[11] American Farmland Trust estimates that between 1992 and 2012, almost 31 million acres of agricultural land were lost to development—an average rate of loss of 1.55 million acres/year (Sorensen et al. 2018). By comparison, Li et al. (2018) in their nationwide study noted an increase of 2.9 million acres in 2012 as compared to 2008 (an average increase of 725,000 acres per year). It is clear that farmland loss is considerable and very likely affects extensification.

3.3 Studies Relied Upon by EPA (2018a) to Quantify LUC Around the Time of Enactment of the RFS Are Based on Unreliable Data and Likely Overestimate LUC

One of the most pervasive issues in many studies of LUC around the time of the enactment of the RFS is reliance on data sets that have proven to be inaccurate. Some of the key publications that present estimates of LUC post-2007 and were relied on by EPA (2018a) include the following:

- Wright and Wimberley (2013) reported that between 2006 and 2011, based on an analysis of USDA's National Agricultural Statistics Service's Cropland Data Layer (CDL), there was a 1.0-5.4% annual increase in the rate of change of WCB grasslands to corn and soy with total LUC of 530,000 ha (Wright and Wimberly 2013).
- Johnston (2013) assessed wetland to row-crop transition rates in the Dakotas by geographical information system analysis of the intersection of CDL with US Fish & Wildlife's National Wetlands Inventory (NWI) and the U.S. Geological Survey's National Land Cover Database (NLCD) and reported an annualized loss rate of 0.28% (5,203 ha./yr. over a 25-32 year period for NWI data) to 0.35% (6,223 ha./yr. over a 10 year period for NLCD data) (Johnston 2013).
- Lark et al. (2015) analyzed LUC nationwide during the period 2008-2012 using CDL, calibrated with ground-based data from USDA's Farm Service Agency (FSA), and further refined using data from the NLCD. They reported that 7.34 million acres (2.97 million ha.) of previously-uncultivated lands became utilized in crop production while during the same period 4.36 million acres (1.76 million ha.) of existing cropland were abandoned with most of this being land enrolled in the CRP. They also reported that 1.94 million acres (785,000 ha.) of converted lands were planted in corn as a "first crop."
- Morefield et al. (2016) studied LUC using the USDA's CDL over the 12-state Midwest Region and report that between 2010 and 2013, 530,000 ha. (1.3 million ac.) of land formerly in the CRP were converted to row crops with the "vast majority" of these lands converted to soy and corn (Morefield et al. 2016). Of this 530,000 ha., 360,000 ha. (890,000 ac.) were grassland, 76,000 ha. (188,000 ac.) were wildlife habitat, and 53,000 ha. (131,000 ac.) were wetland. They further report that areas in the Dakotas, Nebraska and southern Iowa were hotspots for LUC.
- Mladenoff et al. (2016) assessed LUC in the Lakes States (MN, WI, and MI) and determined that during the period 2008-2013, 836,000 ha. (2,066,000 ac.) of non-agricultural open lands were converted to agricultural use, with conversion to corn

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[11] EPA (2018a) Figure 14 at page 33

accounting for 480,000 ha (1,186,000 ac.) (Mladenoff et al. 2016). The authors used USDA's CDL data but combined shrubland and grass/pasture classifications into a single "open land" classification and combined wetland/forest into a single class.

- Wright et al (2017) assessed grassland losses as a function of proximity to ethanol refineries over the period 2008-2012 using USDA's CDL and found that almost 4.2 million acres (1.7 million ha.) of arable non-cropland was converted to crops within 100 miles of refinery locations, including 3.6 million ac. (1.46 million ha.) of converted grassland. Their analysis was based on applying a bias correction factor as per Lark et al. (2015) and making other adjustments.

A major shortcoming of these studies is that the primary data set relied on (CDL) is poor at differentiating between non-crop land classifications. Some authors acknowledged and attempted to correct for this problem to varying degrees. These shortcomings limit the confidence of conclusions regarding the form of the conversion, and even whether actual land use conversion has occurred in some areas.

An illustration of the effect of CDL data uncertainties on many studies relied upon by EPA (2018a) is a paper by Dunn et al. (2017). These authors examined data for 2006-2014 in 20 counties in the PPR using the CDL, a modified CDL dataset, data from the National Agricultural Imagery Program, and in-person ground-truthing, and conclude that analyses relying on CDL returned the largest amount of LUC by a wide margin. They further conclude that errors associated with CDL-based analyses are a major limitation of conclusions drawn from such analyses. In fact, the authors conclude that "*the amount of hectares in the potential error associated with CDL-derived results is generally greater than the number of hectares the CDL-based analysis determined had undergone a transition from grassland, forested land, or wetland to agricultural land".*[12] This suggests that errors in classification inherent in the CDL can result in uncertainty bounds that are of a larger magnitude than the estimates of LUC.

As an example, Dunn et al. (2017) point out that the findings reported by Lark et al. (2015) contradict USDA data indicating that cropland area has remained almost constant during the period 2008-2012. Dunn et al. (2017) is of particular interest because the study focused on the PPR, which has received the greatest attention due to documented ecosystem impacts from habitat loss and wildlife impacts to sensitive species, including population declines of prairie-dependent birds. It is interesting to note that EPA (2018a) acknowledges the specific conclusions reported by Dunn et al. (2017) by stating that adjustments to data made by Dunn et al. (2017) "*led to much lower estimates of land use than either unadjusted CDL and the NAIP for almost all counties examined* [*in the PPR*]".[13] Despite this explicit acknowledgment, EPA goes on to state that "*Nevertheless, these earlier studies* [referring to the studies critiqued by Dunn at al. (2017)] *qualitatively agree with patterns reported in more recent national studies".*[14] EPA's use of the term "qualitatively agree with patterns" in the context of studies that are attempting to quantify LUC after 2007 has little meaning and is misleading to the extent it suggests agreement between studies where little to no such agreement exists.

Table 1 presents a summary of selected results on the analysis conducted by Dunn et al. (2017).

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[12] Dunn et al. (2017) at pages 8 and 9

[13] EPA (2018a) at page 35

[14] EPA (2018a) at page 35

Table 1: Summary of Selected Results as Reported by Dunn et al (2017).

	Forest to Cropland (1000 ha.)			Wetland to Cropland (1000 ha.)		
	Dunn et al. (2017)		Lark et al. (2015)	Dunn et al. (2017)		Lark et al. (2015)
State	NAIP (2013)	CDL	modified-CDL	NAIP (2013)	CDL	modified-CDL
MN[a]	1.7	249	5.6	0	38	10
ND	0.83	222	0.44	0.01	25	7.4
SD	1.2	94	0.47	0	47	5.1
TOTAL	3.73	565	6.51	0.01	110	22.5

[a] Includes forest and grassland that was converted to cropland.

CDL data has 30 m resolution and is tested for inaccuracy each year. The accuracy of the CDL data varies yearly and regionally, which is why authors like Lark et al. (2015) make modifications to the data in an attempt to make it more accurate. Dunn et al. (2017) tested the accuracy of the modifications used by Lark et al. (2015) using NAIP data (see Table 1). NAIP data are images that are have 1 to 2-meter resolution and allow side-by-side viewing across years with high levels of accuracy. Dunn et al. (2017) found that even with the corrections that Lark et al. (2015) made to the CDL data, the modifications produced "*less land flagged as undergoing LUC but the result may not be any more accurate than a result produced without any modification".*[15] These results suggest that for the areas assessed, estimates using only uncorrected CDL data may overestimate actual LUC by a factor of 150 for forests and a factor of 11,000 for wetlands.

Further, EPA (2018a) mischaracterizes the accuracy of the CDL data[16], as the Agency states that CDL accuracies are generally > 90% for corn and soy and cites a study by Reitsma et al. (2016) in support of that assertion; however the accuracies found in the article were actually much lower than 90% for croplands (Reitsma et al. 2016). Reitsma et al (2016) used high resolution imagery to distinguish between cropland, grassland, non-agricultural, habitat, and water body land uses based on data from 2006 and 2012 in South Dakota. They found that cropland accuracy ranged from 89.2% to 42.6% depending on whether there was more cropland than grassland or the reverse. The authors chose data from South Dakota because the state represents a climate transition such that row crops predominate in the eastern portion of the state and grasslands predominate in the western portion of the state; the change in the dominant vegetation allowed them to examine how the surrounding habitat affected accuracy (Reitsma et al. 2016). The authors state that CDL errors that are inherent to the data sets introduce uncertainty into land-use change calculations. EPA's (2018a) failure to recognize the difference in CDL accuracy is especially important since many authors have documented that most of the observed LUC since 2007 has occurred at the margins of cropland/grassland transition areas. While EPA (2018a) falls short of addressing those specific data set concerns, EPA (2018b) recognizes that although satellite imagery can provide information on the types of crops grown on a given parcel of land in a given year, there is no nationwide system for tracking how crops from a particular parcel of land are used, whether for domestically or internationally consumed biofuels or feed or other uses. Thus, as EPA determined, its Triennial Report "did not purport to establish any causal link between the RFS . . . and increased crop cultivation."

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[15] Dunn et al. (2017) at page 10

[16] EPA (2018a) at page 32

3.4 Recently Released Research Purporting to Establish a Quantitative Link Between the RFS and LUC is Poorly Documented and Flawed

A recent presentation of research results by Lark et al. (Lark et al. 2019) appears to be an ambitious effort to establish quantitative causal linkages between enactment of the RFS as a policy to a variety of environmental outcomes using a series of interlinked models. However, their approach rests on the assumption that the price of corn is heavily influenced by increased demand for ethanol due to the RFS, yet the authors ignore other important factors that could be equally or more important. Nor can they differentiate between price drivers associated with global vs. domestic ethanol demand.

The modeling effort begins with estimates of increased demand for corn for ethanol and effects of the increased demand on the price of corn. The authors then model the effect of this increased demand on crop intensification and extensification and abandonment. The authors then apply a “suite” of models, including what they describe as “causal economic models” to evaluate the resultant land use changes as well as the following environmental outcomes: NO_2 emissions, carbon emissions, and consumptive water use.

With respect to the effect of RFS implementation in 2007 on LUC, the authors conclude that during the period 2008-2016, the RFS resulted in an annual average increase of 6.9 million acres of corn planted on existing cropland. In addition, the authors conclude that during the same period, the RFS resulted in an annual average increase of 2.8 million acres of corn planted on new cropland (i.e., cropland converted from other land cover types), or 43% of the total increase in new cropland observed over the period. The authors attribute these changes to a 30% increase in price of corn attributable to ethanol demand created by the RFS.

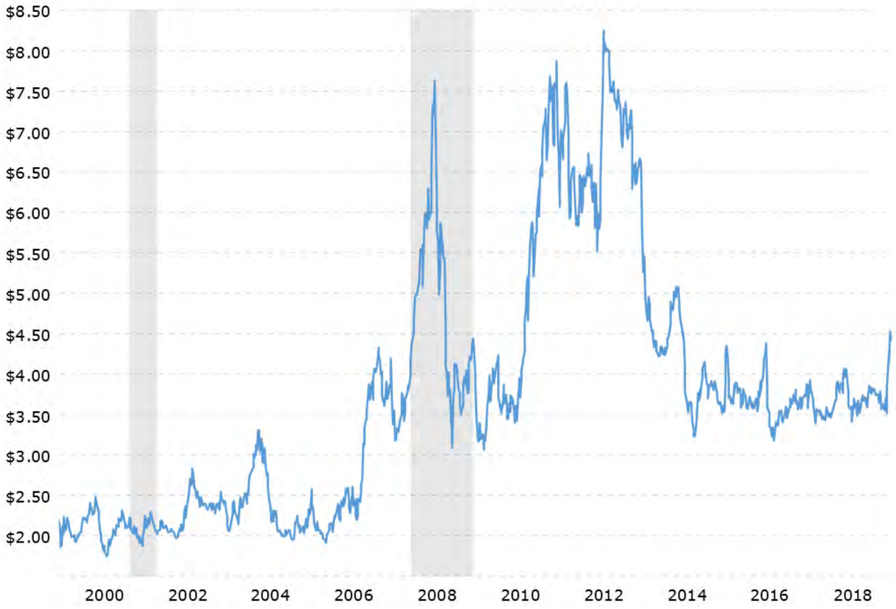
The authors attempted to construct the counterfactual case; that is, simulate what the world would have looked like without the RFS (called the “Business as Usual” scenario) and then compare it to existing conditions in order to obtain and isolate the effects of the RFS. However, when a counterfactual is posed that is too far from the real-world data, conclusions drawn from even well-specified statistical analyses become based on speculation and indefensible model assumptions, rather than empirical evidence. Unfortunately, standard statistical approaches assume the veracity of the model rather than revealing the degree of model-dependence, so this problem can be hard to detect. It is well understood that the greater the distance from the counterfactual to the closest reasonably sized portion of available data, the more the counterfactual depends upon model assumptions and inferences. The seemingly large effects of the RFS reported by the authors are simply their comparison between reality and a manufactured counterfactual situation which may or may not reflect a realistic alternative state.

The authors’ entire analysis rests on estimating price increases attributable to RFS, and that is the primary weakness evident in the work. The pricing model drives the rest of the analysis. By not examining other model specifications, the inherent assumption regarding the association of prices to the RFS remains speculative. In fact, corn prices over the period of analysis were affected by a variety of other factors. For example, rapid economic growth in developing countries led to growing food demand and a dietary transition from cereals toward more animal protein. As a result, global consumption of agricultural commodities has been growing rapidly. Further, most of the increase in corn prices has been driven by higher oil prices. Figures 6 and 7 show nominal prices of West Texas Intermediate crude ($/bbl) and corn ($/bu) for the latest 20-year period. The shaded areas reflect US recessions.

Figure 6: West Texas Intermediate Crude Prices ($/barrel).

(Source: Macrotrends. n.d.)

Figure 7: US Corn Prices ($/bushel).



(Source: Macrotrends. n.d.)

Regarding the ability to “measure” land use change, Lark et al. (2019) explicitly recognize many problems with spatial data interpretation and state that land use change was mapped at the field level using the updated recommended practices by Lark et al (Lark et al. 2015). However, the specific data sets used are not disclosed, and there is no description of how the “recommended practices” were applied. The authors also do not provide an assessment of whether and how the “recommended practices” improved estimates of LUC; rather they simply present the results of their analysis. In addition to not presenting a full description of the methods used, the authors rely on at least some data sets that are not publicly available, therefore limiting the ability of a third party to replicate their work. For example, the authors state that their analysis relies on a database built using field boundary data from the 2008 USDA Common Land Unit (CLU) among other data sources. The CLU database is compiled by the USDA FSA and is not in the public domain.[17]

3.5 EPA (2018a) Failed to Adequately Account for the Role of Cropping Practices and Production of Distillers Dried Grains with Solubles (DDGS) at Ethanol Refineries as Important LUC Offsetting Factors

Numerous authors cited by EPA (2018a) who have researched LUC or increasing corn production, and the relationship of these two phenomena to ethanol production have acknowledged that much of the observed change (either LUC to agriculture or increasing corn) may be attributable to cropping practices rather than conversion of non-agricultural land to corn production. The primary cropping practices that may contribute to increased production of corn, without implicating conversion of noncropland to row crops, are switching fields to corn from other crops and double cropping of corn. The use of DDGS also reduces the need for additional acreage of corn, which is often overlooked in analysis of LUC. Similarly, EPA (2018a) fails to discuss the role of DDGS in potentially offsetting market forces that may contribute to LUC occurring to meet demand for corn for ethanol.

3.5.1 Cropping Practices Have a Major Role in Meeting Increased Demand for Corn

EPA (2018a) acknowledges the potential significance of cropping practices by citing, among other studies, a study by Ren et al. (2016) in eastern Iowa that examined changes in corn and soybean rotations around 2017 and found that the most common rotation over the period 2002-2007 was corn/soy, but this rotation was not evident in 2007 and 2012 (with 59% of the area that had been in rotation prior to 2007 was in two or more years of continuous corn after 2007). The most important conclusion reached by Ren at al. (2016) is ignored by EPA (2018a): "*From our analysis, it is clear that the expansion of corn production after 2007 was realized by altering crop rotation patterns* " (Ren et al. 2016).[18] Although this study pertains to eastern Iowa it is of particular importance since Iowa is the largest producer of corn in the US (17.4% in 2018; USDA-NASS, 2019).[19]

EPA also refers to a study by Plourde et al. (2013) when discussing intensification, but EPA does not underscore the primary conclusion of these authors (Plourde et al. 2013). In assessing data for two distinct time periods (2003–2006 and 2007–2010) in a nine state "Central United States" area (states of AR, IL, IN, IA, MS, MO, NE, ND, and WS) these authors found that the total area impacted by corn production only increased slightly between the two periods, while there was a much greater increase in the intensity of continuous corn rotation patterns. Similarly, in discussion about corn acres increasing mostly on farms that were previously soy over the period 2006-2008, EPA cites Beckman (2013) "*…that increases in corn acreage from 2001-2012 resulted in a net decrease in barley, oats, and sorghum* " (Beckman et al. 2013).[20]

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[17] In fact, the FSA website states the following:
CLU is not in the public domain. Section 1619 of the Food, Conservation, and Energy Act of 2008 (Farm Bill), only allows the sharing of this data to individuals or organizations (governmental or non-governmental) certified by FSA as working in cooperation with the Secretary of Agriculture. Users of the data must be providing assistance to USDA programs, and must require access to CLU data to complete that work (USDA 2012).

[18] Ren et al. (2016) at page 157

[19] Calculated from p. 11 in USDA-NASS 2019

[20] EPA (2018a) at page 40

Although EPA (2018a) acknowledges that changes in cropping practices "could be significant," they do not provide a quantitative or even qualitative assessment of how significant cropping might be in meeting increased demand for corn for ethanol. Inadequate accounting of the role of cropping practices in discussion of ethanol and LUC contributes to the misperception that the increase in corn production to fulfill demand for corn for ethanol necessarily results in adverse LUC.

3.5.2 Production of DDGS Has Offset a Substantial Amount of Demand for Corn as Livestock Feed But this was Not Adequately Acknowledged by EPA (2018a)

EPA (2018a) states that approximately 12% of the total corn production from 2014-2016 was returned to the feed market in the form of DDGS which is produced during the distillation of corn for ethanol. EPA (2018a) also acknowledges a study by Mumm et al. (2014)(Mumm et al. 2014) who conclude that although 40% of corn grown in 2011 was estimated to be utilized in ethanol production, when the offsetting effect of DDGS is accounted for, this acreage is reduced to 25%.[21] Although EPA (2018a) cites some of the findings reported by Mumm et al. (2014), they fail to acknowledge some very important conclusions of these authors regarding potential future projections. Mumm et al. (2014) evaluate four scenarios considering the impact of technological advances on corn grain production, two scenarios focused on improved efficiencies in ethanol processing, and one scenario reflected greater use of DDGS. For each scenario, Mumm et al. (2014) estimate the land area attributed to corn ethanol. Assuming reasonable increases in corn grain yield with anticipated new yield technologies coming into play between 2011 and 2026, the authors estimate that the percentage of land devoted to corn for ethanol will be reduced from the 25% estimated for 2011 to 13% in 2026.

Irwin and Good (2013) reported that DDGS account for much of the decline in feeding of whole corn to livestock since 2007-2008. According to the National Corn Growers Association, between 1,013 and 1,222 million bushels of corn were displaced by DDGS and Corn Gluten Feed (CGF; produced by wet milling at ethanol refineries) between 2009 and 2016 (National Corn Growers Association 2019). For illustration purposes, if we assume an average yield of corn per acre per year of 125 bushels (USDA-NIFA n.d.), then over the period 2009 to 2016_DDG/CGF may have displaced ~8.1 – 9.8 million acres of corn production per year that otherwise would have gone for livestock feed. This offsetting factor is more than the 6.9 million acres (yearly average) of corn planted on existing cropland and the 2.8 million acres (yearly average) of new cropland alleged by Lark et al. (2019) to be attributable to the RFS for the period 2008-2015.

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[21] Mumm et al. (2014) Box 3 at page 53

4. CHANGES IN AGRICULTURAL PRACTICES REDUCE THE LIKELIHOOD OF ENVIRONMENTAL IMPACTS TO WATER RESOURCE AVAILABILITY AND QUALITY

The relationship between corn production and water resource availability and water quality varies geographically and temporally. What is clear but not quantitatively recognized by EPA (2018a), is that advancements in farming practices and technology have reduced the negative impact of farming on the environment. Recent technological advances have resulted in considerable improvements in water use in agriculture in general, and for corn growing, as well as reducing the use of agrochemicals such as fertilizers and pesticides. These improvements have the effect of reducing the likelihood of adverse impacts to water resource availability and quality.

There is no dispute that all agricultural production is strongly tied to the availability and quality of fresh water. Farming practice is based on local and regional climatic and soil conditions which determine whether crops are grown using irrigation from surface water or groundwater sources or are non-irrigated and rely solely on precipitation. Approximately one-quarter of US cropland is irrigated (NAS 2019). The total US irrigation withdrawals for all crops in 2010 averaged approximately 115 billion gallons per day (NAS 2019). The availability of sustainable water sources, more so than any other issue, poses the greatest threat to crop productivity into the future. Corn is a water intensive crop; however, most corn grown in the US is non-irrigated, and this is recognized by EPA (2018a). Over the past decade, there has been increased use of modern and precision agriculture methods (for both water use and agrochemical application) which retain soil moisture and reduce tilling. This trend is expected to continue into the future, with increasing efficiency and effectiveness of resource use, which will result in reducing water and fertilizer needs.

4.1 The Triennial Report’s Discussion of Water Use and Water Quality

Key conclusions in EPA (2018a) relevant to the RFS reset discussion include:

- The environmental impacts of increased biofuel production on water resource use and water quality were likely negative in the past but limited in impact.
- A potential exists for both positive and negative impacts in the future with respect to water resource use and availability, and impact to water quality both locally and regionally.
- Environmental goals for biofuels production could be achieved with minimal environmental impacts (including water and fertilizer/pesticide use) if best practices were used and if technologies advanced to facilitate the use of second-generation biofuels feedstocks.

These messages are consistent with our findings that the environmentally protective goals for biofuel production are highly achievable as best management practices and technological advances in farming continue to be adopted by the farming community. While challenges for fully distributing and implementing these approaches will remain in certain areas (e.g., NAS 2019), the economic drivers for implementing best practices such as increased productivity and savings derived from resource conservation, will undoubtedly continue to steer the farming community toward greater implementation of modern approaches.

The most important statements presented by EPA (2018a) are the forward-looking considerations that biofuel production can (and will) achieve environmental goals by using modern practices. EPA (2018a), however, paints a picture of negative impacts from biofuels feedstock production without using specific and conclusive data to support the claims. For example EPA (2018a):

- Asserts that increased intensity of corn production on existing cultivated land and expansion of crop land negatively impacts water quality but presents no direct evidence of a causal link.
- Does not rely on direct analysis to assess the magnitude of potential water quality impacts but instead makes general statements with no quantitative analysis that connects the water quality impact to specific areas, land, or conditions.
- Recognizes that quantitative assessments are necessary to evaluate whether increases in water demands can be directly attributed to feedstock production. However, EPA (2018a) does not provide the studies or backup to support this evaluation, rather merely speculates that negative impacts must exist.

EPA (2018a) suggests that growing corn for ethanol feedstock is a major contributor to eutrophication and hypoxic conditions in the northern Gulf of Mexico and eutrophication in western Lake Erie. EPA (2018a) attributes these conditions to substantial nutrient loading from agricultural runoff. However, the impact, if any, from corn grown for ethanol production on water quality and availability is not substantiated with data. For example, the attribution by EPA (2018a) that biofuel feedstock production is a contributing factor to these conditions appears to rely on models such as those presented by Michalak et al. (2013) that state corn production "could" be a contributing factor and LaBeau, et al. (2014) that speculate biofuel production "could" contribute to increased nutrient loading to surface water (Michalak et al. 2013, LaBeau et al. 2014).

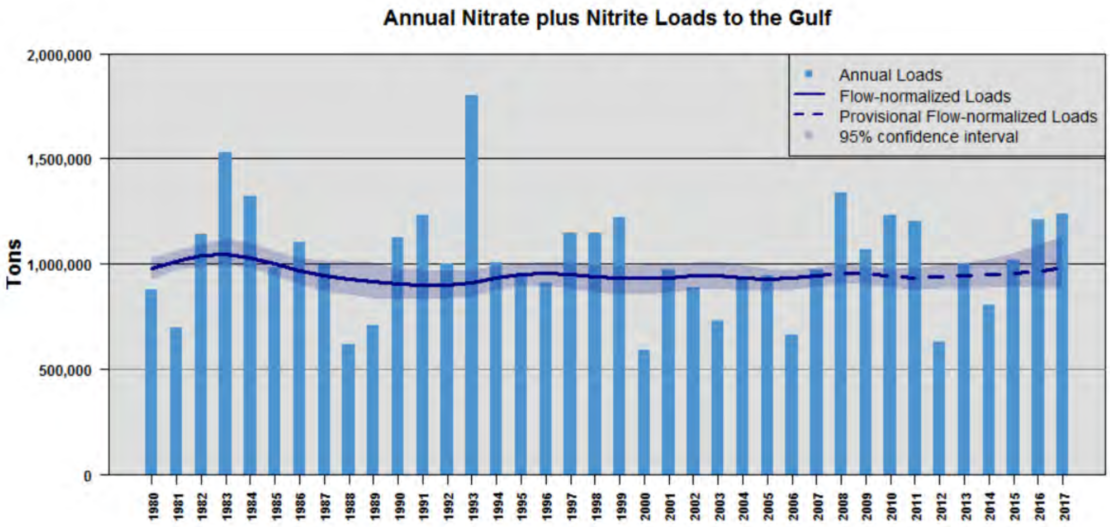
There may be no dispute that excess nutrient loading from the key watersheds that discharge into western Lake Erie and the northern Gulf of Mexico contribute to eutrophication and hypoxia; however, the watersheds are composed of a complex mix of urban and rural uses and wastewater discharges. Agricultural runoff should be considered an important component; however, the direct causal link to corn grown for ethanol production (compared to all other uses and compared to all other agricultural activities) is not substantiated. Indeed, no studies reviewed by Ramboll convincingly link increases in biofuel production to regional hypoxic conditions in surface water bodies. Such conditions have been increasing in frequency and severity since the 1950s, long before ethanol production increased.

EPA (2018a) also fails to acknowledge the importance of regional weather on the occurrence and severity of large-scale hypoxia events. For example, one major variable determining the size of the hypoxic zone (colloquially known as the "dead zone") in the Gulf of Mexico is the rate of flow in the Mississippi River, which may be highly-variable on an annual basis. The National Oceanic and Atmospheric Administration (NOAA) is predicting that the 2019 dead zone in the Gulf of Mexico will cover an area of 7,829 square miles which is close to the record size of 8,776 square miles in 2017 and more than one third larger than the 5-year average size of 5,770 square miles (NOAA 2019). NOAA states that a major factor contributing to the dead zone in 2019 is the abnormally high amount of spring rainfall that has resulted in flows in the Mississippi and Atchafalaya Rivers that are 67% above the average flows over the last 38 years. Data collected by the United States Geological Survey (USGS) indicate that because of these high flows, nitrate loads are about 18% above the long-term average, and phosphorus loads are approximately 49% above the long-term average (USGS 2019).

Finally, EPA (2018a) also fails to recognize that changes in flood-control and navigation improvements in the Mississippi River watershed during the first part of the 20th century dramatically affected the amount of flow from the upper Midwest watersheds that would enter the Gulf of Mexico without environmental buffering from natural tributaries (NOAA 2000). The higher flow rates allowed greater unimpeded flow of water containing nutrients to the Gulf of Mexico than would otherwise have occurred (NOAA 2000).

It is interesting that while EPA (2018a) relies on speculation and qualitative studies to associate corn grown for ethanol to hypoxia in western Lake Erie and the Gulf of Mexico, EPA (2018a) also reports that there has been a reduction in total nitrogen concentrations in surface water bodies in Iowa (the highest corn producing state and an area of corn growth intensification). We note that nutrient loading to the Gulf of Mexico has been relatively stable on average since at least 1980 – an important consideration as corn yield has increased during this time period (USGS n.d.) even as farmed acreage has been stable. This indicates that even during the increased use of corn for ethanol, there has been no net change to nutrient loading to the Gulf of Mexico and thus there is no support for the assertion of a direct relationship between ethanol production on the hypoxia conditions in the Gulf of Mexico. This evidence refutes claims made to the contrary by EPA (2018a).

Figure 8: Annual Nitrate and Nitrite Loading to the Gulf of Mexico 1980-2017.



(Source: USGS n.d.)

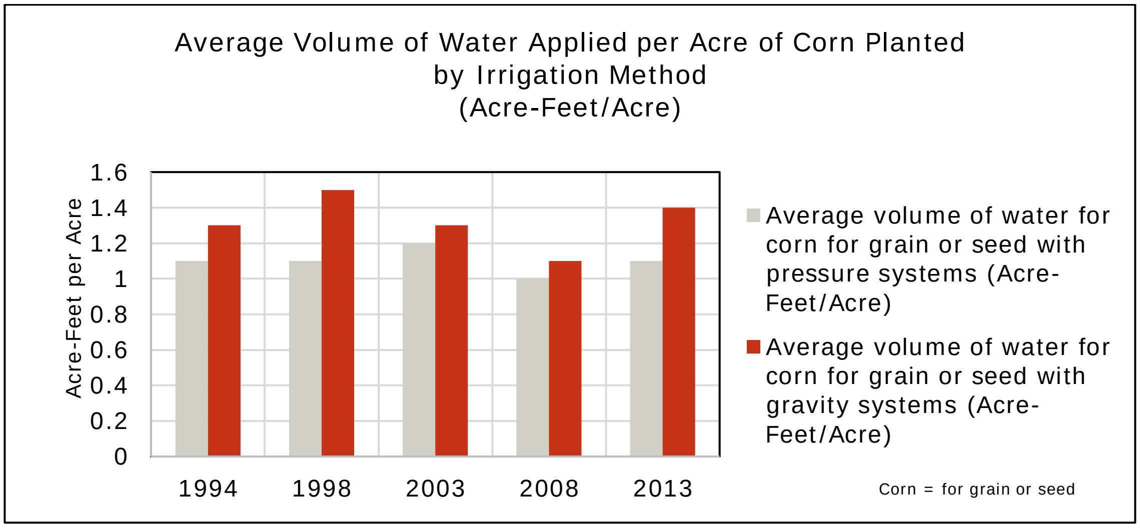
The fact that agricultural practices in general can result in nutrient runoff is acknowledged, although modern efficiencies and conservation methods have improved over time. Modern practices apply technology for increased efficiency and harness continuously improving data analysis to develop and implement best management practices. There is strong evidence that the agricultural community, including biofuel feedstock producers, are adopting modern agricultural practices (Vuran et al. 2018). EPA (2010 and 2018a) acknowledge and strongly advocate for these modern practices and note that negative impacts to environmental resources will be reduced with the use of modern approaches to tilling, fertilizer use, water use, and precision agriculture. If these practices were not being implemented, the expectation is that nutrient loading, and thus hypoxic conditions, should have been increasing along with the increased yield over the past several decades. However, the data from NOAA and the USGS show stability in nutrient loading, which would thus indicate that the net flux of nutrients has not been increasing even while crop yields may have been increasing.

4.2 Agricultural Improvements in Irrigation are Reducing Water Use

The trend of increasing yield per acre farmed extends to both irrigated and unirrigated corn crops, indicating that changes in yield are not likely attributed to irrigation alone. According to the 2012 statistics from the USDA (USDA-ERS 2018a) irrigated corn acreage represented about 25% of all irrigated acreage in western states, and about 24% of all irrigated acreage in the eastern states. Additionally, the USDA has shown that irrigation for all crops, including corn, has decreased even as the farming acreage has essentially been stable over the past 35 years. The USDA attributes this trend to improvements in physical irrigation systems and water management. The USDA also notes that significant capital investments in on-farm irrigation is continuing, particularly in the western states, where most of the irrigated farm-land is concentrated. As an indication of a positive trend in irrigation reduction, the University of Nebraska, Lincoln reports that in Nebraska (as a bell-weather of other dry western states), the percentage of all corn acreage that is irrigated has declined from a high of 72% in 1981 to 56% in 2017 (University of Nebraska 2018).

USDA data indicate that there has been no substantial change in the volume of water applied to corn crops (for grain or seed) since the 1990s (Figure 9) (USDA-NASS 2013). This stability in the average volume of water applied to corn crops, combined with the plateau in area of corn planted, suggests that the quantity of water applied to corn crops has not substantially increased since at least the 1990s, despite intensification.

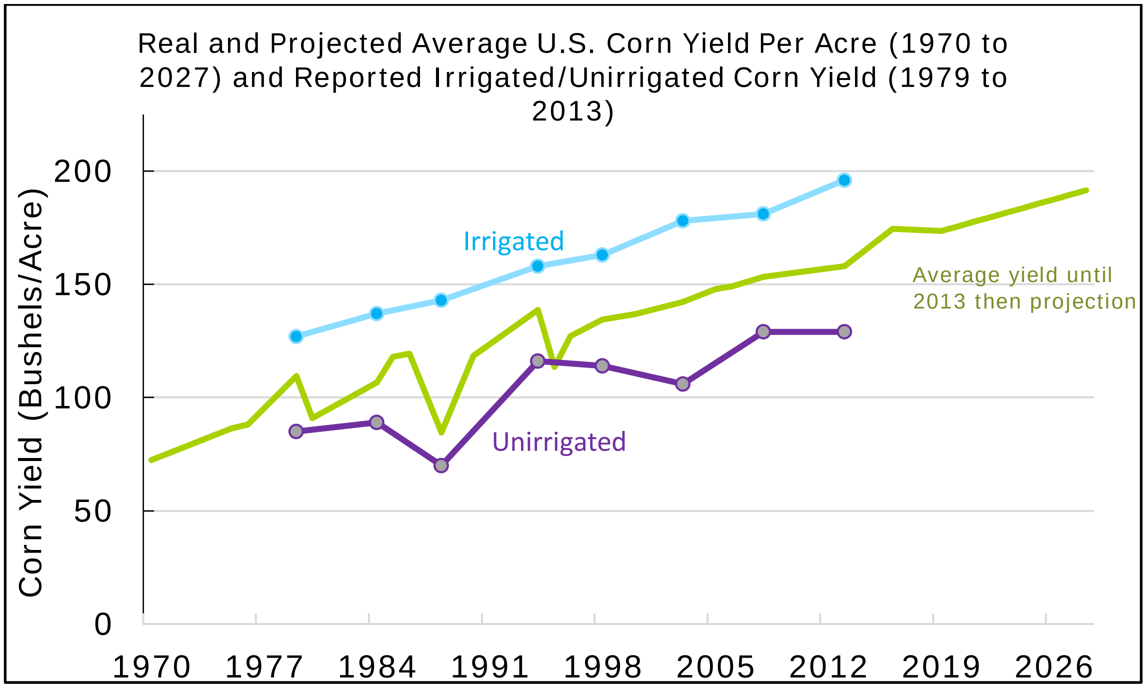
Figure 9: Volume of Water Applied to Irrigated Corn Crops Since 1994, by Irrigation Method.



(Source: USDA-NASS 2013)

Because irrigation provides a stable water resource to the farmed field (assuming the water source that supplied irrigation is also stable), crop yields on irrigated land are generally more regular (e.g., less variable and often more substantial) than for non-irrigated land (Figure 10). Note, however, that from at least 1979 to 2013, increases in yield also have been observed in unirrigated corn crops (USDA Farm and Ranch Irrigation Survey). Specifically, in 1979, irrigated land produced 127 bushels per acre on average, versus 85 for unirrigated land. By 2013, irrigated land produced 196 bushels per acre on average, versus 129 bushels per acre for unirrigated land, representing a 54% and 52% increase, respectively.

Figure 10: While Irrigated and Unirrigated Corn Crops Have Both Experienced General Increases in Yield, Irrigated Crops More Reliably Produce Higher Yields.



(Source: USDA-NASS 2013)

Regions of greatest corn production are moving eastward away from the regions of greatest irrigated water use, providing further evidence that year-to-year changes in corn planting have little to negligible impact on total U.S. water supply. For example, in 2016, the five leading states in annual corn production (Illinois, Nebraska, Iowa, Minnesota, and South Dakota) produced over 60% of the corn grown in the U.S. (USDA-ERS 2016). This statistic is a change from the 2010s when the irrigation of corn crops was even more concentrated in the drier Northern Plains (Colorado, Montana, Nebraska, Wyoming, and North and South Dakota) and dry Southern Plains (Kansas, Oklahoma, Texas) regions. In 2007, the USDA reported that the thirteen leading states in total irrigated acres for all crops of farmland, accounted for nearly 80% of all U.S. irrigated land, but that they were concentrated in arid western states (USDA-ERS 2018a). Of the top five corn-producing states, none made up more than 15% of the total U.S. irrigated acreage. The increased growth in wetter states such as Illinois and Minnesota eases the water supply demand for the total yield of all irrigated corn acres.

USDA anticipates that changes in corn production will result in appreciable yield increases (e.g., 16.1 more bushels per acre by 2028) (USDA-NASS 2017). It is therefore reasonable to expect that technological and methodological changes to farming will continue to result in significant reductions in water use per unit of corn production. Table 2 presents an overview of prevailing opportunities for water savings in irrigated agriculture.

Table 2: Technological and Methodological Improvements to Irrigation of Corn Crops.

Technological Advancement	Approximate water savings factor	Baseline scenario	Demonstrated potential yield increase	Notes
Subsurface drip irrigation	25-35%	vs. center pivot system	15-33%	Costs 40-50% higher than center pivot systems but returns on investment can accrue within 2—5 years. In 2007, only 0.1% of irrigated corn farms used this.
Rain water harvesting and storage	50+%	vs. natural soil runoff	20-52%	Includes 1) harvesting of surface runoff from roads; 2) field micro-catchment to increase fallow efficiency in rain.
Precision agriculture	13%	vs. without government-run weather network	8%	Includes use of global positioning system, geographical information systems, in situ soil testing, remote sensing crop and soil status, real-time weather info. Adoption rate slightly higher in corn belt.
Conservation structures	18%	vs. conventional agriculture	27%	Examples include grass vegetation strips. Adoption is higher in areas of highly erodible land.

(Sources: Netafim n.d., Gowing et al. 1999, Shangguan et al. 2002, National Research Council 2008, Biazin et al. 2012, Allen 2013, Barton and Elizabeth Clark 2014, Center for Urban Education about Sustainable Agriculture (CUESA) 2014, Qin et al. 2015)

Subsidized government programs offer farmers incentives to implement water conservation strategies. For example, because of prolonged drought conditions, California recently installed a network of 145 automated statewide weather stations, so that farmers could manage their water resources more efficiently (CIMIS 2019).

With the focus on drought and long-term reductions in supplied water in some states (such as California), more farms are moving away from “traditional, less-efficient application systems” (USDA-ERS 2018a). For example, the number of farms using inefficient gravity irrigation systems decreased from 62% in 1984 to 34% in 2013, converting mostly to pressure-sprinkler irrigation which is more efficient than gravity irrigation, but which still leaves room for improvement. Currently, almost 10% of farms use soil-moisture or plant-moisture sensing devices or commercial irrigation scheduling services. Sensor technology can optimize irrigation scheduling and hence increase water use efficiency. Though less than 2% of farms use simulation models right now (USDA-ERS 2018a), the anticipation is that additional large industrial farms (which make up a large volume of total yield) also will employ water use simulation models that are based on corn growth patterns and weather conditions. Adoption of these technologies will continue to grow in the U.S., and particularly in the west, where 72% of water irrigation investment takes place and farmers have recent experience with low water supply following the 2012-2016 drought.

Barriers to implementing these measures are lessening but it is recognized that issues relating to the following are still at play: (1) farmer concerns about the impact of new practices on yields; (2) tenant or lease issues that discourage the installation or use of new equipment; (3) institutional issues related to Federal Crop Insurance Program; (4) irrigation water rights laws like "use it or lose it;" and (5) cost of implementation. The Great Plains area had traditionally been risk-averse to implementing subsurface drip irrigation techniques because of the upfront costs and uncertain lifespan of the systems; however, there have been improvements in the technology and irrigators are increasingly aware of the additional incentives for water conservation and protecting water quality (Lamm and Trooien 2003).

Genetic engineering or selection for improved drought tolerant corn cultivars has also contributed to increases in corn crop productivity. Additionally, genetic breeding has shown that yields can be maintained with lower water requirements (nearly 25% reduction), in addition to studies that suggest corn crops can forego the initial irrigation without significant adverse effects to the harvest (Xue, Marek, et al., 2017). Mcfadden et al. (2019) reported that with drought being among the most significant cause of crop yield reduction, the spike in use of irrigation water to reduce such losses can be a major negative impact to water resource availability particularly in the drier western states. Even though many water-intensive crops, including corn, are grown on non-irrigated land, the use of drought-tolerant corn, which was commercially introduced in 2011, had increased to over 22 percent of the total U.S. planted corn acreage by 2016 (Mcfadden et al. 2019). More important, this percent of use was greatest in the driest corn-producing states of Nebraska (42 percent) and Kansas (39 percent). Even the less severe drought-impacted though important corn-growing states of Minnesota, Wisconsin, and Michigan saw drought-tolerant corn planting ranging between 14 and 20 percent of total acreage. There is no guarantee that drought-tolerant crops will be effective against the most severe droughts; however, this use can be seen as similar to the use of crop-insurance to protect farmers against loss while still providing product for use during low-water years. The longer-term advantage is that less irrigation water would be required even under normal water years.

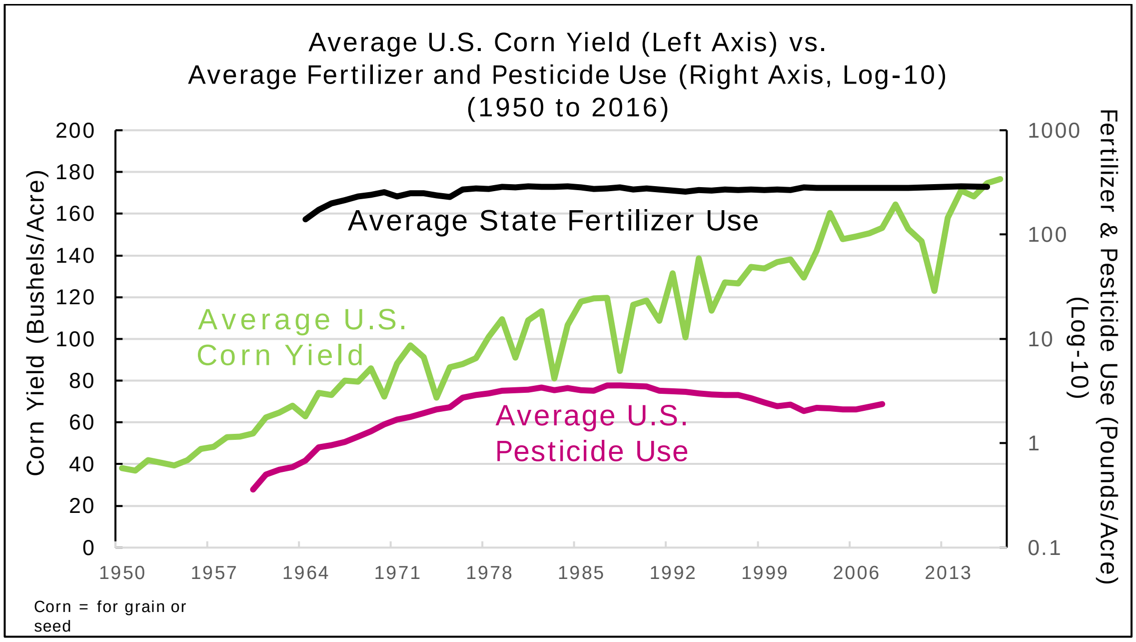
Liu, et al (2018) states that best management practices for reducing agricultural non-point source pollution are widely available even with the challenges related to the large number of agricultural producers and the spatially variable and temporally dynamic nature of the nutrient loading cycles. Greater adoption of the improved practices will rely on: (1) better identification of the higher risk areas; (2) a commitment from local, state and federal authorities to assist the farming community in applying the new approaches by allowing innovations to be implemented without unnecessary regulatory impediments; and (3) better financial incentives. Liu, et al (2018) also note that lack of information and misdirected communications can negatively impact the adoption of new techniques and encourages government, consumers, and farmers to work together to more consistently communicate the advantages of technology adoption.

4.3 Technological Improvements in Agriculture Translate to Reductions in Potential Water Quality Impacts

Government institutions including USDA and academic institutions such as California State University, Fresno have promoted research into the use of precision agriculture to reduce the need for both nutrient and pesticide use (as well as supplied water) because in addition to a reduced environmental impact, the techniques result in cost savings for farmers by improving yield per acre. In addition, the greater use of area-wide databases that provide better information and awareness of water quality conditions helps to identify areas where additional best management practices can be applied. For example, utilization of the USGS water quality mapping reports (e.g., USGS 2017) helps provide data for surface water chemistry trends (i.e., nutrients, pesticides, sediment, carbon, salinity) and aquatic ecology from 1972 to the current editions.

Recent advancement in technology for fertilizers and pesticides have reduced the use of agricultural chemicals while increases in crop yield continue. While use of fertilizer on corn typically accounts for more than 40% of commercial fertilizer used in the U.S. since the 1980s (USDA-National Resources Conservation Service [NRCS] 2006, EPA 2018c), there has been a plateau in the mass of fertilizer applied to corn crops (on average on a state-by-state basis), as well as an overall decrease in the mass of pesticide applied to corn crops (see Figure 11;(USDA-NASS 2013, Fernandez-Cornejo et al. 2014, USDA-ERS 2018c). In 1987, the average mass of pesticide active ingredient application per area of corn planted in the U.S. peaked at approximately 3.58 pounds per acre. In 1984, fertilizer use peaked at approximately 290 pounds per acre. The USDA and EPA report similar trends; for example, U.S. spending on pesticides for all crops peaked in 1998, and consumption of commercial fertilizers peaked in 1981 (Fernandez-Cornejo et al. 2014, EPA 2018c).

Figure 11: Both Pesticide and Fertilizer Use on U.S. Corn Crops Appear to Have Peaked in the 1980s



(Source: USDA [ibid.])

The application of slow released (or controlled) nitrogen fertilizer during peak uptake is one key to improving nutrient efficiency and utilization (Lal, R. (Ed.), Stewart 2018). Under optimum moisture and temperature conditions, use of slow released nitrogen fertilizer can greatly reduce leaching of nutrients. However, further research is necessary to discern the best slow release fertilizer for a given crop species (Rose 2002). Other advanced chemical technologies such as use of bioreactors, can offer additional reductions in pesticide and fertilizer in corn production. Bioreactors such as those that redirect water in farm fields through tiles to underground woodchips where nitrate is removed by microorganisms, can reduce nitrogen in run-off by 15% to 90% (Iowa Corn n.d., Christianson 2016).

Recent surveys and data from the use of the modern and technology-based agricultural management systems have shown reduced resource needs and significant cost savings (NAS

2019; Liu, et al. 2018). The USDA also has shown that a “guidance-based” system for corn production can save thousands of dollars each year with a return of investment of two to three years for this technology (USDA-NRCS 2006). Furthermore, the USDA reports that “…precision agriculture reduces environmental pollution and improves water quality by reducing nutrient runoff [while] other benefits include: improved crop yield; reduced compaction [of fields]; labor savings; and more accurate farming records.” Finally, there are fewer barriers to nearly all farmers in using precision technologies because of grants that are available for purchasing equipment and free public access to the Federal Global Position System that makes it economically possible for producers to use the new precision tools to save energy and reduce costs by improving or implementing the following: (a) yield monitoring, (b) grid soil sampling, (c) precision and variable-rate nutrient application; and (d) soil moisture monitoring. Precision agriculture technologies are quickly adopted by farmers in the United States; the rate of adoption for all precision technologies was 72.47 percent in 2010, as compared to just 17.29% in 1997 (Vuran et al. 2018). USDA found that if guidance-based farming was used on just 10 percent of planted acres in the U.S., fuel use would be cut by 16 million gallons, herbicide use would be reduced by 2 million quarts and pesticide use would lower by 4 million pounds per year(USDA-NRCS 2006). The results would be better environmental conditions and substantial increase in financial savings for the farmer/producer.

4.4 Reduction in Water Usage for Ethanol Processing

Opportunities exist for implementing water reduction programs during biofuel production. Excluding the non-fuel component, the primary processes that require water consumption in ethanol production include heating and cooling. Water losses occur through: (1) evaporation, drift, and blow down from cooling towers; and (2) blow down from boilers. Losses vary with both the ambient temperature of the production plant, and the degree of boiler condensate and blow down water reuse and recycling. Generally, dry mills use less water than wet mills. In a 2007 Renewable Fuels Association survey of 22 ethanol production facilities (representing 37% of the 2006 volume produced), dry mills used an average of 3.45 gallons of water per gallon of ethanol produced and wet mills used an average of 3.92 gallons of water per gallon of ethanol produced. Efforts to use recycled waste water are increasing and will reduce the need for using supplied water during the conversion process.

Keeney and Muller (2006) report that in Minnesota, water use by dry mill ethanol refineries ranged between approximately 3.5 and 6.0 gallons of water per gallon of ethanol in 2005 which followed a 21% reduction in water use by dry mill ethanol refineries from 1998 to 2005 (representing an annual reduction of approximately 3%). More recently, Dr. Steffen Mueller of the University of Illinois (Chicago) Energy Resources Center notes that water consumption by ethanol plants is continuing to decrease and dramatically so. Mueller (2016) documents a reduction of approximately 5.8 to 2.7 gallons of water per gallon of ethanol produced between 1998 and 2012 in dry mills.

Wu and Chiu (2011) noted additional trends that suggest decreases in the water demands of existing and new ethanol plants. Freshwater consumption in existing dry mill plants had, in a production-weighted average, dropped 48% in less than 10 years to water use rates that are 17% lower than typical mill values. Water use can be minimized even further through process optimization, capture of the water vapor from dryers, and boiler condensate recycling to reduce boiler makeup rates.

5. RECENT ESTIMATES OF HEALTH DAMAGES FROM CORN PRODUCTION ARE UNRELIABLE AND MISLEADING

A recent publication in *Nature Sustainability* (Hill et al., 2019) estimates US annual health damages caused by particulate air quality degradation from all direct farm and indirect supply chain activities and sectors associated with corn production. Although the authors do not reference the RFS, they do mention corn grown for ethanol, and the publication has been referenced by third parties in a manner suggesting that corn grown for ethanol may be associated with adverse health outcomes. Ramboll's review indicates that the conclusions presented by Hill et al. (2019) are unsubstantiated and likely overestimate adverse health impacts if any.

These "life-cycle" activities and sectors examined by Hill et al. (2019) include air emissions from farms and upstream processes that produce the chemical and energy inputs used in corn crop production: fuel, electricity, agrichemical production, transportation and distribution. Downstream activities such as corn distribution and food/fuel processing are not considered in the study. The authors develop an annual county-level emissions inventory of air pollutants for all related sectors, then apply a specific "reduced form model" (RFM) that converts those emissions into spatial distributions of annual fine particulate air concentrations (or $PM_{2.5}$) and resulting human exposure, premature mortality, and monetized health damages.

$PM_{2.5}$ comprises microscopic particles smaller than 2.5 microns in diameter, with chemical constituents that include direct (primary) emissions (dust and smoke) along with the several secondary compounds chemically formed in the atmosphere from gas precursor emissions: nitrate from nitrogen oxide (NOx) emissions, ammonium from ammonia emissions, sulfate from sulfur oxide (SOx) emissions, and secondary organic aerosols (SOA) from volatile organic compound (VOC) emissions. $PM_{2.5}$ is a concern for human health because particles of this size can penetrate deep into the lungs and enter the bloodstream, which can potentially result in both acute and chronic effects to the respiratory and cardiovascular systems. Epidemiological studies have found associations between $PM_{2.5}$ exposure and mortality and these associations are used by Hill et al. (2019) to calculate health impacts from corn production. The authors find that impacts to annual-average $PM_{2.5}$ concentrations from corn production are primarily driven by emissions of ammonia from nitrogen fertilizer.

Ramboll reviewed details of the specific RFM used by Hill et al. (2019), called the Intervention Model for Air Pollution (InMAP; Tessum, Hill, et al., 2017) to calculate ambient $PM_{2.5}$ impacts from corn production. InMAP calculates atmospheric dispersion, chemistry and removal (deposition) from direct $PM_{2.5}$ and precursor gas emissions. It then converts resulting annual $PM_{2.5}$ concentrations to human exposure metrics from which premature mortality and associated damages are determined. Hill et al. (2019) provide only an overview of the process to develop emission inventories, which limits our capacity to review. However, given the importance of ammonia emissions to the results reported by Hill et al. (2019), we enumerate well-known uncertainties involved in estimating emissions from agricultural activities. In addition, although Hill et al. (2019) did not provide explicit details on the impact assessment, we provide a summary of the key uncertainties associated with estimating health and associated costs from $PM_{2.5}$ exposures. It is noteworthy that the authors do not provide any uncertainty or sensitivity analyses that can provide important context for the interpretation of the results and conclusions.

Based on our review of Hill et al. (2019) and of Tessum et al. (2017), we draw the following conclusions:

- InMAP uses annual-average data for emissions, meteorology, and chemical/removal rates to estimate annual-average $PM_{2.5}$ impacts. Use of annual averages is inappropriate for representing processes that operate over shorter time scales ranging from minutes to several months (e.g., atmospheric dispersion and chemical formation of $PM_{2.5}$). The authors acknowledge that this weakness in their approach results in spatial errors in annual average $PM_{2.5}$ calculations. These spatial errors can significantly impact the resulting exposure and mortality estimates. The authors, however, do not present sensitivity analyses to assess the impact of the model assumptions, nor do they include any plausible range of uncertainty or variability with their modeled $PM_{2.5}$ concentration or mortality estimates.
- The 2005 modeling year upon which InMAP is based is not representative of more recent chemical conditions of the atmosphere in the U.S. because there have been significant reductions in precursor emissions that directly reduce the capacity to form $PM_{2.5}$. We estimate that this leads to an overestimate of the $PM_{2.5}$ contributions from corn production by more than a factor of 2. Therefore, resulting health and economic damages are likely overestimated.
- Ammonia emission estimates, which are the largest driver of mortality in the Hill et al. (2019) analysis, are the most uncertain aspects in any air quality modeling exercise because: (1) emissions are largely from agricultural sources that vary both spatially and temporally due to weather and farming practices; (2) many different methods are used to estimate ammonia emissions, and each can yield very different rates and exhibit a high degree of error; (3) annual average ammonia emission inventories fail to account for important seasonal variations and related complex interactions with sulfate and nitrate chemistry; (4) ignoring diurnal and intra-daily ammonia emission variations have been shown in the literature to overestimate ambient ammonia concentrations by as much as a factor of 2. These numerous uncertainties and compounding error rates call into question the estimates of emissions that drive the rest of the Hill analysis.

Based on our review, InMAP is not typically able to reproduce $PM_{2.5}$ impacts estimated by more complex state-of-the-science air quality models. In fact, its performance is worst for the very $PM_{2.5}$ component (ammonium) that Hill et al. (2019) model indicates is the highest contributor to PM mortality from corn production. This renders InMAP especially unreliable for this key PM component.

In addition to the number of significant uncertainties in all modeling aspects of the Hill et al. (2019) analysis, including the emissions estimates and the RFM InMAP modeling, there is also a significant amount of uncertainty associated with estimating health impacts from air pollution concentrations and from quantifying the costs of these health impacts.

The health impact assessment is based on a single epidemiological study that found associations between $PM_{2.5}$ concentrations and mortality. While these studies suggest that such an association exists, there remains uncertainty regarding a clear causal link. This uncertainty stems from the limitations of epidemiological studies to establish causality because these studies are based on inadequate exposure estimates and these studies cannot control for many factors that could explain the associations between $PM_{2.5}$ and mortality – which, for example, may not be related to $PM_{2.5.}$ from the source being investigated (e.g., lifestyle factors like smoking). In fact, the components of $PM_{2.5}$ that may be associated with adverse health effects are yet unknown, but evidence suggests that carbonaceous particles are more toxic, than inorganic particles such as those derived from ammonia and nitrate or sulfate.

Overall, the uncertainties enumerated above result in unreliable estimates of $PM_{2.5}$ exposure, mortality and related costs associated with corn production, each associated with a large range of variability.

6. ENVIRONMENTAL IMPACTS ASSOCIATED WITH ETHANOL PRODUCTION CANNOT BE VIEWED IN A VACUUM, WITHOUT CONSIDERATION OF SUCH IMPACTS ASSOCIATED WITH GASOLINE PRODUCTION.

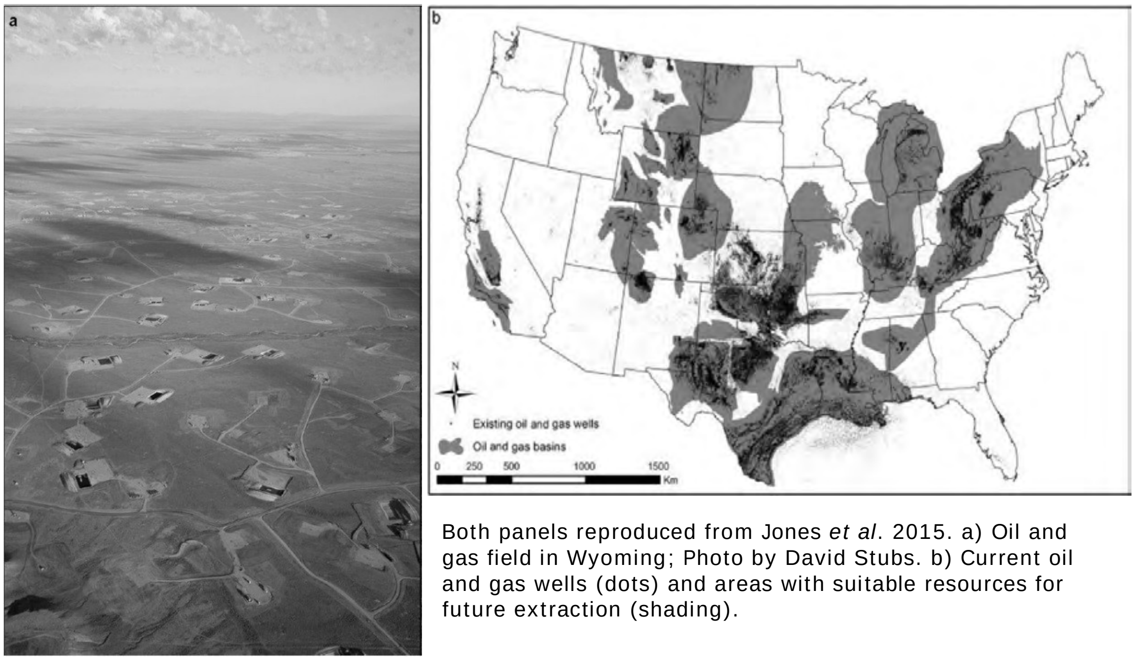
EPA (2018a) acknowledges that it fails to address environmental impacts associated with gasoline production. Spills of petroleum, gasoline, and a wide range of other fluids used in the exploration, production, and refining processes as well as land use change to support those activities all have adverse effect on water quality, ecosystems (including wetlands), and wildlife. Additionally, both conventional and unconventional oil and gas extraction place demands on water supply. Failure to address impacts associated with gasoline production relative to impacts from ethanol production does not present a balanced view of alternative energy sources and casts a negative bias on ethanol production. Parish et al. (2013) recognize the importance of understanding differences in environmental effects of alternative fuel production so that the relative sustainability of alternatives can be adequately assessed in policy-making and regulatory decisions. Parish et al. (2013) assessed negative environmental impacts through the supply chain for ethanol production and gasoline production and found that impacts from ethanol production are more spatially limited, are of shorter duration, and are more easily reversed than those associated with gasoline production. It was beyond the scope of this report to expand upon the work of Parish et al. (2013) or other comparative studies, rather this Section presents a brief description of the wide range of potential impacts associated with petroleum production stemming from land use changes as well water use and impacts to water quality.

6.1 Impacts of Gasoline Production Associated with Land Use Change

Oil and gas can be extracted using conventional or unconventional (i.e., hydraulic fracturing) methods, with some resultant variability in associated land use change impacts. Both methods require the construction and maintenance of a well pad and placement of pumping machinery. To install any onshore well pad, the land must be cleared and leveled, which requires the construction of access roads in most cases. A water well to provide water to the site and a reserve pit for cuttings and used drilling mud may also be necessary. Once this infrastructure is in place, the oil rig can be assembled on site. Diesel engines and electrical generators provide the power for the rig. Once the oil has been reached, for a conventional well, a pump is installed and much of the rig and other machinery can be removed and some altered areas can be restored. However, the pad area and some access roads and pipelines must remain throughout the life of the well. A typical lease area has many different oil wells and pads that are connected by roads and utilities which fragment the surrounding habitat. In Texas, well pad density may be over 55 pads per square mile (Hibbitts et al. 2013). The typical lifespan of an oil or gas well is 20-30 years, though this varies due to geology and the amount and type of oil present (Encana Natural Gas 2011). Once the well and pad have reached the end of their life, they may be removed, and the area can be restored. However, restoration does not eliminate the environmental damage the well caused; research has shown that local biodiversity loss can have cascading effects on ecosystem productivity and function (Butt et al. 2013).

In the United States, the land use change caused by wells is considerable due to the high numbers of wells in many locations (Figure 12).

Figure 12: Oil and gas field in Wyoming; Areas with Suitable Resources for Future Extraction.



Both panels reproduced from Jones *et al*. 2015. a) Oil and gas field in Wyoming; Photo by David Stubs. b) Current oil and gas wells (dots) and areas with suitable resources for future extraction (shading).

In 2017, there were 990,677 onshore and offshore oil wells in the US, down from 1,038,698 in 2014 (U.S. EIA 2018a). The average size of an onshore unconventional well pad is 3.5 acres (Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences n.d.), while an onshore conventional well pad in Texas is about the same, or roughly 3.4 acres (Young et al. 2018a). When only the direct footprint of onshore domestic wells is considered, the US had over 1,429,999 acres of well pad infrastructure in 2011 (Trainor et al. 2016). Trainor et al. 2016 predicted that by the year 2040, the direct footprint of oil and gas land use could increase to 15,891,100 acres. The actual landscape impacts are almost double the footprint, due to the spacing requirements of wells (Trainor et al. 2016). Thus, the full landscape impact of oil and gas estimated for 2040 is roughly 31,782,200 acres. The large landscape effects of oil and gas have implications for environmental effects.

Conventional and unconventional wells require roads and other impermeable infrastructure that result in highly altered landscapes (Jones et al. 2015, Garman 2018). The land use change to altered landscapes has direct effects on habitats and wildlife (Butt et al. 2013, Garman 2018, Young et al. 2018b). Land use change for well construction increases habitat fragmentation, pollution, noise and visual disturbance, and causes local habitat destruction; all of which can decrease biodiversity (Butt et al. 2013, Garman 2018, Young et al. 2018b). Some of these disturbances, such as fragmentation, are not unique to oil and gas extraction, and research on their effects is explained in other literature (Brittingham et al. 2014). For example, it is well known that fragmentation can split breeding populations and reduce genetic variability within each population, potentially making them less adaptable to other disturbances (Keller and Largiadèr 2003, Langlois et al. 2017).

Wildlife populations have been shown to decrease near areas with oil and gas production due to habitat fragmentation, density of wells, human activity, noise and light pollution, avoidance, and other factors (Jones et al. 2015). For example, habitat fragmentation by well pads reduced the use of preferred habitats of lizards in Texas, which is likely to decrease the populations of habitat specialist species (Hibbitts et al. 2013). Density of well pads has been shown to decrease the population size of several species of songbirds in Wyoming (Gilbert and Chalfoun 2011). Greater sage-grouse (*Centrocercus urophasianus*) in Montana and Wyoming were found to avoid sagebrush habitats that would otherwise be high quality when those areas are near natural gas development (Doherty et al. 2008). Threatened woodland caribou (*Rangifer tarandus caribou*) avoid areas within 1000 m of oil and gas wells and 250 m of roads in northern Alberta, Canada, especially during calving season (Dyer et al. 2001). This avoidance reduces available habitat and can decrease caribou population size (Hervieux et al. 2005). Direct mortality from contact with infrastructure is also a problem; an average of 8.4 birds die in each uncovered reserve pit each year (Trail 2006), thousands more birds die due to gas flare stack emissions (Bjorge 1987), and many more may die due to the gas flare stacks and gas compressors on well sites (Jones et al. 2015).

Development of areas for oil and gas production causes secondary land use conversion as more people move into the production area. If the well is in a remote area the increase in population size can cause other cascading negative effects such as illegal hunting and the increase in introduction of exotic species of plants and animals. Both direct and cascading environmental impacts can be especially harmful in delicate ecosystems, such as the Prairie Pothole Region (Gleason and Tangen 2014).

The United States is composed of many different habitats that energy development affect (McDonald et al. 2009), as shown in Figure 13. When comparing Figure 12 and Figure 13, it is clear that oil and gas resources and well locations fall into many habitat categories, although temperate grassland and temperate forest may be the most highly affected.

Figure 13: Major Habitat Types in the United States.

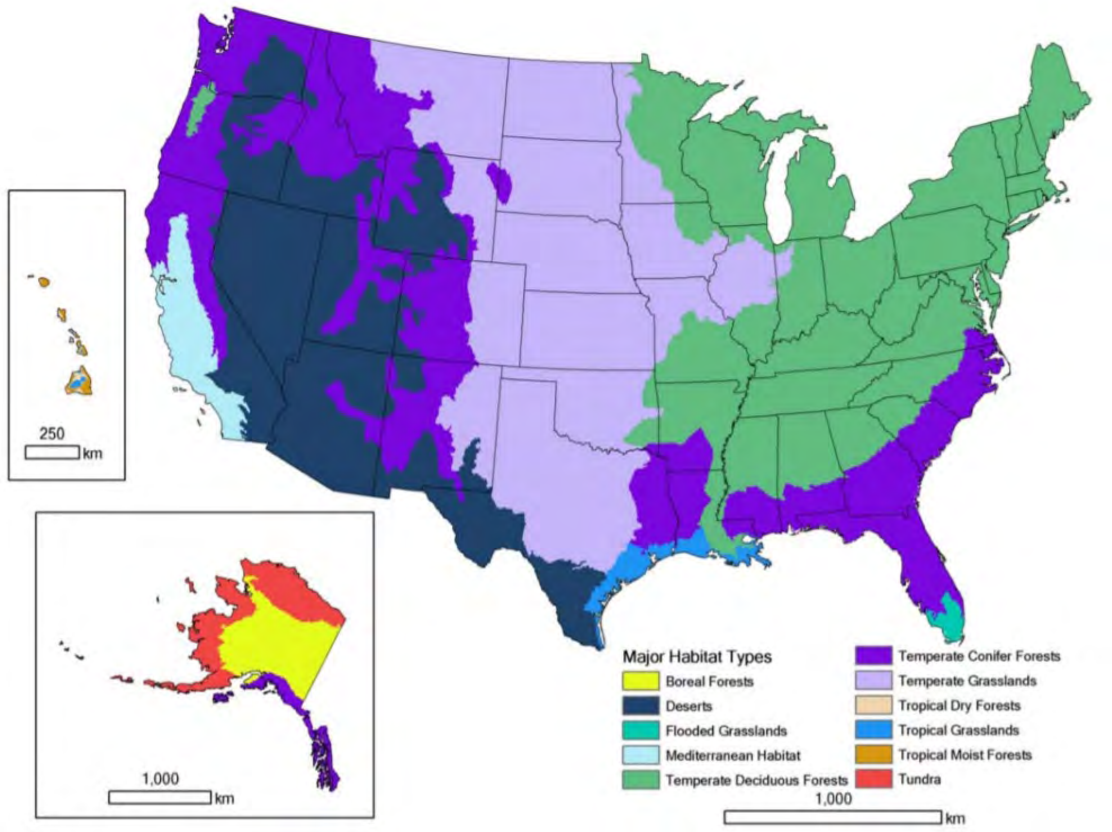


Figure reproduced from McDonald et al. 2009

6.2 Water Quality Impacts Associated with Spills

6.2.1 Unconventional Oil and Gas (UOG)

The most common UOG production method in the U.S. is hydraulic fracturing. A study of UOG wells sites in Colorado, New Mexico, North Dakota, and Pennsylvania estimated 55 spills per 1,000 well-years (where a well-year is a unit denoting the operation of one well for a period of one year; Patterson, Konschnik, et al., 2017). Actual spill rate varied by state, from about 1% (Colorado) to 12% (North Dakota). Median spill size by state varied from 120 gallons (0.5 m^3, Pennsylvania) to 1,302 gallons (4.9 m^3, New Mexico). Total spill volume over ten years (2005 to 2014) was estimated to range from 1,447 m^3 (380 thousand gallons; Pennsylvania) to 33,937 m^3 (9 million gallons; North Dakota). The study found that over 75 percent of UOG production sites spills occur during the first three years of a well's life. It also found that wells with one spill have a higher probability of future spills (Patterson et al. 2017).

Relative to total oilfield spills, the number of spills at UOG production sites is relatively small. EPA (2015) associates only 1% of spills (457 of 36,000 spills across nine states) with hydraulic fracturing. Of the 457 spills assessed by EPA (2015), 300 were reported to reach soil, surface water, or groundwater. The total reported spill volume includes an estimated 540,000 gallons released to soil, 200,000 gallons released to surface water, and 130 gallons reaching groundwater (EPA 2015). Patterson et al. estimate of 6,648 spills associated with all stages of UOG production covering ten years (2005 to 2014). By contrast, the estimate by EPA (2015) focuses only on hydraulic fracturing and covered seven years (2006 to 2012).

6.2.2 Conventional Oil and Gas

The movement of raw petroleum and petroleum products consists of a complex distribution and storage system, which has many chances for accidents, spills, leaks, and losses from volatilization. Consistent national statistics are lacking for many stages in the overall oil distribution and storage system. (ATSDR 1999). Statistics from the American Petroleum Institute (API) based on U.S. Coast Guard data exist for U.S. Navigable waters, but these are limited primarily to coastal areas and large rivers but can include lakes and estuaries.

Data were readily available for the period 1997-2006 from API (API 2009) and are presented for illustration purposes. API reported approximately 10.8 million gallons of oil was spilled into U.S. Navigable Waters from 1997-2006. This includes spills by vessels and facilities (onshore and offshore). The amount spilled per year varied from 466,000 (2005) to 2.7 million (2004). Of the 10.8 million gallons of oil spilled over the period:

- 3.7 million gallons were from onshore facilities;
- Just over 620,000 gallons were from pipelines;
- 226,000 gallons were from offshore facilities;
- 36,000 gallons were from railroads, tank trucks, and passenger cars;
- And most of the remaining spills (5.7 million gallons) were from vessels.

The figures above do not include the Exxon Valdez spill in Alaska in 1989 of 10.8 million gallons (API 1998 as cited in ATSDR 1999) or the Deepwater Horizon spill in 2010 (which post-dated the API study) where EPA reports that 4 million barrels (approximately 168 million gallons) spilled during the 87-day period of the incident (EPA n.d.).

6.3 Toxicity and Other Ecological Impacts of Oil and Associated Products

Total petroleum hydrocarbon (TPH) toxicity to ecological receptors depends on the hydrocarbon composition, exposure pathway, and exposure duration (i.e., acute or chronic). Additionally, TPH in the form of product (e.g., crude oil) can cause physical and chemical toxicity. Acute exposure typically occurs following an accidental release, which causes immediate exposure to high concentrations of petroleum products. Chronic exposures are typically associated with low-level releases over long periods of time, such as from a leaking underground storage tanks and groundwater contamination. Acute exposure following a large oil spill has both physical and chemical impacts and can have immediate ecosystem impacts. In contrast, chronic low-level releases have more subtle impacts typically related to chemical toxicity (Interstate Technology & Regulatory Council [ITRC] 2018).

EPA (1999) describes oil toxicity effects on wildlife according to four categories: physical contact, chemical toxicity, reproductive problems, and destruction of food resources and habitats. These categories of toxicity are described relative to acute and chronic exposures below.

6.3.1 Physical Contact

Terrestrial plants, invertebrates, small animals (mammals, amphibians, reptiles) and birds can become smothered by oil and aquatic organisms can similarly become smothered and lose their ability to uptake oxygen. When fur or feathers of larger mammals or birds contact oil, they get matted down, causing the fur and feathers to lose their insulating properties, placing animals at risk of freezing to death. Additionally, in the case of birds, the complex structure of feathers that allow birds to float or to fly can become damaged, resulting in drowning for aquatic birds (EPA 1999).

6.3.2 Chemical Toxicity

Toxicity to the central nervous system is the major mechanism of toxicity to ecological receptors. Early life-stage aquatic invertebrates and fish can also exhibit phototoxicity (ITRC 2018). These and other toxicological effects are summarized below. Chemical toxicity is typically associated with chronic exposures, however, if petroleum products are present in high enough concentrations, negative health effects, including mortality can occur from acute exposure.

Oil vapors may be inhaled by wildlife, which can cause damage to some species' central nervous system, liver, and lungs. Animals are also at risk from ingesting oil, which can cause red blood cell, intestinal tract, liver, and kidney damage. Skin and eye irritation can also occur from direct contact with oil (EPA 1999). Fish that are exposed to oil may suffer from changes in heart and respiratory rate, enlarged livers, reduced growth, fin erosion, a variety of biochemical and cellular changes, and reproductive and behavioral responses. Chronic exposure to some chemicals found in oil may cause genetic abnormalities or cancer in sensitive species (EPA 1999).

6.3.3 Reproductive Effects

Oil can be transferred from birds' plumage to the eggs they are hatching. Oil can smother eggs by sealing pores in the eggs and preventing gas exchange. Also, the number of breeding animals and the number of nesting habitats can be reduced by a spill.

Scientists have observed developmental effects in bird embryos that were exposed to oil. Long-term reproductive problems have also been shown in some studies in animals that have been exposed to oil (EPA 1999).

6.3.4 Destruction of Food Resources and Habitats

Species that do not directly contact oil can be harmed by a spill. Predators may refuse to eat their prey because oil contamination gives fish and other animals unpleasant tastes and smells, which can lead to starvation. Alternatively, a local population of prey organisms may be destroyed, leaving no food resources for predators. Predators that consume contaminated prey can be exposed to oil through ingestion. This causes bioaccumulation of oil compounds in the food chain. Depending on the environmental conditions, the spilled oil may linger in the environment for long periods of time, adding to the detrimental effects. In freshwater lentic systems, oil that interacts with rocks or sediments can remain in the environment indefinitely, leading to persistent ecological impacts (EPA 1999)

6.4 Additional Water Quality Impacts Associated with Petroleum Production

Production water and fluids used in conventional and unconventional oil and gas production are an additional source of potential contaminants and may have negative impacts on the environment. In the U.S., an estimated 21 billion barrels of produced water is generated each year (Aqwatec n.d.). Production water can be highly saline (up to 15 times saltier than seawater) and can contain elevated levels of chemicals and radioactive elements. This water can kill vegetation and prevent plants from growing in contaminated soil (Miller and Pesaran 1980, Miller et al. 1980, Adams 2011, Pichtel 2016). Hydraulic fracturing fluids contain numerous chemicals to enhance gas and oil extraction. EPA identified 1,173 chemicals associated with hydraulic fracturing activities and chronic oral toxicity values are available for 147 of the chemicals identified (Yost et al. 2016). The potential for toxicity to wildlife and ecosystems depends on the quality of the production water, which varies by production site.

6.5 Additional Water Quality and Supply Impacts Associated with Exploration, Production, and Refining

Water is necessary for both conventional and unconventional oil and gas extraction as well as refining with unconventional oil and gas exploration and production having the higher water demand requirements. This makes oil and gas development a competitor for limited water resources with nearby populations and agriculture, in a time when water rights are often hotly contested (Strzepek and Boehlert 2010). High source water consumption can alter stream flows and affect aquatic ecosystem function, including declines in specific fish species around production sites (Dauwalter 2013, Jones et al. 2015). Additionally, produced water, especially from unconventional oil and gas development, has high total dissolved solids and may be contaminated with other chemicals, making it a pollutant that is expensive and difficult to treat (Gregory et al. 2011, Gleason and Tangen 2014).

There are 135 petroleum refineries in the United States (U.S. Energy Information Administration [USEIA] 2018b, 2019). Over time, the number of petroleum refineries has decreased, but the capacity per refinery has increased (ATSDR, 1999; USEIA 2018b). Gross crude oil inputs to refineries averaged 16.6 million barrels per day in 2017 (USEIA 2018c). An estimated 2.3% of total refinery output is released to the environment through spills or leaks (ATSDR 1999).

Petroleum refinery wastewaters are made up of many different chemicals which include oil and greases, phenols (creosols and xylenols), sulfides, ammonia, suspended solids, cyanides, nitrogen compounds and heavy metals. Refinery effluents tend to have fewer of the lighter hydrocarbons than crude oil but more polycyclic aromatic hydrocarbons, which are generally more toxic and more persistent in the environment (Anderson et al. 1974, Wake 2005). Aquatic ecosystems around refinery discharges are often found to have low biodiversity and a low abundance of fauna. Often the impacted area is limited to a specific distance from the discharge point. This distance varies depending on the site and the effluent. Studies have estimated the impacted range to be 200 m to 1.6 km from the effluent site (Petpiroon & Dicks, 1982; Wharfe 1975 as cited in Wake, 2005). Refinery effluent has also been attributed as the cause of lack in recruitment in some areas, that it may either kill early life stages of aquatic organisms (e.g., settling larvae) or deter them from settling near discharges (Wake 2005).

7. LIMITATIONS

The conclusions, opinions and recommendations presented herein represent Ramboll's professional judgment based upon reasonably available information and are products of and limited by Ramboll's assigned and agreed upon scope of work. In preparing this report, Ramboll relied upon information provided by its client and/or third parties, and also relied upon certain additional publicly available information. Ramboll, however, did not conduct an exhaustive search or review/analysis of all potentially relevant information. The conclusions, opinions and recommendations presented herein, and all other information contained in this report, necessarily are valid only to the extent that the information reviewed by Ramboll was accurate and complete. Ramboll reserves the right to revise this report if/when additional relevant information is brought to its attention. In addition, Ramboll did not consider matters outside of its limited scope of work. Accordingly, the conclusions, opinions, recommendations and other information contained herein may not adequately address the needs of all potential users of this report, and any reliance upon this report by anyone other than Growth Energy, or use of a nature, or for purposes not within Ramboll's scope of work is at the sole risk of the person/entity so relying upon or otherwise using this report. Ramboll makes no representations or warranties (express or implied) regarding this report beyond those made expressly to its client, and Ramboll's liability in relation to this report and its related scope of work is limited under its client contract.

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EXHIBIT 2

RAMBOLL. NOVEMBER 29, 2019. MEMORANDUM: SUPPLEMENTAL ANALYSIS REGARDING ALLEGATIONS OF POTENTIAL IMPACTS OF THE RFS ON SPECIES LISTED UNDER THE ENDANGERED SPECIES ACT. PREPARED FOR GROWTH ENERGY. RAMBOLL, SEATTLE WA.

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ESA Comments - Attachment B

Docket # EPA-HQ-OAR-2019-0136

Supplemental Notice of Proposed Rulemaking; Renewable Fuel Standards Program: Standards for 2020 and Biomass-Based Diesel Volume for 2021, and Response to the Remand of the 2016 Standards

November 29, 2019

RAMBOLL

ENVIRONMENT
& HEALTH

MEMORANDUM

SUPPLEMENTAL ANALYSIS REGARDING ALLEGATIONS OF POTENTIAL IMPACTS OF THE RFS ON SPECIES LISTED UNDER THE ENDANGERED SPECIES ACT

Prepared for	Growth Energy
Date	11/29/2019

OBJECTIVES AND SCOPE

This memorandum supplements the analysis in our August 2019 report, "*The RFS and Ethanol Production: Lack of Proven Impacts to Land and Water*" ("Ramboll Report"), in which we analyzed potential environmental impacts of the RFS program and concluded that there are no proven adverse impacts to land and water associated with increased corn ethanol production under the RFS. The impetus for this supplemental memorandum is a recent D.C. Circuit opinion on a petition for review of EPA's final rule setting the renewable fuel standards for 2018 (the "2018 RVO Rule"). *Am. Fuel & Petrochemical Mfrs. v. EPA*, No. 17-1258 (D.C. Cir. Sept. 6, 2019). The Court remanded the rule back to the agency to further consider petitioners' claims that EPA failed to comply with the Endangered Species Act (ESA). Specifically, the Court directed that under ESA Section 7, EPA must make an appropriate determination as to whether the 2018 RVO Rule "may affect" a listed species or critical habitat.

We are aware that the ESA Section 7 consultation issue is relevant not only to the remand in the above case, but also to future EPA rulemakings with respect to the Renewable Fuel Standard Program (RFS), including EPA's proposed rule setting the renewable fuel standards for 2020 (the "2020 RVO Rule"). Following on our 2019 Report, we are providing this supplemental analysis to explore further whether there is any evidentiary basis in the record for EPA to conclude that the RFS program "may affect" a listed species or critical habitat. This memorandum focuses on the technical aspects of the record relied upon by the Court that were supplied by petitioners' exhibits, including:

- Declaration of Dr. Tyler Lark (July 27, 2018; referred to herein as the Lark Declaration)
- U.S. Environmental Protection Agency, *Biofuels and the Environment: Second Triennial Report to Congress.* Washington, D.C. (June 29, 2018)
- Declaration of C. Elaine Giessel (July 27, 2018)
- Declaration of Aaron Viles (July 20, 2018)
- Declaration of William A. Fontenot (July 24, 2018)
- Declaration of Katherine M. Slama (July 26, 2018)
- Declaration of Andrew E. Whitehurst (July 26, 2018).

Problem Understanding

The allegations of potential impacts to listed terrestrial species that are presented in the Lark Declaration (and referenced in the Court opinion) center on an assumed relationship between the RFS and habitat loss or degradation due to presumed land conversion to grow biofuel feedstock. The Lark Declaration also references potential impacts to aquatic species due to an assumed relationship between biofuel feedstock grown for ethanol production and water quality degradation due to use of agrichemicals (e.g., fertilizers and pesticides) and the potential for increased erosion.

The relationship between the RFS and impacts to land and water, if any, would be effected via a complex causal chain consisting of the following major relationships:

A. RFS and increased demand for ethanol

⇩

B. Increased demand for ethanol and upward pressure of this demand on the price of ethanol feedstock (mainly corn)

⇩

C. Price of corn and an individual farmer's decision to plant corn

⇩

D. Individual farmer's decision to double crop corn, switch from another crop to corn, or farm new land

⇩

E. Location, type, and magnitude of adverse impact to terrestrial and aquatic habitat

Each of the above relationships, in turn, encompasses several interrelated variables, each variable is likely to change on an annual basis, and many of the relationships are co-dependent. The Lark Declaration does not consider these relationships in a meaningful way, and instead relies on unsupported assumptions and speculation.

There are several lines of evidence indicating that increased demand, if any, for ethanol resulting from the RFS has not been a discernible driver of land use change. One of the most basic lines of evidence has to do with the historical trend in the number of acres in the U.S. devoted to growing corn. Historical data generated by the U.S. Department of Agriculture (USDA) shows that acres planted in corn nationwide is currently at or below levels reported in 1926 and in the last 2 decades has generally fluctuated between 80 million acres and 100 million acres (Figure 1).

The amount of land in the U.S. devoted to growing corn has remained at or below historical levels despite the following trends:

- Total corn production (bushels per year) has increased about 7-fold over the period of record
- Corn produced for ethanol has increased by a factor of 12.5 since 1986 and now accounts for about 50% of corn grown.

This increase in corn production and corn production devoted to ethanol, without an apparent increase in acres planted, is attributed to a 7-fold increase in corn yield (bushels per acre).

The 7-fold increase in corn production nationwide over the period of record has not been accompanied by a nationwide increase in the acres of corn planted. This lack of association in itself calls into question whether there is a causal link between increased demand for corn grown for ethanol and demand for increased acreage of corn, which in turn calls into question the causal relationship between increased demand for corn for ethanol and land conversion. The remainder of the report delves more deeply into each step in the potential causal chain between the RFS and impacts to species. In particular, causal steps B, C, and D are discussed in Section 2 below, and causal step E is discussed in Section 3 (for terrestrial listed species mentioned in the Lark Declaration) and Section 4 (for aquatic listed species mentioned in the Lark Declaration). Analysis of the effect of the RFS on increased demand for ethanol (causal step A above) is outside the scope of this memorandum.

Summary of Findings

Our technical review of the assertions made in the Lark Declaration lead to the following overall conclusions:

- Assertions that increased corn ethanol production under the RFS has resulted in land use change and conversion of non-agricultural land to production of biofuel feedstock are unsubstantiated for several reasons, including the following:
    - Acres planted in corn across the United States has remained close to or below the total acres planted in the early 1930s despite increases in demand for corn as human food, animal feed, and biofuels over this nearly 90-year period. This fact by itself calls into question the relationship between the RFS and land use change.
    - The causal relationship between the RFS and the price of corn is not supported by the evidence, and therefore, the Lark Declaration's presumption that increased corn prices drive land use change are unsubstantiated.
    - The Lark Declaration does not adequately consider the many disincentives to the farmer of converting non-agricultural land to growing any given crop, and thus assertions in the Lark Declaration that the RFS and price of corn has resulted in land conversion are also unsubstantiated.
- Assertions that RFS-driven land use change has resulted in impacts to particular ESA listed species are without foundation for multiple reasons, including:
    - The Lark Declaration asserts that land use change spurred by the RFS has resulted in impacts to listed terrestrial species of birds, mammals, and insects.
    - The evidence presented in the Lark Declaration to support the alleged impacts are poorly researched and the examples used to support many assertions instead actually *refute* the assertions.
- Assertions that RFS-driven biofuels agriculture adversely impacts water quality are also unsubstantiated for multiple reasons, including:
    - The Lark Declaration asserts that biofuels (corn and soy) agriculture has worsened the Gulf of Mexico dead zone, imperiling Gulf sturgeon, loggerhead turtles, and sperm whales, yet provides no supporting evidence; no studies are cited that specifically quantify the effect of corn or soy crops as threatening these species or their habitats.
    - The Lark Declaration also asserts that biofuel (corn and soy) agriculture is associated with impaired waters pursuant to Section 303(d) of the Clean Water Act but fails to acknowledge cases in which such designations were made well before the RFS came into effect. Our independent assessment of specific examples presented in the Lark Declaration indicates that the allegations of impacts from corn or soy on impaired water bodies is unsubstantiated.

In sum, there are least two important causal chains that must be quantified and linked together to demonstrate a relationship between increased corn ethanol production under the RFS and impacts to ESA-listed species: 1) a causal chain linking the RFS to land use change and water quality impacts; and 2) a causal chain linking impacts to land and water with specific impacts on the survival or reproduction of ESA-listed species. Each of these causal chains is made up of many embedded biophysical and economic relationships that, in turn, are influenced by a myriad of interrelated variables. The Lark Declaration fails to consider these causal relationships in a meaningful way, relying instead on unfounded assumptions and speculation to support its thesis.

1. Examination of the Causal Link Between the RFS and Impacts to Listed Species

1.1 Overview of Causal Analysis

Causal analysis is a method that is used to determine root causes for observed outcomes. It is used in many fields such as medicine, business management, economics, ecology, and has been used to explore the causes of land use change (Efroymson et al. 2016). The point of causal analysis is to look behind outcomes or symptoms to determine the actual cause, instead of assuming the most obvious cause is the root of the issue. For example, if a patient presents to a doctor with knee pain because they hurt themselves gardening, the doctor may simply give pain medication. If the doctor looks deeper using a more holistic causal analysis approach, the doctor may find that the patient is out of shape or that they have arthritis. If the symptom is treated without fully understanding the root cause of the problem, the problem will not be solved in the long term.

Causal analysis begins with creating a causal diagram that includes all causal components of an outcome. In the next section, we use a causal diagram to examine how farmers make decisions about crop species planted and land expansion.

1.2 The RFS/Land Conversion Causal Chain

The relationship between the RFS and the potential for land conversion is addressed in the Ramboll report, primarily in Section 3.2. The decision to alter land from non-agricultural uses to agriculture in general is made at the farm level and is influenced by a myriad of factors including predicted weather conditions, crop output and input prices, innovations in cropping equipment, crop insurance, disaster assistance, and marketing loans. The Ramboll report cites three publications in particular which address the complexity of the causal relationship between increased production of corn ethanol and land use change (Section 3.2 page 16-17). As one example, Efroymson et al. (2016) discusses the use of formal causal analysis to clarify the relationship between biofuels policy and land use change and concludes that studies relying on single lines of evidence alone are insufficient for establishing probable cause. Many such studies are cited by EPA (2018) and indeed, many such studies rely on simple temporal changes occurring around the time of the enactment of the Energy Independence and Security Act (ESIA) or simple spatial associations (e.g., land use change proximity to ethanol plants) in an attempt to link land use change and increasing corn production.

The assertion that the EISA increased the expected market price of corn and directly caused land use change is not supported by a causal analysis. Figure 2 illustrates a simplified causal diagram including the many components that influence planting decisions by farmers. It is clear from this diagram that the expected market price of any given crop is not the only relevant factor in planting decisions. Farmers often have limited freedom to change crop types or expand their farmed areas. For example, planting, cultivating, and harvesting machinery is not interchangeable between all crop types. Farmers may only be able to choose between two or three crops that their current machinery is capable of handling. Additionally, farmers are locked into crop rotation schedules to maintain soil conditions and crop health. Furthermore, all fields cannot be harvested at the same time due to limited machinery, so crops with different harvest times must be planted to ensure high-quality output. If farmers are participating in government subsidy or incentive programs, they may be limited in the types of crops they can plant. Areas in the conservation reserve program cannot be planted until the term of the contract expires, and water use restrictions, or limitations of irrigation machinery, can limit expansion of field size.

For farms, even if the species of crop or the expansion of field size were not restricted as described above, market forces themselves affect planting decisions. Deciding what to plant is a gamble. Farmers must consider many factors, including their own costs, resources, and market price estimates.

Successful farmers must bring in enough profit for both salaries and capital costs; meaning that costs must be well below profits. Besides the obvious costs of fertilizer, water, labor, and machinery, the price of transportation to get products to market must be considered, as well as costs of insurance given the location, climate, and predicted weather. The decision to expand farmed areas could be a poor one if the marginal costs exceed marginal profits. This is especially a concern when expanding farmland into areas around currently farmed fields, which may be less suitable for farming because of steeper inclines or poorer quality soil. Additional costs will also be incurred when expanding into natural areas where drainage of wetlands or removal of trees and other obstructions will be required, which is a disincentive to increase farmed acreage. These dynamics are explored in more detail in the following section.

2. Lack of Evidence of a Causal Link Between RFS and Land Use Change

A recent report by Lark et al. (2019) is a comprehensive attempt to establish quantitative causal linkages between the enactment of the RFS and a variety of environmental outcomes using a series of interlinked models. The fundamental premise of their work is the assumption that the price of corn is heavily influenced by increased demand for ethanol due to the RFS, yet the authors ignore other important factors that have a considerable effect on demand and supply conditions (Lark et al. 2019 is discussed in detail in the Ramboll Report at Section 3.4.) Staab et al. (2017), for example, find that there are many other contributing factors affecting demand for corn, including market speculation, stockpiling policies, trade restrictions, macroeconomic shocks to money supplies, currency exchange rates, and economic growth. As one example, rapid economic growth in developing countries led to growing food demand and a dietary transition from cereals toward more animal protein and the corn products used as cattle feed. As a result, global consumption of agricultural commodities has been growing rapidly. In fact, it appears that most of the increase in corn prices has actually been driven by higher oil prices (Figure 3). The U.S. Energy Information Administration estimated that of the total cost per acre of producing corn in 2013 (approximately $350/ac.), nearly two thirds was spent on fuel, lubricants, electricity and fertilizer[1]; and fertilizer is known to be closely linked to oil prices[2].

Moreover, Lark et al. (2019) and other authors who have attributed land use change to the RFS do not adequately consider the wide range of factors that influence farmers' individual planting decisions. These factors determine the relative prices expected to be faced by farmers. That is, the futures prices of different crops relative to each other help a farmer determine the crop planting mix (what and how much). While relative prices may help a farmer determine the potential crop mix farmed on the land, other supply factors influence the potential costs of production. These include weather, soil quality and temperature conditions; pests and disease (McConnell 2018); moisture (Queck-Matzie 2019);energy and fuel costs; interest rates; storage costs; seed and fertilizer costs; and "preventive" planting (Schnitkey et al. 2019) programs such as COMBO (Crop Insurance), the Cropland Reserve Program (CRP), and others.

Temporal uncertainty is something that farmers face in all their planting decisions. Farmers need to decide today what and how much to plant in the next growing season. Farmers are responsive to crop prices which act as a clearing house to reflect future demand and supply conditions and help alleviate the uncertainty associated with future conditions. This means that a variety of factors described above determine planting decisions, and these factors, coupled with the uncertainty of future prices and costs, weakens the link between the supposed increase in price of corn due to the RFS and planting decisions.

In making crop mix decisions, farmers consider relative futures prices and expected profitability of plantings (futures price vs. cost to produce; (Kleiber 2009, Staab et al. 2017, Hecht 2019, Springborn

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[1] https://www.eia.gov/todayinenergy/detail.php?id=18431#

[2] https://agmanager.info/sites/default/files/pdf/2019.4.pdf

2019). Weather is also an important consideration in a farmer's decision on whether to implement "prevented" planting (Reiley 2019, Springborn 2019). Futures prices, profitability, and weather forecasts are factors assessed by a farmer to determine where to plant and how much of each crop to plant (Kleiber 2009, Reiley 2019, Springborn 2019). Farmers examine, among many other factors, the relative price ratios of crops to determine an optimal planting mix, and if a farmer decides to increase production of a certain crop, this can be accomplished by either producing more of the crop on existing land (intensification) or putting new land into production (extensification, which may result in land use change). All else being equal, extensification is the least preferred option as it is the option most likely to involve additional expenditures such as land clearing and other preparation. This option will also be dependent on the expected yield of new fields, which relative to existing fields, is most likely to be sub- or infra-marginal and will require more intensive inputs to achieve desired yields (Schiller 2017). Given these considerations, farmers will typically consider switching crops and increasing yield on existing acreage (Ling and Bextine 2017) before farming new land. Intensification efforts can include precision farming as well as traditional techniques regarding plant spacing, pest management, etc. (Queck-Matzie 2019). (The positive environmental effects of precision farming and other technological advances in agriculture are described at length in the Ramboll report at Section 4).

In summary, studies have shown only a modest effect on corn prices potentially associated with the RFS (Kleiber 2009, Babcock and Fabiosa 2011, Carter et al. 2018, Renewable Fuels Association 2019). In addition, factors affecting farmers' planting decisions include much more than the expected market price of the crop (Kleiber 2009, Staab et al. 2017). Other important factors include the expected yield of the crop (Reiley 2019); and a myriad of production costs including the cost of seed, fertilizers and pesticides, machinery, crop insurance, labor, fuel, and land rental costs (Corn Agronomy 2006, Staab et al. 2017, Hecht 2019). The decision to expand crops onto new land entails additional hurdles and costs beyond costs associated with changing crops or intensifying production on existing acreage. For these reasons and those discussed more extensively in the Ramboll report (at Section 3.4), it is unreasonable to draw a direct causal connection between the RFS and land use change.

3. Lack of Evidence of a Causal Link Between the RFS and Impacts to Terrestrial Species

In the absence of a causal link between the RFS and land use change—and in particular land conversion from grassland, wetland, or forest to corn and soy—there can be no causal link between the RFS and impacts to terrestrial species due to loss or degradation of habitat. In an attempt to establish a causal link between the RFS and impacts to terrestrial listed species, the Lark Declaration presented several examples of quantitative analysis of land conversion from presumably natural land cover to presumably corn and soy. These examples relied on approaches to land conversion analysis presented by Lark et al. (2015). Lark et al. (2015) analyzed land use change nationwide during the period 2008-2012 using the U.S. Department of Agriculture (USDA) Cropland Data Layer (CDL), calibrated with ground-based data from USDA's Farm Service Agency (FSA), and further refined using data from the National Land Cover Database (NLCD). The approach used by Lark et al. (2015) purportedly included methods to "correct" for known errors and uncertainties in the CDL database. However, the approach used by Lark et al. (2015) has been shown to be flawed, resulting in a gross overestimate of land use change.

The Ramboll Report (Section 3.3 pages 19 and 20 and Table 1) discusses work by Dunn et al. (2017) which examined data for 2006-2014 in 20 counties in the prairie potholes region using the CDL, a modified CDL dataset, data from the National Agricultural Imagery Program, and in-person ground-truthing. Dunn et al. (2017) concluded that analyses relying on CDL returned the largest amount of land use change by a wide margin. They further concluded that errors associated with CDL-based analyses are a major limitation of conclusions drawn from such analyses. In fact, Dunn et al. (2017) concluded that “the number of hectares in the potential error associated with CDL-derived results is generally greater than the number of hectares the CDL-based analysis determined had undergone a transition from grassland, forested land, or wetland to agricultural land”. This suggests that errors in classification inherent in the CDL can result in uncertainty bounds that are of a larger magnitude than the estimates themselves (thereby even predicting “negative” land conversion to agriculture within the uncertainty bounds). Specifically, Dunn et al. (2017) pointed out that the findings reported by Lark et al. (2015) contradict USDA data indicating that cropland area has remained almost constant during the period 2008-2012.

The Lark Declaration also cited other authors who purport to establish a quantitative link between the RFS and land use change based on geographic associations (e.g., increased conversion of land to biofuel feedstock in close proximity to ethanol refineries). The Ramboll report specifically identified the following key flaws in studies that attempt to quantify land use change to biofuel feedstocks (Section 3.1 pages 14 and 15):

- Like Lark et al. (2015), many other studies of land use change to agriculture depended on unreliable data sets such as CDL data, lacked ground-truthing, and were regional or state-specific. These problems preclude extrapolation of results nationwide.
- The literature assessing LUC relative to the RFS generally fails to consider the considerable loss of agricultural land due to growth in urban areas and the role this loss may have on the pressure to expand agricultural lands elsewhere.

It is reasonable to presume that the Lark Declaration presented the best examples that could be found to make the case for the habitat of a particular species having been impacted by land conversion to corn or soy spurred specifically by the RFS. In the following sections, we analyze and respond to specific examples presented in the Lark Declaration. In each case we analyzed, we found fatal flaws in the examples presented in the Lark Declaration. These flaws are either associated with a lack of temporal association or a lack of geographical association (or both) and a lack of potential causative mechanism.

3.1 Whooping crane (***Grus americana***)

The Whooping Crane is currently classified as an endangered species. Current places of residence include Florida, Texas, central Canada, and Wisconsin. Migrating flocks reside in either Texas, Florida, central Canada, or Wisconsin (Cornell University 2019) primarily in wetlands or muskeg (swampy woods with lakes). In 1941, the total population had declined to 21 birds. Conservation efforts, including protection of wintering grounds and educating hunters, has helped increase the population. As of 2019, more than 350 whooping cranes reside in North America, including 174 migrating cranes (USFWS n.d.). The population has been increasing over time, with no dip apparent after the RFS in 2008 (Figure 4). In fact, after 2007, the population of whooping cranes appears to have increased even faster than it did between 1990 and 2007 (Figure 4)

A total of three known flocks currently exist throughout North America: two migrating flocks and one non-migrating flock. One migrating flock spends summers in the Wood Buffalo National Park in Canada and winters in Texas at the Aransas National Wildlife Refuge. The other migrating flock nests in Wisconsin for the summer and flies south to Florida in the winter. These flocks have been sighted taking short rests in Kansas at either Cheyenne Bottoms or Quivira National Wildlife Refuge (QNWR) whilst migrating. A non-migratory flock remains in Florida year-round (USFWS n.d.).

The migrating flocks reside in national refuges or national parks that have protection plans in place. For example, the QNWR prohibits hunting when whooping cranes are present to avoid accidental shootings. The U.S. Fish & Wildlife Service reports that refuges only integrate farming for specific wildlife conservation efforts.

Whooping Cranes spend time in marshes, shallow bays and tidal flats, with the occasional venture to nearby farmland. Their diet varies by area but may include fish, mice, insects, berries, seeds, crabs and snakes. The Whooping Crane's wide variety of food preferences opens opportunity to scavenge in several locations, including corn fields (USFWS n.d.).

The Lark Declaration argues that conversion to cropland "adjacent to its critical habitat and wintering grounds" may negatively impact the livelihood of the Whooping Cranes. Lark does not discuss the landscape of the adjacent land at issue nor the distance of these adjacent habitats from the whooping crane's current nesting grounds. The images Lark refers to in support of this claim are in Appendix 7 to the Lark Declaration. The image in Appendix 7 includes boundary locations of the critical habitat (Cheyenne Bottoms and QNWR) briefly visited by the Whooping Cranes (Bloomberg n.d.), as well as the nearest ethanol refinery. Ramboll further investigated these images and found that they did not support Lark's claims.

Multiple areas on the Lark Declaration's maps that show corn or other crops growing in or near Cheyenne Bottoms and QNWR were errors in the USDA Cropland Data Layer (CDL). One particularly egregious error shows corn growing in the southeast corner of Cheyenne Bottoms Pool 2 (Figure 5). It is clear from aerial imagery in Google Earth going back to 1992 that no corn is growing in Pool 2 (Figure 5). Ramboll further confirmed the lack of corn by contacting staff at the reserve on November 18 and 19 of 2019. Reserve staff confirmed that Pool 2 was usually under water, and although they had planted a cover crop for the benefit of wildlife in some dry years, the cover crop had never been corn[3]. Ramboll investigated multiple years of Google Earth aerial imagery for areas near to Cheyenne Bottoms and QNWR and also within QNWR that Lark showed as converted to corn; these images failed to show any new crop cultivation after 2007.

In summary, the data presented in Lark's declaration does not support his assertion that the RFS spurred land use change to biofuels in or near Cheyenne Bottoms and the QNWR. To the contrary, it appears that there is little or no land use change to agriculture near either reserve that supports whooping crane migrations in Kansas, and that such land use change, if any, has not been attributed to the RFS. Further, the population of whooping cranes in the United States has risen and continues to rise since the RFS, suggesting that even if the RFS has resulted in some land conversion in areas potentially used by the whooping crane, this conversion has not resulted in any discernible adverse impact on whooping crane populations. Due to the lack of evidence of land use change, any assertion that the recovery of whooping crane populations would have been more rapid had it not been for the RFS would be purely speculative[4].

3.2 Piping Plover (***Charadrius melodus***)

There are three distinct populations of piping plover in the U.S.: Great Lakes, Northern Great Plains, and Atlantic Coast. Piping plover populations on the Great Lakes are listed as endangered, whereas populations in the Northern Great Plains and Atlantic coast are listed as threatened. Piping Plover population declines have been attributed to human disturbance, habitat loss and predation. Piping

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[3] Phone communication between Ramboll and Cheyenne Bottoms Ranger Station (620-793-3066) on November 17th and 19th, 2019

[4] This point applies as well to other species discussed below, where the data show recovery of the species during the time frame in which the RFS program has been implemented.

plover management strategies are targeted at limiting access to beachgoers and off-road vehicles, pet restrictions, and public education[5].

The Lark Declaration implicates land conversion for crop production (and presumably by extension, land conversion to corn or soy as a result of the RFS) as a potential impact to piping plover populations, citing Cohen (2009)[6] as documenting “disruption of plover habitat” in the Great Lakes endangered population. In fact, Cohen et al. (2009) studied two Atlantic Coast piping plover breeding areas in West Hampton Dunes, a barrier island in New York State. The only mention of land conversion made by the authors was in reference to urban development. In addition, the authors cite predation management (domestic cats and fox) as key to the recovery of the populations at the sites they studied. Thus, this study cited in the Lark Declaration is not relevant to the premise that land conversion spurred by the RFS results in impacts to piping plover, and in fact specifically points to urban development and predation as the primary stressors to these populations.

The U.S. FWS Midwest Region fact sheet describes the following threats to Great Lakes piping plover populations: Coastal beach habitat loss due to commercial, residential, and recreational developments; and effect of water control structures on nesting habitat; vehicle and pedestrian use of beaches; harassment or mortality of birds by dogs and cats; and predation by fox, gulls, and crows[7]. Habitat protection measures include controlling access to nesting areas, nest monitoring and protection, limiting residential and industrial development, and properly managing water flow[8]. Thus, like the Atlantic Coast populations, land use change due to agriculture is not a recognized threat to the Great Lakes populations.

In the Northern Great Plains, piping plover breed on river sandbars, along reservoir shorelines, and in manmade habitat such as commercial sand mines. Similar to the Atlantic Coast and Great Lakes populations, declines of this population are attributed mainly to harassment of birds and nests by people, domesticated animals, and vehicles; shoreline habitat loss due to development projects; human-induced increased predation; and water-level regulation policies that disrupt nesting behavior or destroy nesting habitat (NRC 2005). Appendix 8 to the Lark Declaration provides an example of conversion of some riparian forest habitat adjacent to a farm field along the Missouri River sometime between spring 2012 and late winter 2015. This example, however, does not portray any loss of critical habitat for this species (i.e., critical habitat for the piping plover in the Missouri River is sand bar or sandy shoreline habitat and not forest), and therefore does not support the premise in the Lark Declaration that land conversion spurred by the RFS results in impacts to piping plover.

Thus, based on a review of the specific citations relied upon by the Lark Declaration as well as publications by the U.S. Fish and Wildlife Service (USFWS) regarding endangered and threatened populations of piping plover, we find no evidence that agriculture in general, or land conversion to corn and soy due to the RFS in particular, results in impacts to piping plover. Such claims in the Lark Declaration are unsubstantiated.

It is worth noting that, in addition to discussing land conversion, the Lark Declaration cites a study by Fannin (1993)[9] when suggesting that pesticides or other contaminants from agricultural practices (and by extension, presumably agriculture for biofuels feedstock spurred by the RFS) could jeopardize piping plover egg survival. Fannin and Eamoil (1993) collected 16 piping plover addled (unhatched) eggs in 1989 and 3 piping plover addled eggs in 1990 and analyzed the contents for a wide range of metals and

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[5] https://naturalhistory2.si.edu/smsfp/irlspec/Charad_melodu.htm

[6] The Lark Declaration incorrectly cites Cohen et al. (2009)

[7] https://www.fws.gov/midwest/endangered/pipingplover/pipingpl.html

[8] https://www.fws.gov/midwest/endangered/pipingplover/pipingpl.html

[9] We believe that the Lark Declaration incorrectly cites Fannin and Eamoil (1993)

several organochlorine pesticides, including DDT and its breakdown products. DDT and to a lesser extent, other organochlorine pesticides are known to cause eggshell thinning and reproductive failure, principally in raptors and fish-eating birds. DDT was banned from use in the United States in 1972, and chlordane was banned in 1988. It is also widely known that many species made dramatic recoveries in the years following the ban of DDT, most notably the bald eagle. Use of these and other organochlorine pesticides in agriculture were terminated decades prior to the enactment of the EISA and implementation of the RFS. Thus, any suggestion in the Lark Declaration that the use of pesticides on biofuel crops may be resulting in eggshell thinning in piping plover lacks foundation.

3.3 Yellow-Billed Cuckoo (***Coccyzus americanus***)

The Western U.S. Distinct Population Segment of *C. americanus* (western yellow-billed cuckoo) was proposed as threatened on October 3, 2013 (FR 79:192, October 3, 2014; USFWS 2014). Within the last 50 years the species' distribution west of the Rocky Mountains declined substantially mainly due to loss of streamside habitat. USFWS (2014) reports that current impacts from agricultural activities on yellow-billed cuckoo habitat are mainly associated with livestock overgrazing in riparian areas.

Yellow billed cuckoo breed in dense willow and cottonwood stands in river floodplains. The Lark Declaration states that their threatened status is due largely to the “destruction of these habitats from anthropogenic activities, including agriculture,” and presumably by extension, land conversion to biofuel feedstock (corn and soy). However, the Lark Declaration fails to acknowledge that with the exception of Glenn County in California, there is no overlap between significant corn or soy growing areas and critical habitat for the species. This is primarily due to the fact that most corn and soy production in the U.S. occurs east of the Rocky Mountains.

Figures 6, 7, and 8 show areas reported to be in corn in the USDA CDL database for 2018 within the boundaries of designated critical habitat for the Western yellow-billed cuckoo in Glenn County, along with available Google Earth aerial images of these areas. The maps in figure 6 show that with only a couple of exceptions there is no overlap between Western yellow-billed cuckoo habitat and counties with corn and soy cultivation. The Google Earth images in figure 7 and 8 clearly show that these areas were in agricultural production as early as 1998, a decade before the RFS could possibly have influenced land conversion, and at approximately 55.5 acres, they account for only 0.036% of the total available critical habitat for the species in California (155,635 acres). Thus, not only is there no overlap between critical habitat for this species and significant corn growing areas, but in the two instances in California where the CDL reports corn to be grown in critical habitat, areas were in agricultural production long before the RFS.

As with the piping plover, the Lark Declaration also suggests that western yellow-billed cuckoo is adversely impacted by eggshell thinning due to pesticides. For the reasons described above, any eggshell thinning observed in this species cannot possibly be associated with the RFS and any such implied association is unsubstantiated.

3.4 Poweshiek Skipperling (***Oarisma poweshiek***)

The Poweshiek skipperling, was once abundant in remnant native prairie habitat in Indiana, Illinois, Iowa, Michigan, Minnesota, North Dakota, South Dakota, Wisconsin, and Manitoba, Canada; but is now thought to be present only in Wisconsin, Michigan, and Manitoba. The USFWS lists several stressors that may be acting to reduce populations of the butterfly, with loss and degradation of habitat being one of the initial stressors for its decline. The USFWS states that other stressors are unknown but might include disease or pesticides.

The Lark Declaration (paragraph 15, page 12) states "Habitat fragmentation poses a key threat to the Poweshiek skipperling, and there are several instances where land has recently been converted to cultivate either corn or soybeans within close proximity to its critical habitat in Minnesota, North Dakota, and South Dakota". Paragraph 15 refers to Appendix 6, which we presume to be their best example to illustrate land conversion due to RFS. Appendix 6 presents a map showing Poweshiek skipperling critical habitat in Minnesota, the location of an ethanol refinery, and polygons depicting presumed land conversion from native tall grass prairie to corn or soy. Appendix 6 is based on a comparison of data from 2008 to 2016 and methods documented in Lark et al. (2015; see above description of shortcoming of these methods). The second page of Appendix 6 shows two images from Google Earth, one from May 21, 2008 and another from June 23, 2011--presumably showing conversion of two farm fields adjacent to Poweshiek skipperling critical habitat from grassland to cropland. The refinery depicted in Appendix 6 was confirmed by Ramboll to be the Valero refinery in Aurora, North Dakota; approximately 28 miles from the illustrative farm fields.

Several facts indicate that the assertions in the Lark Declaration regarding the Poweshiek skipperling are flawed, and, in fact, land conversion from tall grass prairie to corn or soy due to the RFS could not have had an impact on this listed species:

- The last confirmed sightings of *O. poweshiek* in Minnesota were in 2007, despite extensive annual surveys beginning in 2013[10]. The RFS went into effect in 2008 so could not possibly have had an adverse effect on this species in Minnesota. Similar trends were seen in other states (Environment Canada 2011):
  - In Iowa, the species was in decline by 2003 and was last observed in 2008
  - In North Dakota, the species was thought to be extirpated by 2008; with only 8 individuals seen in a survey in 2001.
  - In South Dakota, The species began to disappear from five South Dakota sites in 2002 and many of these sites were observed to be idle with no range or grass management. At these sites, the decline was attributed loss of floral diversity, increase in grasses and forbs, and an increase in exotic species. The species was last observed at Hartford Beach State Park and the Waubay National Wildlife Refuge in 2002, Pickerel Lake State Recreation Area in 2004, Wike Waterfowl Production Area in 2006, and Scarlet Fawn Prairie in 2008. Several sites where they had been recorded in the past were surveyed in 2010 and no adults were observed.
- The Valero Aurora refinery in North Dakota began operation in 2003 and reached a capacity of 120 million gallons per year (MGY) in 2005[11], three years before the enactment of EISA. Therefore, any increased demand for corn in the vicinity of the refinery would have been met prior to any possible effect of the RFS, and therefore there cannot be a causal relationship between the RFS and land conversion impacting *O. Poweshiek* in Minnesota.
- Dana (1997) conducted a survey for the Dakota skipper (*Hesperia dacotae*) butterfly in several critical habitat areas of Minnesota, including Hole-in-the-Mountain Prairie Lincoln County, Minnesota South of the town of Lake Benton (the same area depicted as critical habitat in the Lark Declaration Appendix 6). The Dakota skipper has very similar habitat requirements as Poweshiek skipperling. Dana (1997) states that the principal threat to this species in this area is probably the use of herbicides for weed and brush control in privately owned pastures as well as overgrazing and mowing

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[10] https://www.dnr.state.mn.us/rsg/profile.html?action=elementDetail&selectedElement=IILEP57010

[11] https://www.valero.com/en-us/AboutValero/ethanol-segment/aurora

by County Park staff, and possibly excavation for construction materials. Dana (1997) specifically states that conversion of additional prairie to cropland (in general) is at most, a minor threat[12].

- Appendix 6 of the Lark Declaration shows satellite images from Google Earth for the years 2008 and 2011 presumably to contrast land use in the year the EISA was enacted and several years after the RFS went into effect. However, there is no information provided to substantiate the claim that the highlighted areas were indeed grassland in 2008. In fact, when other satellite images readily available on Google Earth are examined, it is clear that the subject areas were in agriculture as early as 1992. Further, upon viewing the Google Earth images available in subsequent years for the subject areas, there is no evident expansion of cropland since 1992 into what is now designated as critical habitat for the Poweshiek skipperling (Figure 9).

For the reasons described above, the assertion in the Lark Declaration that land conversion spurred by the RFS has adversely impacted critical habitat of the Poweshiek skipperling are unsubstantiated.

3.5 Other Insects

The Lark Declaration also mentions the threatened Dakota skipper (*Hesperia dacotae*), the endangered rusty patched bumble bee (*Bombus affinis)*, the endangered Hine's emerald dragonfly (*Somatochlora hineana*), and the endangered Salt Creek tiger beetle (*Cicindela nevadica lincolniana*) as other insect species that could “potentially be affected by biofuel feedstock production”. In no case, does the Lark Declaration provide any evidence to support that assertion. The Dakota skipper and rusty patched bumble bee are both prairie/grassland species. Although there has been habitat loss and fragmentation to varying degrees across the ranges of these species, there is no evidence presented that habitat loss occurring after 2008 was directly linked to the presumed RFS-induced land conversion.

As to Hine’s emerald dragonfly, USFWS (2013) states the following:

- The greatest current threat to this species is from invasive plants
- There are effective protections against habitat loss (wetland filling and draining)
- Past habitat loss was due to commercial and industrial development.

USFWS (2013) does not mention any impact related to agriculture. Therefore, the Lark Declaration’s assertion of impacts to Hine’s emerald dragonfly due to the RFS is unsubstantiated.

With regards to the Salt Creek tiger beetle, the Lark Declaration also provides no evidence or discussion of the causal relationship between the RFS and impacts to this species. The Salt Creek tiger beetle is currently found at only three sites in Lancaster County, Nebraska occupying 15 acres in saline wetland habitat[13]. The Nebraska Game and Parks Commission states that the biggest threat to the habitat of this species is stream channel modification[13]. The USFWS (2013b; page 33284) cites two publications from 2003 and 2005 in its statement that “in the past 150 years, approximately 90 percent of these wetlands have been degraded or lost due to urbanization, agriculture, and drainage” but does not mention agriculture as a threat to habitat of this species after the implementation of the RFS in 2008. In fact, the USFWS (2013; page 33285) shows a graph presenting results of surveys of adult Salt Creek tiger beetles 1991 to 2012 which indicates a consistent increase in population over the period 2008-2012 with an approximate doubling in numbers over that period (Figure 10). Based on the information presented above, we find that the Lark Declaration’s assertion of impacts to the Salt Creek tiger beetle due to the RFS is also unsubstantiated.

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[12] Note that these observations, including the statement regarding habitat threats, predate the EISA by 11 years.

[13] Nebraska Department of Game and Parks

3.6 Blackfooted Ferret (***Mustela nigripes***)

The black-footed ferret was listed as endangered across its entire range on March 11, 1967.[14] The is no critical habitat designated for this species. Black-footed ferret population status and distribution is closely tied to that of prairie dogs. Prairie dogs make up more than 90% of the black-footed ferret's diet and prairie dog burrows provide shelter and den habitat for the species. Major threats to black-footed ferret populations include conversion of native grasslands to agriculture, prairie dog eradication programs that were once widespread, and disease; and much of the remaining habitat for black-footed ferret is fragmented due to fragmentation of prairie dog towns by agriculture and human development (USFWS 2018).

The Lark Declaration states that "Given the connection between the Renewable Fuel Standard and the conversion of grasslands to agricultural land within the Black-footed ferret's range, further assessment seems warranted", but provides no explanation or evidence to support such a "connection". The Center for Biological Diversity (CBD 2019) reports that the last captive black-footed ferret died in 1980, and at that time, the animals were thought to be extinct in North America. In 1981 the species was re-discovered in a Wyoming prairie dog colony. Between 1991 and 1999, about 1,200 ferrets from that population were released at sites in Wyoming, Montana, South Dakota, Arizona and along the Utah/Colorado border (CBD 2019). It is estimated that about 1,410 black-footed ferrets are currently living in the wild (CBD 2019). Figure 11illustrates the estimated population status of black-footed ferrets in the wild, including a rapid recovery beginning in about 2000 and extending past 2008, the year the EISA was enacted and the RFS was implemented. The continual and unabated recovery of black-footed ferret populations after 2008 also serves to undermine the assertion in the Lark Declaration that the RFS has had adverse impacts on black-footed ferret.

Figure 12 illustrates the locations of black-footed ferret populations (reintroduced) and acres planted in corn and soy in 2018. With few exceptions, there is no overlap between counties with some acreage in corn or soy and locations where black-footed ferret have been introduced. The Lark Declaration presents no evidence of impacts from land conversion spurred by the RFS, and, in fact, evidence suggests that impacts due to loss of habitat (for all reasons) occurred long before any potential influence of the RFS and most of the species recovery has occurred since 2008. Therefore, we conclude that the Lark declarations' assertions of a causal relationship between the RFS and impacts to black-footed ferret lack foundation.

4. Lack of Evidence of a Causal Link between the RFS and Hypoxia in the Gulf of Mexico or the RFS and Water Quality Impacts in Streams Supporting Listed Species

4.1 Lack of Evidence of a Causal Relationship Between the RFS and Hypoxia in the Gulf of Mexico

The alleged link between increased corn production for ethanol and hypoxia in the Gulf of Mexico (and western Lake Erie) is addressed in Section 4.1 of the Ramboll report. While it is not unexpected that nutrient loading (including from agriculture in general) to the Gulf of Mexico via the Mississippi River contributes to the formation of a seasonal hypoxic "dead zone" in the Gulf of Mexico, there is no information demonstrating a link between increased corn ethanol production under the RFS and specific and quantifiable causes of observed hypoxic conditions in the northern Gulf of Mexico. The consensus, based on the vast majority of technical articles we have reviewed is that hypoxia is due to algal

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[14] https://www.fws.gov/mountain-prairie/es/blackFootedFerret.php

production driven by excess nitrogen that enters the northern Gulf of Mexico via the Mississippi River and related watersheds together with certain hydrologic conditions, including vertical stratification and temperature dynamics within the Gulf of Mexico water column. The hypoxia condition is not new and as shown by the U.S. Geological Survey and other institutions, has been an ongoing phenomenon for several decades and well before the RFS was initiated in 2008. The loading of annual nitrate plus nitrite to the Gulf of Mexico has been relatively consistent since comprehensive monitoring began in approximately 1980[15] with the three largest measured annual loading values occurring in 1993, 1983, and 1984, respectively, and thus well before the RFS was envisioned. Bianchi et al. (2010) conclude that understanding the complexity of this highly dynamic system or predicting flux and source areas with high precision is not reliable by simply referring to the numerous mostly general models that are relied on by recent authors (including Lark).

The Lark Declaration (at page 20), for example, refers to the pre-RFS study by Donner and Kucharik (2008) that “predicts” an increase in flux of dissolved inorganic nitrogen (DIN) by the Mississippi and Atchafalaya Rivers of between 10% and 34% using models that rely on hypothetical predictions of land use scenarios and discharge. Although Donner and Kucharik (2008) discuss the model validation approach, the validation results are imperfect indicating considerable overestimates in some cases, and underestimates in others. Furthermore, the model does not appear to provide a precise fit between the simulated results and the observed DIN discharge numbers collected from the few field stations identified in the study. An important complication in using a model like this to make predictions is the differentiation between urban (e.g., septic, industrial and municipal waste water plants, and residential runoff) and agricultural sources. As noted by Alexander, et al (2007), additional complications also are that nutrient sources typically are statistically estimated in the models, and then adjusted based on the model calibration. Model calibration uses “trial and error” processes for simulating numerous parameters that are themselves influenced by hydrologic and biogeochemical processes, nutrient uptake by a wide variety of soil types, climatic (short and long-term) conditions, and (as most relevant currently), improvements in fertilizer application and cropping and drainage patterns. Essentially, by providing examples of failed predictions using models, Bianchi, et al. (2010) make the case to not rely solely on numerical models.

Notably, the influence of weather is a very important condition for the formation of the Gulf of Mexico “dead zone” and is totally independent from loading of DIN from any particular sources. The influence of weather on the formation of the Gulf of Mexico “dead zone” is discussed in the Ramboll report in Section 4.1, page 26, where for example, the U.S. Geological Survey[16] estimated that flooding in the spring of 2019 resulted in an increased loading of nitrate and nitrite of approximately 18% when compared to the long-term average loading to the Gulf of Mexico.

The alleged quantitative relationship between increased corn grown for ethanol and nutrient loading to the Gulf of Mexico is further called into question by data from the U.S. Geological Survey indicating that annual nitrate plus nitrite loading to the Gulf of Mexico has remained relatively constant over the period 1980 to 2017 (Figure 13). This indicates that even during the period of increased use of corn for ethanol, there has been no appreciable net change to nutrient loading to the Gulf of Mexico. For this reason alone, there is no support for the assertion of a direct relationship between ethanol production on the hypoxia conditions in the Gulf of Mexico. In addition, EPA (2018) reports that there has actually been a reduction in total nitrogen concentrations in surface water bodies in Iowa which is the highest

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[15] https://nrtwq.usgs.gov/mississippi_loads/#/GULF

[16] https://www.usgs.gov/news/very-large-dead-zone-forecast-gulf-mexico?qt-news_science_products=4#qt-news_science_products

corn producing state. This further refutes the broadly stated allegation that there is a link between expanded corn production (for any reason) and increased nutrient loading to the Gulf of Mexico.

The Lark Declaration mentions the following listed species as potentially impacted by the Gulf of Mexico dead zone: the threatened Gulf sturgeon (*Acipenser oxyrinchus desotoi*), the loggerhead turtle (*Caretta caretta* listed as endangered and threatened depending on location), and the endangered sperm whale (*Physeter macrocephalus*). With regards to Gulf sturgeon, it is instructive to look at the geographical location of critical habitat for the species and the occurrence of the dead zone in the Gulf of Mexico. The dead zone forms west of the Mississippi River Delta over the continental shelf (< 200 m water depth) of Louisiana and sometimes extends to Texas[17]. Figure 14 depicts Gulf sturgeon critical habitat occurring exclusively to the east of the Mississippi River delta and the hypoxic zone in 2019 (the largest recorded) located exclusively to the west of the Mississippi River delta. NOAA's Gulf of Mexico Hypoxia Watch site presents results from dissolved oxygen monitoring for the period 2001 to 2019[18]. These results show that hypoxia rarely extends near critical habitat areas for Gulf sturgeon, and when these conditions exist, they are limited to a relatively small area offshore of Biloxi, Mississippi. Waters to the east and south did not exhibit hypoxic conditions in any year monitored.

Moreover, the migratory behavior of Gulf sturgeon minimizes the probability of encountering hypoxic waters, should they occur in their critical habitat. Oxygen depletion in the Gulf of Mexico increases in late spring, worsens over the summer, then dissipates in the fall; whereas gulf sturgeon move into rivers in the spring and fall and spend the summer months in the riverine habitat, then subadults and adults move into estuarine waters in the fall to feed and then move into marine waters in the winter. Thus, the Lark Declaration provides no evidence of a relationship between Gulf sturgeon critical habitat and potential impacts from hypoxia in the Gulf of Mexico due to nutrient inputs from the Mississippi River basin. In addition, NOAA does not list hypoxia as a threat to the species, rather it lists contaminants, dredging, dams, and climate changes as the threats[19]. For these reasons, the presumption in the Lark Declaration that the RFS has resulted in impacts to Gulf sturgeon is unsubstantiated.

Loggerhead turtles and sperm whales have pan-global ranges and only a limited number of individuals over a limited portion of their life spans would be likely to encounter the Gulf of Mexico dead zone. Because both are air-breathing animals, adverse effects to these species from hypoxia, if any, could only be indirect (e.g., reduced prey abundance).

The loggerhead turtle is the most common sea turtle in the southeastern U.S., and they nest mainly along the Atlantic coast of Florida, South Carolina, Georgia, and North Carolina and along the Florida and Alabama coasts in the Gulf of Mexico[20]. The Lark declaration states that "The increasing frequency of red tides and harmful algae blooms in the Gulf of Mexico as well as the increased duration and extent of the hypoxic dead zone caused by agricultural runoff in the Mississippi River have been reported to both directly and indirectly affect sea turtles" and cites NMFS et al. (2011) for this proposition. Yet, NMFS (2011) makes no mention of hypoxia, and red tide is only mentioned in the context of the west coast of Florida. The Lark Declaration also states that "Loggerheads in the near-shore northern Gulf of Mexico waters may be exposed to hypoxia…", citing Hart et al. (2013) for this proposition. However, Hart et al. (2013) studied nesting sites and movement patterns only along the Alabama and Florida coasts and reported movement patterns southward along the Florida west coast, away from the Gulf of Mexico dead zone. As noted above, since 2001, hypoxia in the Gulf of Mexico did not extend to the west

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[17] https://pubs.usgs.gov/fs/2006/3005/fs-2006-3005.pdf

[18] https://www.ncddc.noaa.gov/hypoxia/

[19] https://www.fisheries.noaa.gov/species/gulf-sturgeon

[20] https://www.fisheries.noaa.gov/species/loggerhead-turtle

coast of Florida. Therefore, the assertions in the Lark Declaration that the RFS has resulted in impacts to loggerhead turtles by means of hypoxia in the Gulf of Mexico lack foundation.

Sperm whales inhabit all of the world's oceans, having one of the widest distributions of any marine mammal. NOAA does not list hypoxia as a threat to this species, rather vessel strikes, entanglement, ocean noise, marine debris, climate change, oil spills, and contaminants are listed as threats.[21] Several researchers have investigated the distribution of sperm whales and other cetaceans in the Gulf of Mexico. Davis et al. (2002) report a resident breeding population within 100 km of the Mississippi delta and suggest that the edge of the continental slope south of the Mississippi River delta provides the oceanographic deep-water conditions with locally enhanced primary and secondary productivity. The Gulf of Mexico dead zone does not extend to the continental slope, rather it is oceanographically limited to the continental shelf where water depths are less than 200 m.

In sum, attributing adverse impacts to these species to hypoxia induced by nutrient enrichment in the Mississippi River basin is speculative. Attributing any potential for adverse effects due solely to theoretical increases in nutrient inputs from expanded corn production spurred by the RFS is unsupportable.

4.2 Lack of Evidence of a Causal Relationship Between the RFS and Water Quality Impairment in Streams Supporting Listed Species

Surface water use impairment is determined under Section 303(d) of the Clean Water Act, which predates initiation of the RFS program by several decades. The Lark Declaration at Appendix 5 provides maps of 303(d) impaired water bodies in several geographic regions and asserts a causal relationship between the RFS and the 303(d) listing. Figure 15 compares the 303(d) maps for 2002 (as produced by the State of Illinois) and the 2015 map presented in the Lark Declaration. This figure clearly shows that a major water body near Carbondale has been impaired for more than 17 years—well before the RFS went into effect in 2008. Similar comparisons can be made for areas of North Dakota used for illustration in the Lark Declaration at page 92 where 303(d) impairments were tracked by the State in 2004[22]), and for areas of central Minnesota (Lark Declaration at page 94) where in 2002, the Minnesota Pollution Control Agency (MPCA) provided a list of its 303(d) impaired lakes[23] noting that nutrients were part of the root cause in many of them. The attempt in Lark's Declaration to tie such impairments to the RFS using the 303(d) maps (Appendix 5) is fundamentally flawed, for the reasons described below.

The maps shown in the Lark Declaration (Appendix 5) do not show watershed hydrology that explicitly links areas of crop production, ethanol refining, and impaired water bodies. As Bianchi, et al (2010) observed, general maps and information, such as the geographic placement of crop production in a regional map, is insufficient to establish a causal link between the RFS and water quality due to the complexities of numerous factors, including timing, weather, local farming practices, soil chemistry and physical properties, hydrology, other rural and urban release mechanisms.

Another example of the Lark Declaration's presentation of faulty data—with respect to the alleged link between the RFS and streams with impaired water quality—is a sub-basin in northeastern Kansas depicted on figure 5-6 of the Lark Declaration. We selected this sub-basin for closer examination because it appears to be a worst-case example of the purported causal relationship, based on the relatively large proportion of area identified as land converted to corn or soy and the proximity of a relatively large area to a 303(d) listed water body. Figure 16 presents a reproduction of figure 5-6 from

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[21] https://www.fisheries.noaa.gov/species/sperm-whale

[22] https://deq.nd.gov/publications/WQ/3_WM/TMDL/1_IntegratedReports/2004_Final_ND_Integrated_Report.pdf

[23] https://mn.gov/law-library-stat/archive/urlarchive/a042033-1.pdf

the Lark Declaration, together with the selected sub-basin and presumed land conversion area immediately adjacent to the stream. Figure 17 presents a simple examination of publicly-available Google Earth aerial images of this area over time is instructive. Google Earth aerial images of this area clearly depict it in agricultural use as early as 1991 with no apparent expansion since that time including the period 2008-2018.

Further, we performed a spatial analysis of land allegedly converted to biofuels feedstock cultivation after 2008 (using figure 5-6 from the Lark Declaration) within the watershed depicted in Figure 17 (even though we know that in at least the case illustrated by Figure 17; this allegation is incorrect). Such an analysis indicates that in the watershed area of 55,840 acres, the total area devoted to crops (exclusive of grassland) in 2015 based on LCD NASS data, was approximately 18,940 acres (or 34% of the total watershed area). Of the total acres in crops, approximately 880 acres (or 1.6% of the watershed) was in corn or soy in 2015. Of the allegedly “converted” fields identified in the watershed in figure 5-6 of the Lark Declaration, the closest field to the impaired water body is approximately 390 feet (the field shown in Figure 17) and the average distance of all presumably converted fields to the impaired stream is approximately 4,860 feet. Barring mass wasting of agricultural soils, very poor practices, or spills of fertilizers, loading of nutrients to water bodies from agricultural fields (e.g., in pounds per acre per year) is expected to decrease with distance; even at a distance of 390 feet, an appropriately managed farm field would be expected to have very little transport of nutrients over that distance. Even if one assumed that all of the presumably “converted” areas were indeed converted, the total loading of nutrients from these fields (all else being equal) compared to all other agriculture would be expected to be vanishingly small (e.g., the presumably “converted” soy and corn area is only about 4.6% of the total crop area).

As an additional example, we performed a spatial analysis of the watershed associated with critical habitat for the Arkansas shiner (*Notropis girardi*) as depicted in the Lark Declaration at page 105. For this watershed area of 471,400 acres, the total area devoted to crops (exclusive of grassland) in 2016 based on LCD NASS data, was approximately 175,500 acres (or 37% of the total watershed area). Of the total acres in crops, approximately 590 acres (or 0.13% of the watershed) was in corn or soy in 2016. Of the allegedly “converted” fields identified in the watershed in the figure at page 105 of the Lark Declaration, the closest field to the impaired water body is approximately 2.5 miles and the average distance for all fields to the critical habitat is approximately 10 miles. For this example, even if one assumes that all the area devoted to corn or soy in 2016 was the direct result of the RFS, the proportion of total crop area and the distance between the corn or soy fields is so vanishingly small as to undermine any claims of impact to the Arkansas shiner.

These quality control checks on the evidence presented in the Lark Declaration demonstrate the flawed nature of the assertions presented therein. This analysis, along with the fact that the 303(d) designations predate the RFS, undermines the assertion that there is a causal relationship between the RFS, reduced water quality in Section 303(d) impaired streams, and potential adverse impacts to listed aquatic species.

5. Conclusions

Our conclusions follow from the technical review of the assertions made in the Lark Declaration including an evaluation of the literature cited and an independent check of the geographical information presented in the Declaration. Our conclusions include the following:

- Assertions that increased corn ethanol production under the RFS has resulted in land use change and conversion of non-agricultural land to production of biofuel feedstock are unsubstantiated

  - Acres planted in corn across the United States has remained close to or below the total acres planted in the early 1930s despite increases in demand for corn as human food, animal feed, and biofuels over this nearly 90-year period. The increase in demand has largely been met by an approximately 7-fold increase in yield (bushels per acre). The lack of causal relationship between demand for corn and acres planted in corn calls into question the causal relationship between increased demand for corn for ethanol and land conversion, and, in turn, potential impacts of land conversion on endangered species.
  - The causal relationship between the RFS and the price of corn is unsupported by the evidence. Recent efforts to quantify the relationship ignore the multiple domestic and international economic factors affecting the price of corn. These factors include the overall increase in global consumption of agricultural commodities in general, due to expanding economies. In addition, most of the increase in the price of corn (as well as other crops like soy and wheat) since 2005 has been attributed to higher oil prices.
  - The Lark Declaration (and the literature relied upon therein) does not adequately consider the myriad factors that influence a farmer's decision to convert non-agricultural land to growing any given crop. In addition, the Lack Declaration fails to consider that converting new land is likely the least preferred option a farmer has for increasing production because it most likely involves additional expenditures such as land clearing and other preparation. Nor does it consider that the potential yield that can be expected of new fields, which, relative to existing fields, may be sub- or infra-marginal and may require more intensive inputs to achieve desired yields. For these and other reasons, assertions in the Lark Declaration that the RFS has resulted in land conversion are unsubstantiated.

- Assertions that RFS-driven land use change has resulted in impacts to particular ESA listed species are without foundation —The Lark Declaration asserts that land use change spurred by the RFS has resulted in impacts to listed terrestrial species of birds, mammals, and insects. However, the evidence presented is poorly researched (including citations to irrelevant documents and misinterpretation of data) and the examples used to support many assertions instead actually *refute* the assertions. For example, eggshell thinning in birds is mentioned as a potential impact of biofuels production, yet the chemicals responsible for this adverse effect were banned decades before the RFS took effect. In addition, several examples of supposed land use change were presented using approaches that are shown to be flawed, among other things, by testing the assertions against images from Google Earth. Specifically, we checked several claims of land conversion that are based on methods by Lark et al. (2015) against historical Google Earth Images that clearly show fields had been converted long before the RFS went into effect (e.g., in areas allegedly impacting the whooping crane, Poweshiek skipperling, and yellow-billed cuckoo).
- Assertions that RFS-driven biofuels agriculture adversely impacts water quality are unsubstantiated—The Lark Declaration asserts that biofuels (corn and soy) agriculture has worsened the Gulf of Mexico dead zone, imperiling Gulf sturgeon, loggerhead turtles, and sperm whales, yet provides no supporting evidence. The Lark Declaration fails to cite any studies that associate corn or soy crops (let alone corn or soy crops directly traced to the RFS program) to any impacts to these species or their habitats. In fact, information related to the life histories of all three species indicates that the area within which the dead zone forms each summer does not overlap geographically (or temporally, in the case of the Gulf sturgeon) with critical or important habitat of any of the species. The Lark Declaration also fails to consider that the Gulf of Mexico dead zone had been forming on a regular basis for decades before the RFS went into effect. The Lark Declaration also asserts that biofuel (corn and soy) agriculture is associated with state designation of impaired waters pursuant to Section 303(d) of the Clean Water Act but

fails to acknowledge cases in which such designations were made well before the RFS came into effect. it also presents no assessment of the potential loading of nutrients to impaired water bodies. Our independent assessment of specific examples indicates that an assertion of impacts from corn or soy on impaired water bodies is unsubstantiated.

In sum, there are at least two important causal chains that must be quantified and linked together to demonstrate a relationship between increased corn ethanol production under the RFS and impacts to ESA-listed species: 1) a causal chain linking the RFS to land use change and water quality impacts; and 2) a causal chain linking these impacts to land and water with specific impacts on the survival or reproduction of ESA-listed species. Each of these causal chains is made up of many embedded biophysical and economic relationships that, in turn, are influenced by a myriad of interrelated variables. The Lark Declaration fails to consider these causal relationships in a meaningful way, relying instead on unfounded assumptions and speculation to support its thesis.

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7. Figures

Figure 1. Total U.S. Planted Acres of Corn Per Year

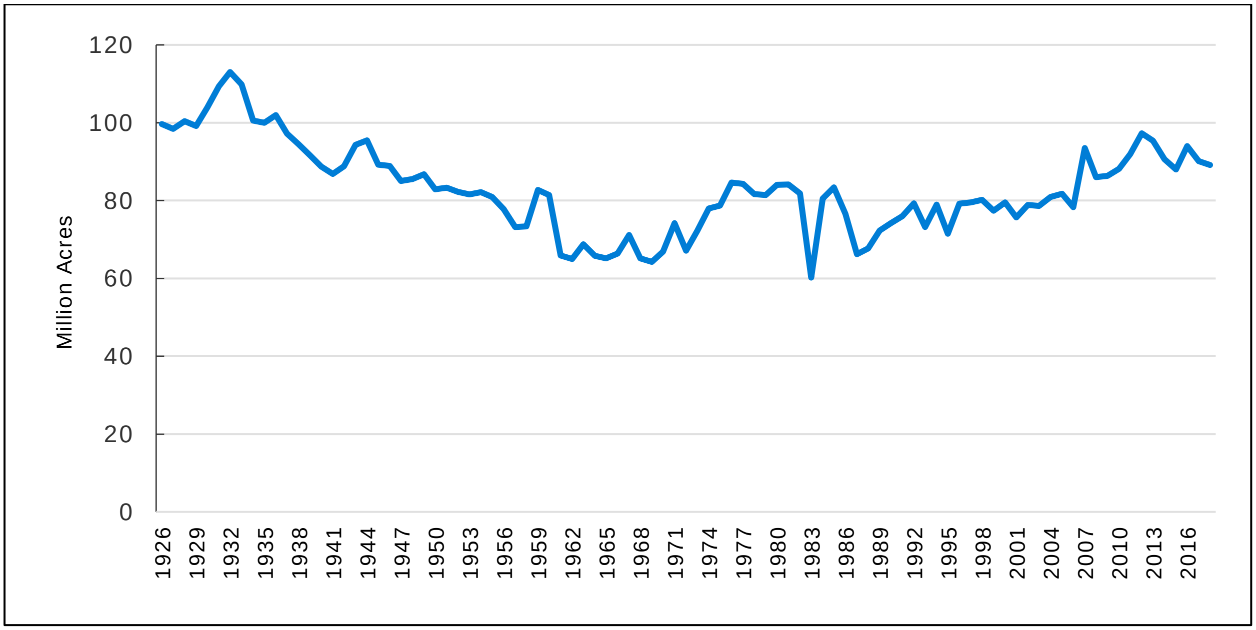


Figure 2. The decision about which crop to plant is made at the farm level, and takes many different components into account

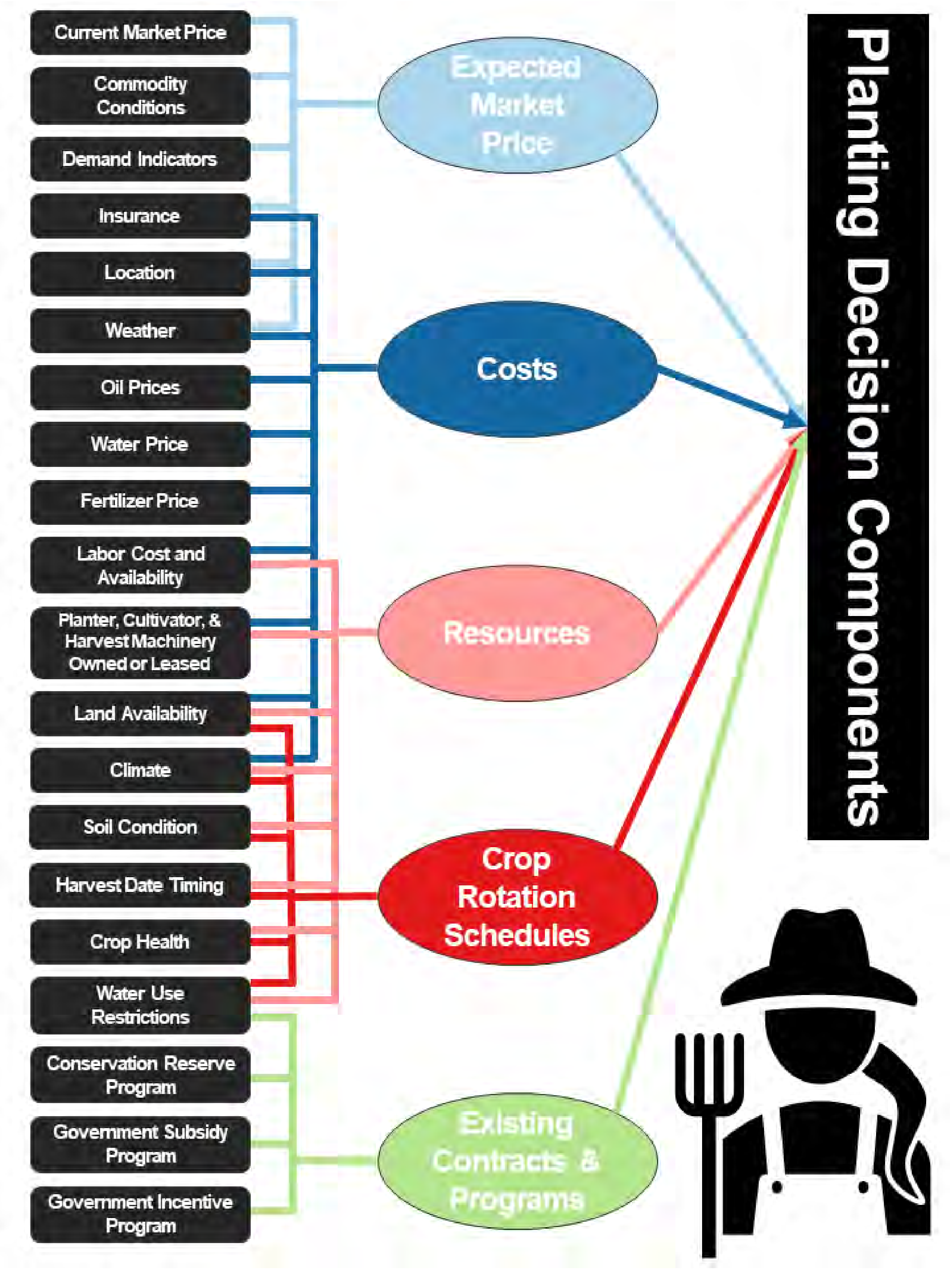


Figure 3. U.S. crude oil prices compared to crop prices, 2005 to 2015. From Staab, et. al. 2017

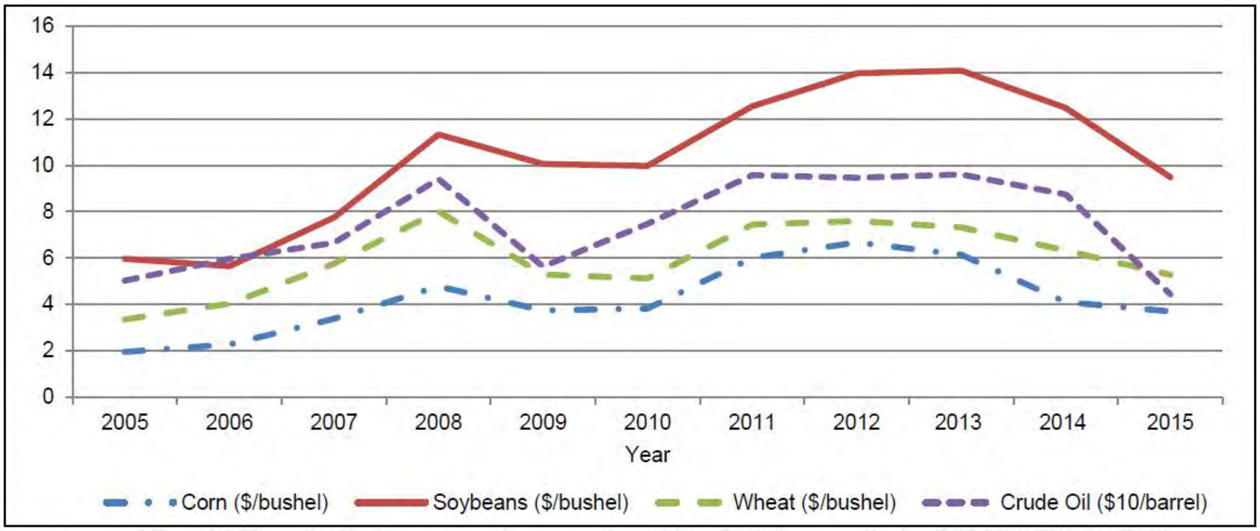
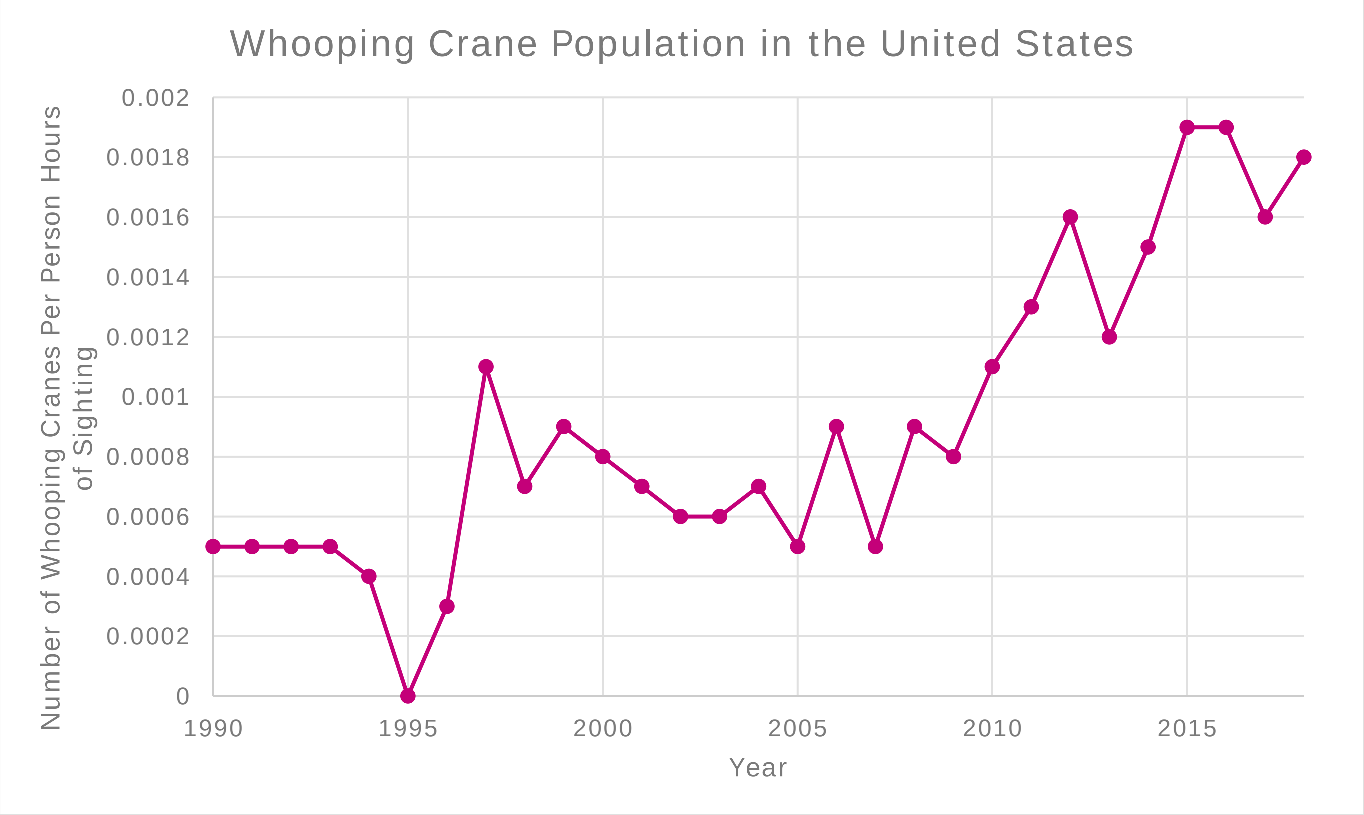


Figure 4. United States whooping crane population 1990 to present. Data are from the Audubon Society's Christmas Bird Count Database[24] and are shown here by the number of cranes per person hour of observation time.



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[24] http://netapp.audubon.org/CBCObservation/

Figure 5. Example of error in USDA Cropland Data Layer upon which Lark's argument rests. An area within the Cheyenne Bottoms Reserve was identified as corn by the USDA CDL. Examination of aerial imagery showed no corn, and conversations with staff at the reserve confirmed that corn was never planted there.

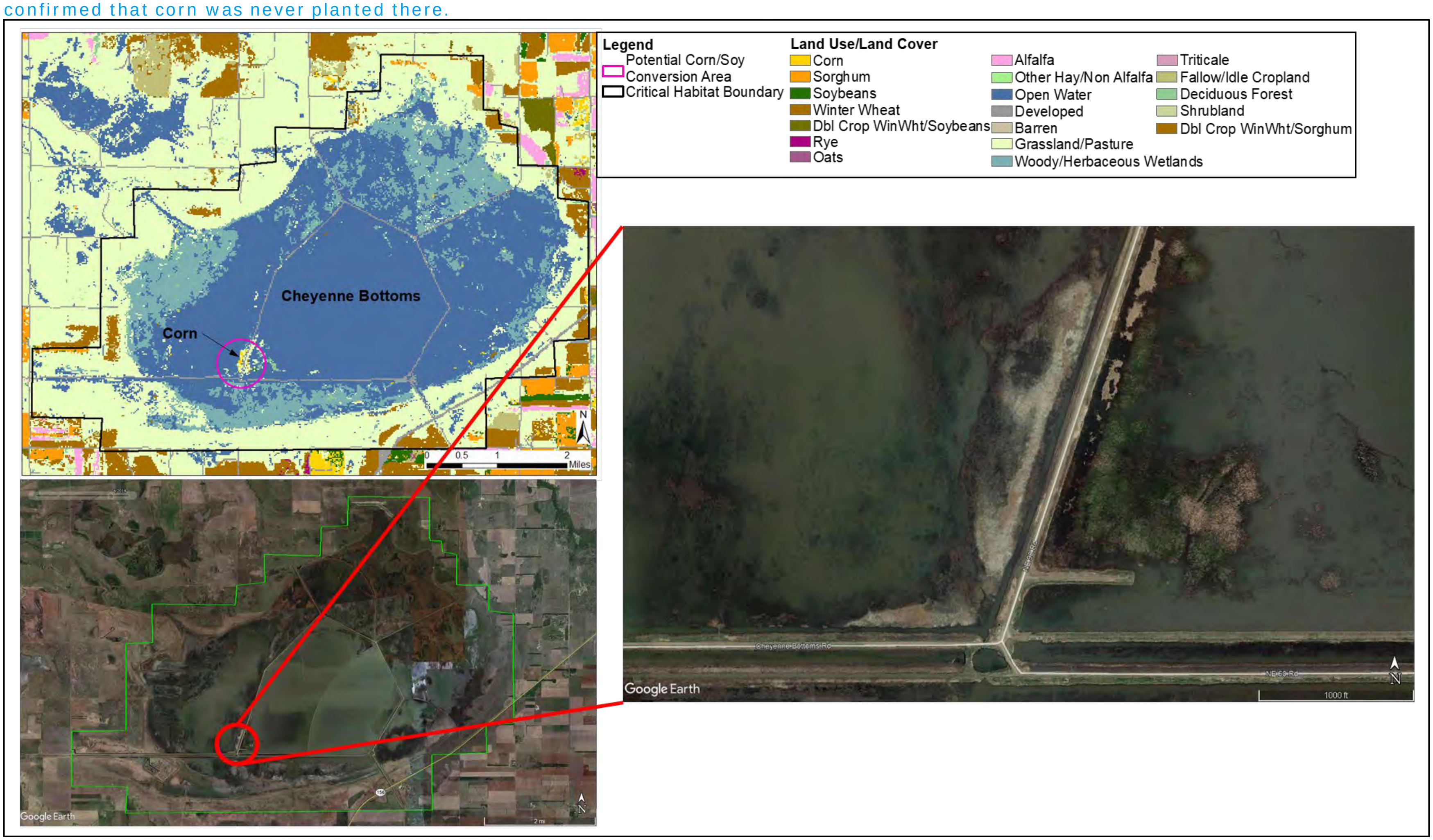


Figure 6. Western yellow-billed cuckoo critical habitat and corn and soy production by county

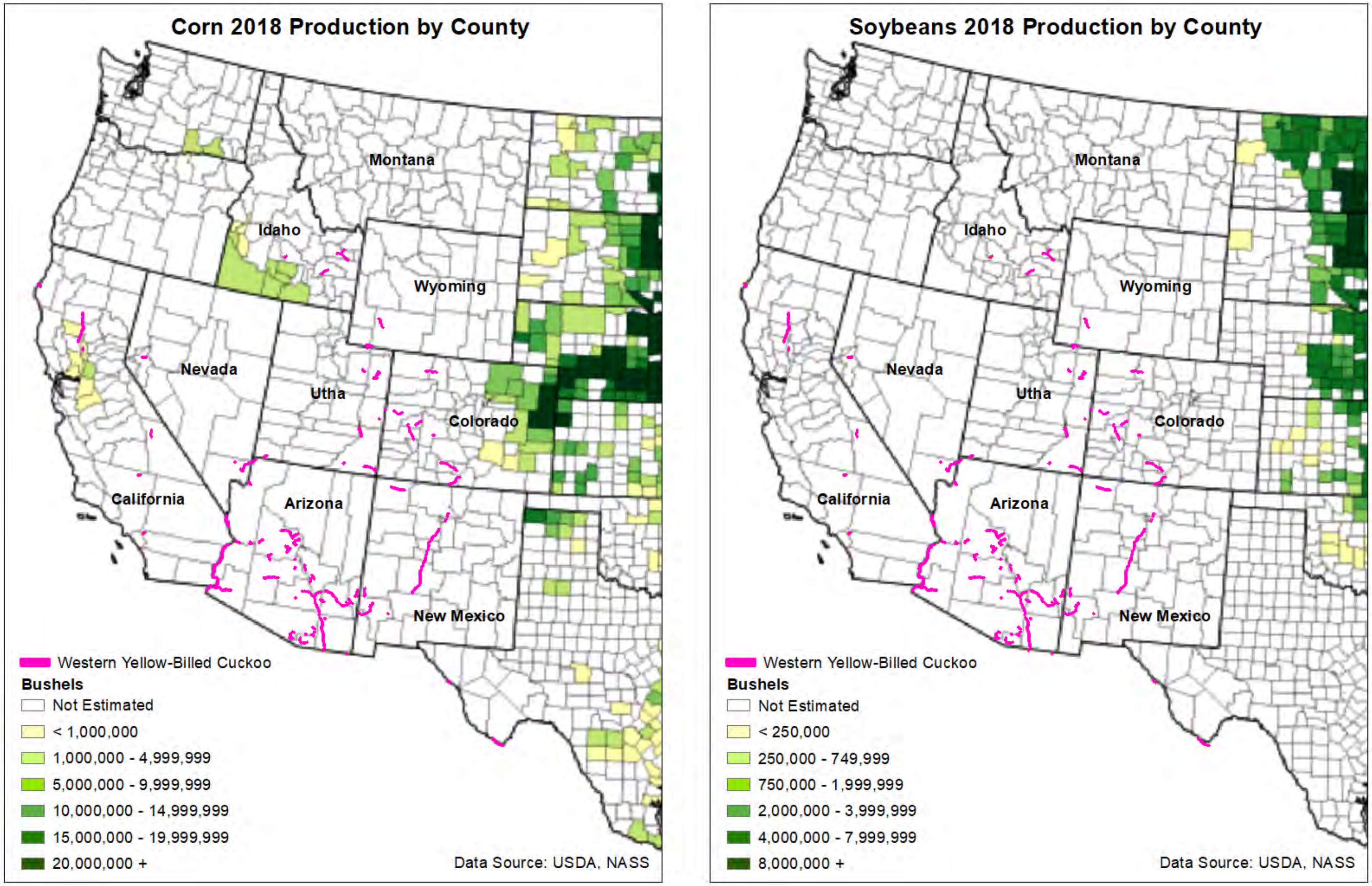
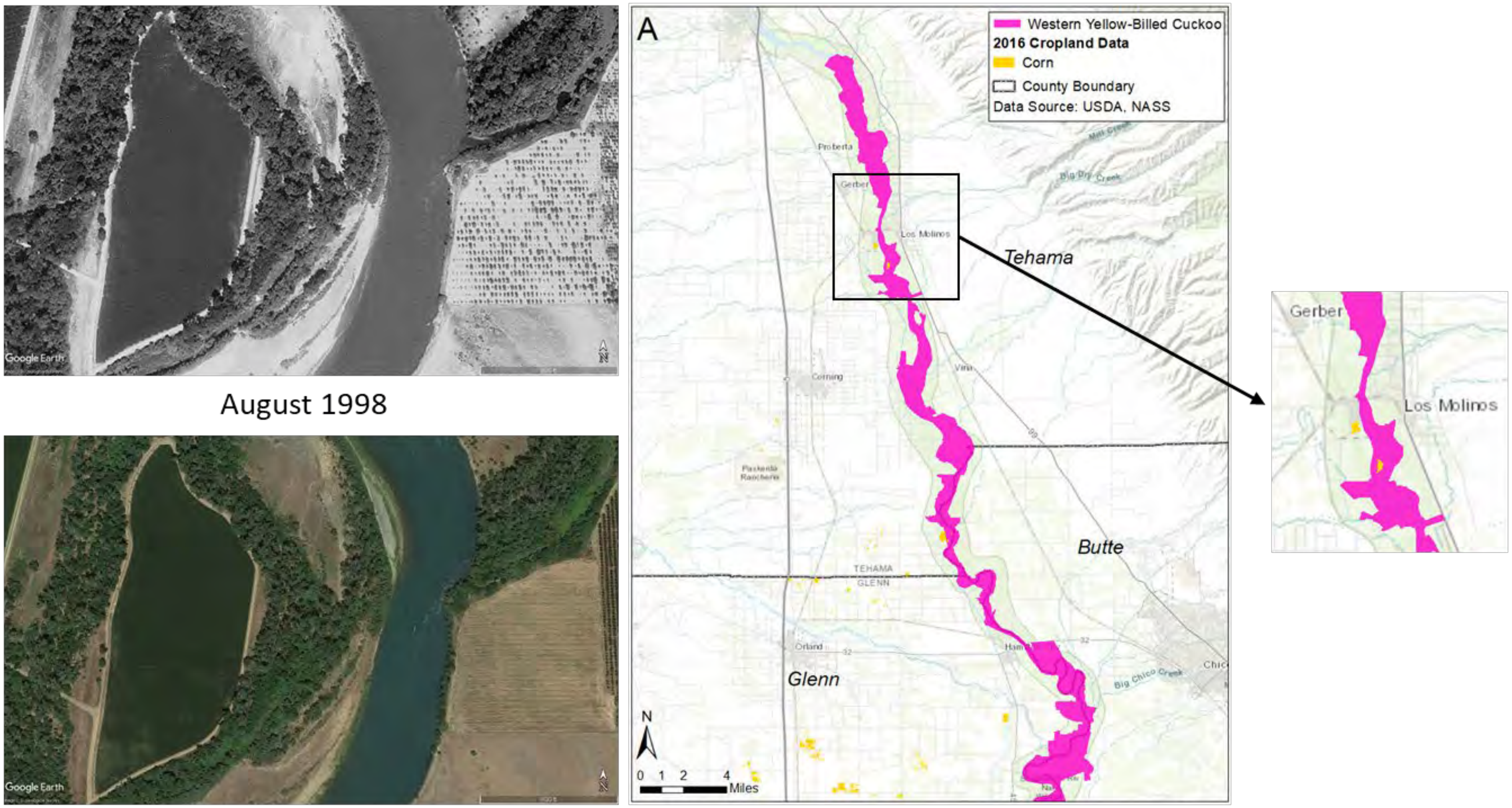


Figure 7. Area near Los Molinos, CA where 2018 CDL show corn within the boundaries of the critical habitat for Western yellow-billed cuckoo and Google Earth images from 1998 2014 document no conversion after 2008.



August 1998

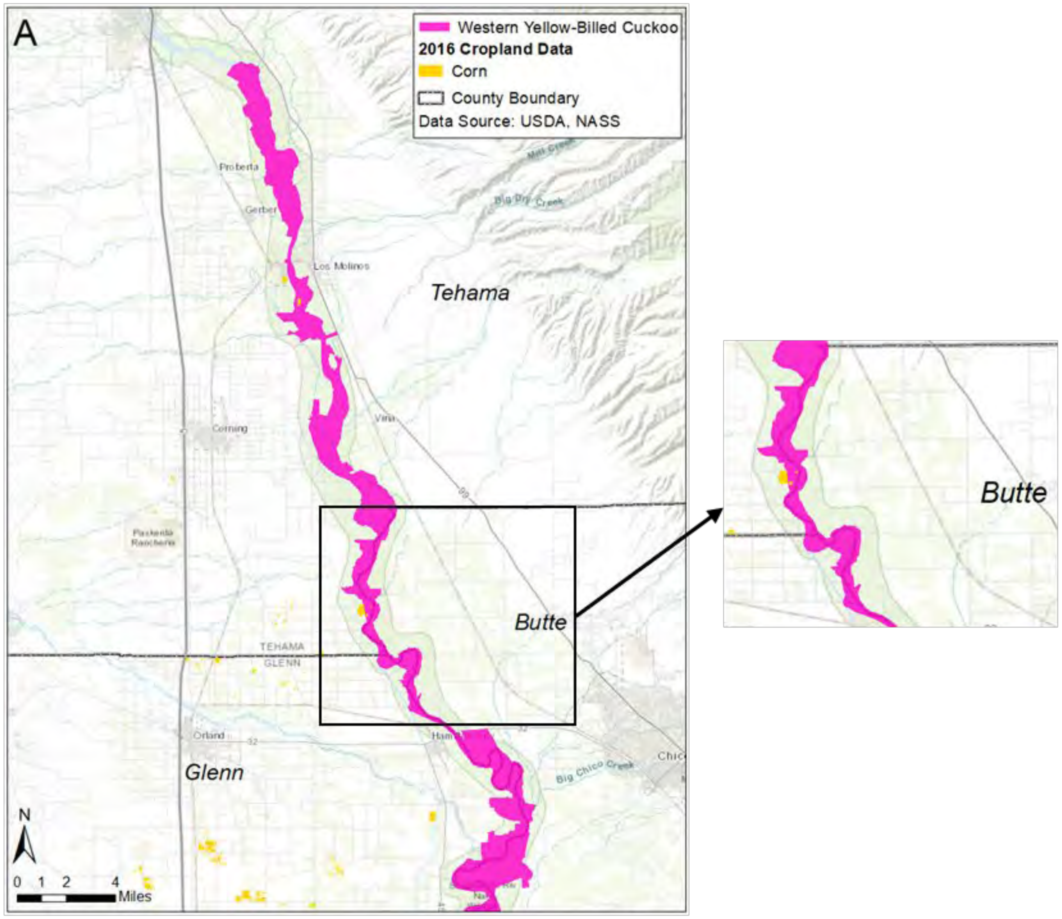
July 2011

2016 USDA Corn/Soy Cropland

Figure 8. Area near Butte, CA where 2018 CDL show corn within the boundaries of the critical habitat for Western yellow-billed cuckoo and Google Earth images from 1998 2014 document no conversion after 2008.

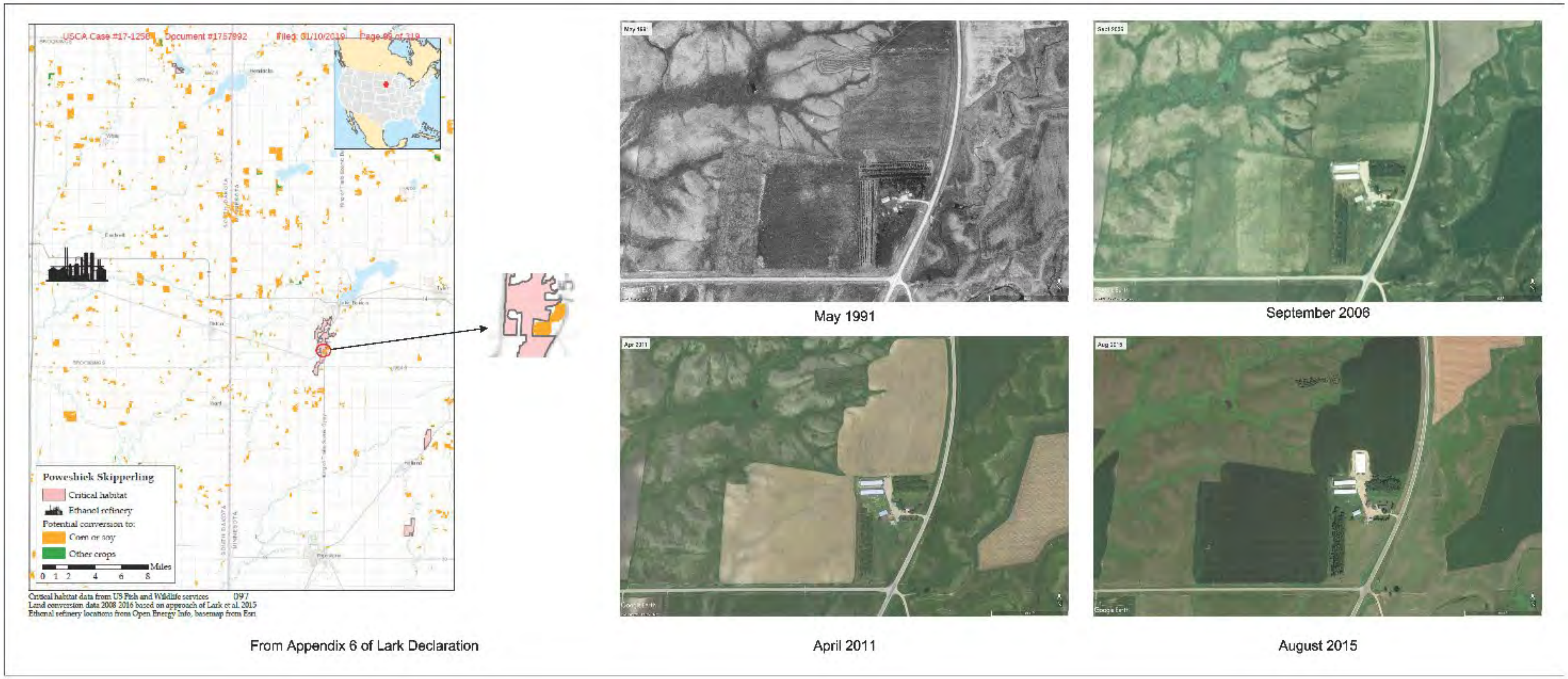
August 1998

July 2013



2016 USDA Corn/Soy Cropland

Figure 9. Aerial images from Google Earth demonstrating that the area highlighted in the Lark Declaration Appendix 6 was clearly in agriculture as early as 1991, and there was no evident expansion of the area into what is now designated as critical habitat for Poweshiek skipperling after 2008



Critical habitat data from US Fish and Wildlife services D97
Land conversion data 2008 2016 based on approach of Lark et al. 2015
Ethanol refinery locations from Open Energy Info, basemap from Esri

From Appendix 6 of Lark Declaration

May 1991

September 2006

April 2011

August 2015

Figure 10. Adult Salt Creek tiger beetles counted during visual surveys 1991-2012 (excerpted from Federal Register 2013)

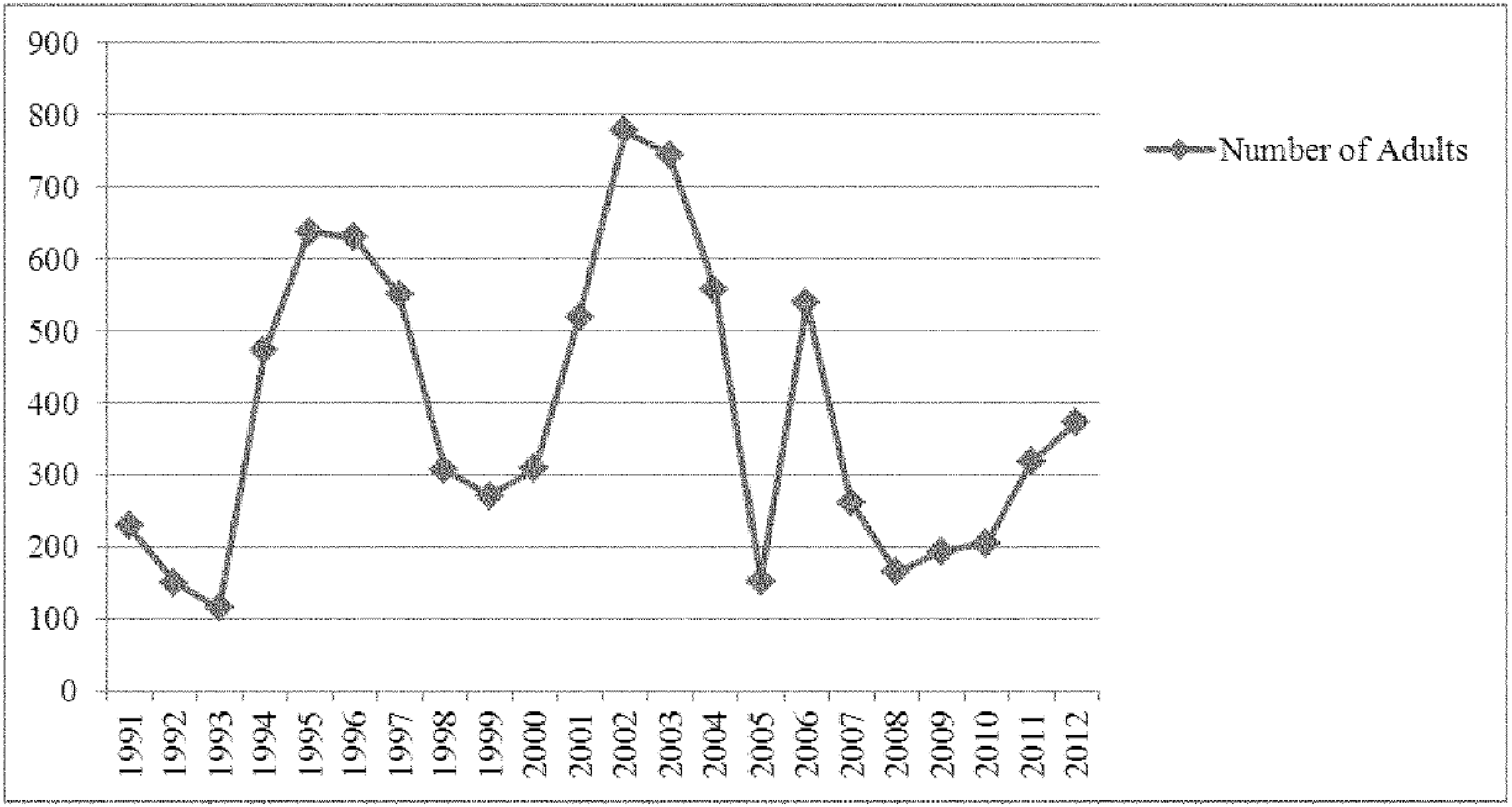
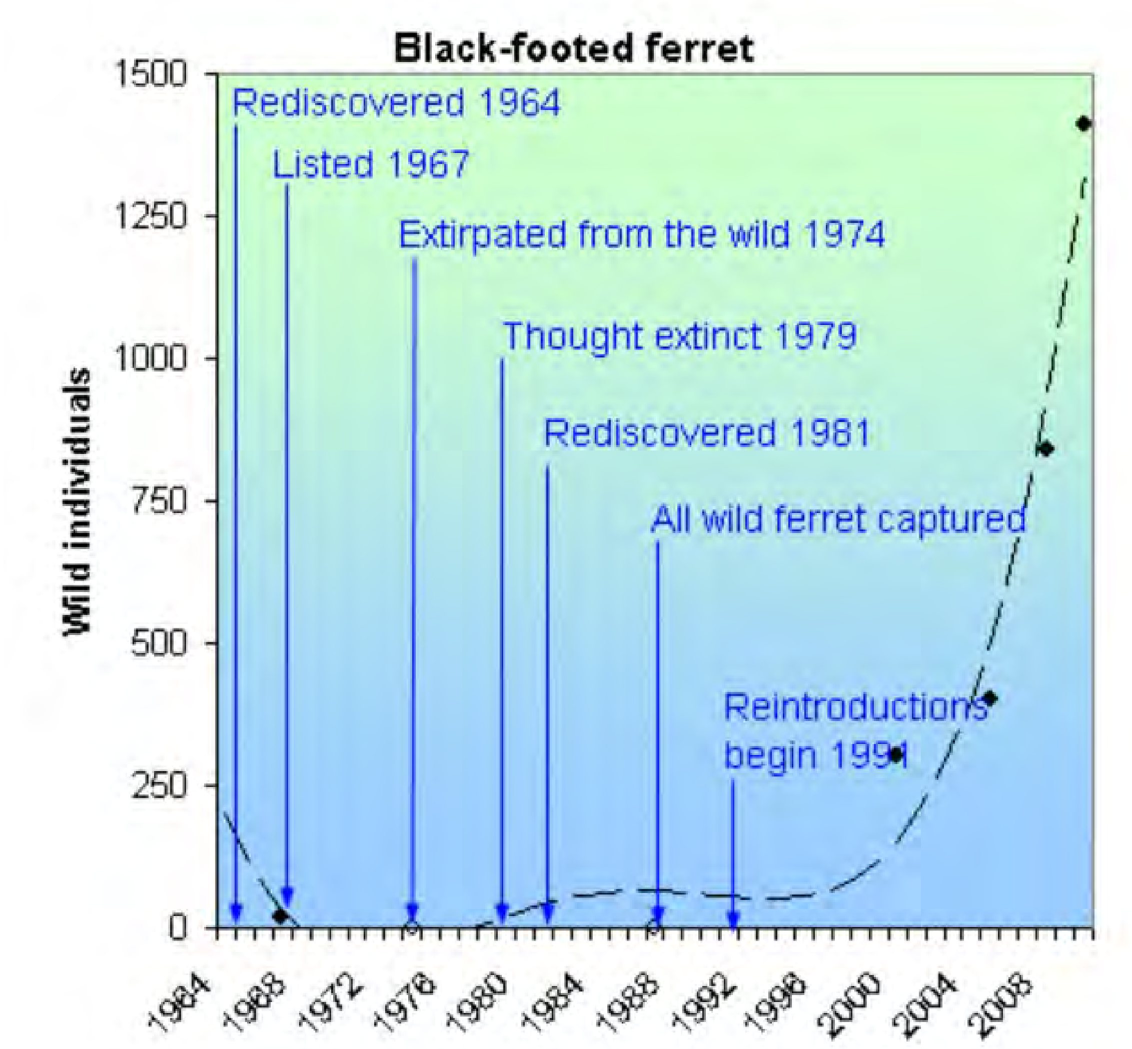
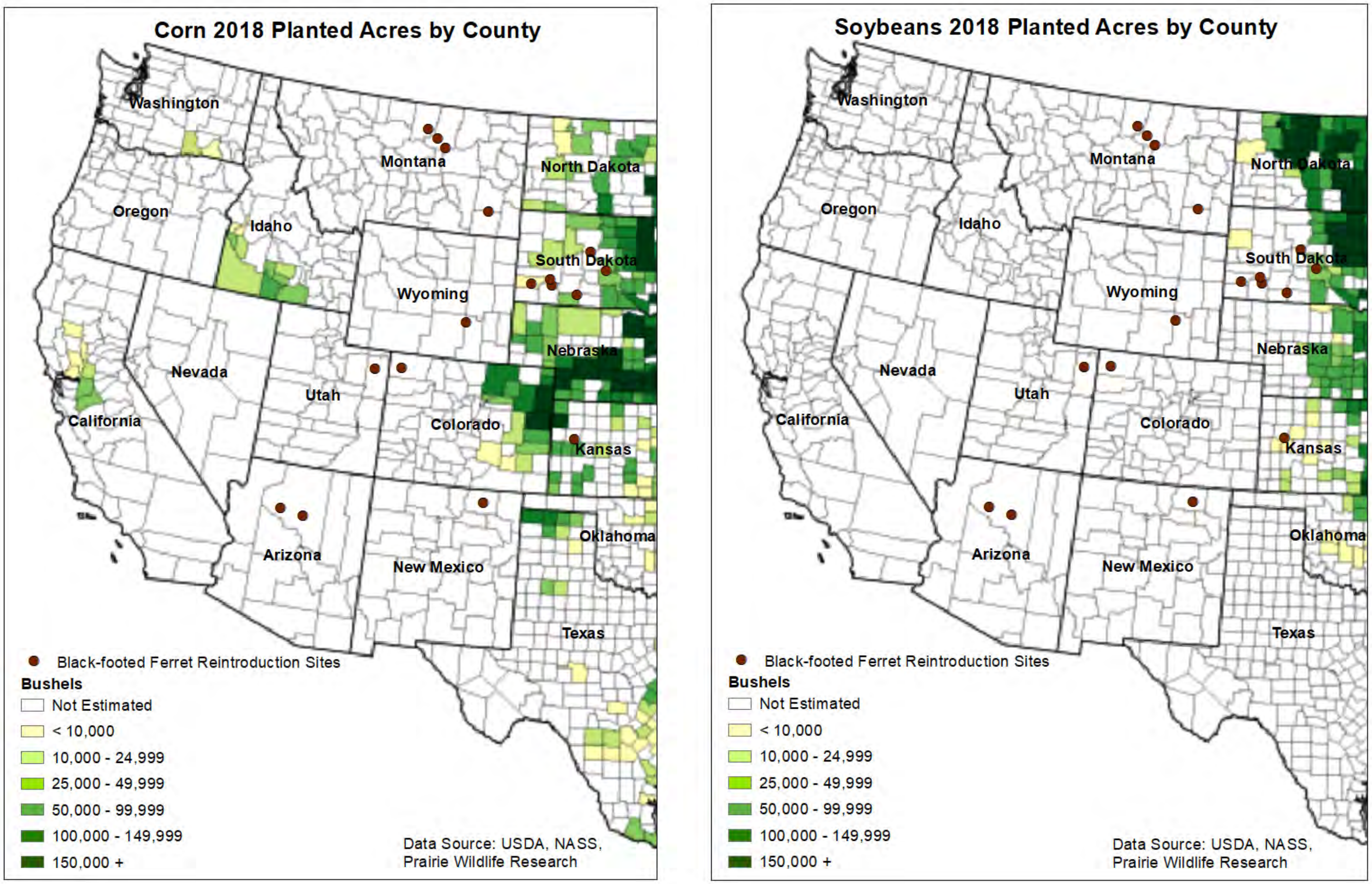


Figure 11. Wild black footed ferret population status 1964 to 2012



SOURCE: https://www.biologicaldiversity.org/species/mammals/black-footed_ferret/

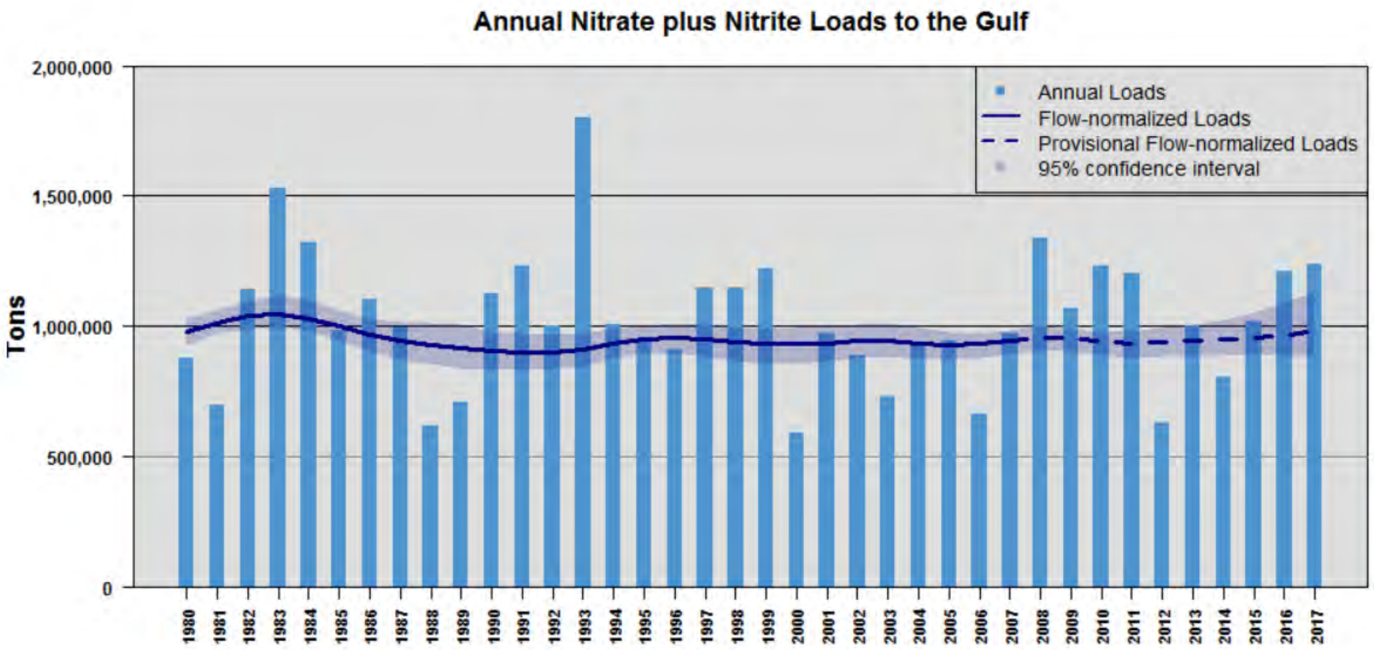
Figure 12. Location of black-footed ferret populations and counties with corn and soy planted 2018



Data Source: USDA, NASS, Prairie Wildlife Research

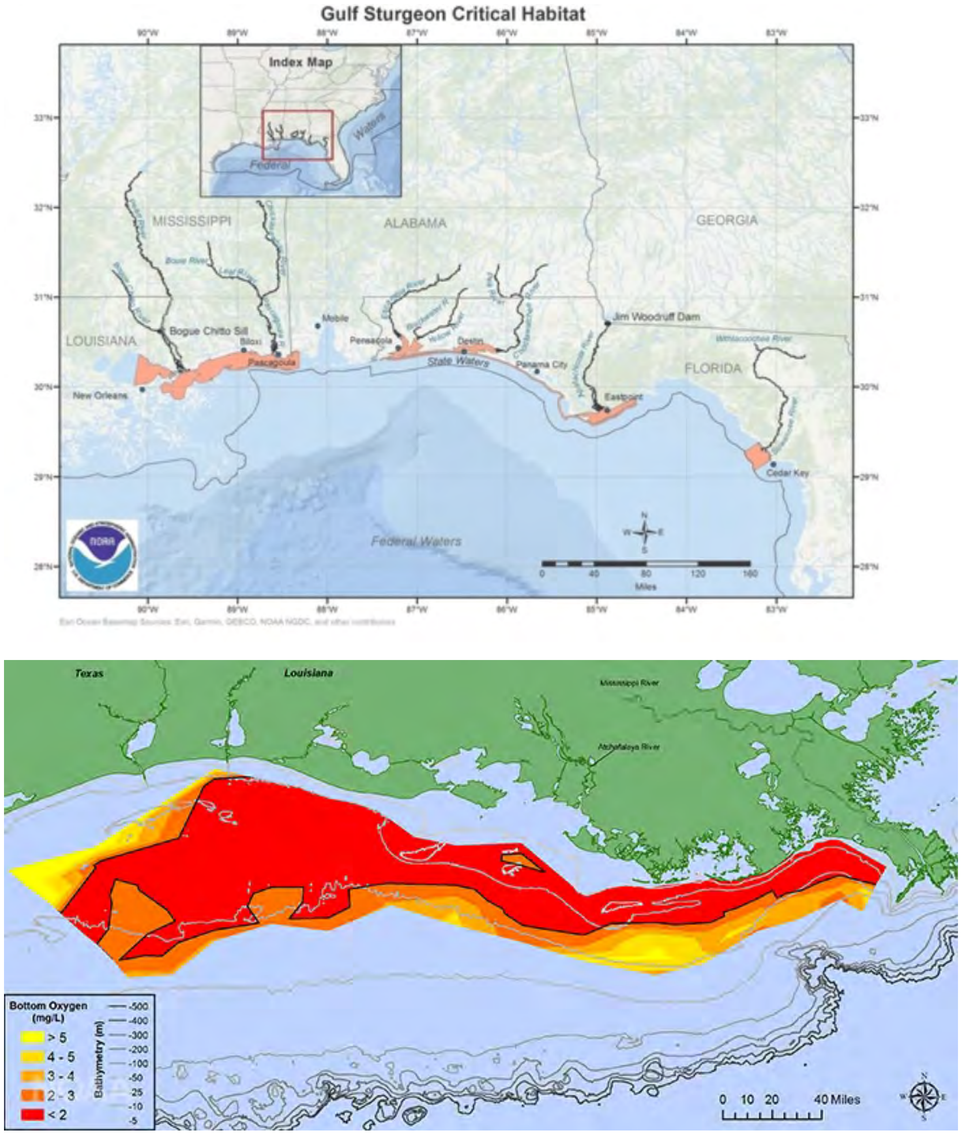
Data Source: USDA, NASS, Prairie Wildlife Research

Figure 13. Annual nitrate plus nitrite loading to the Gulf of Mexico 1980 to 2017



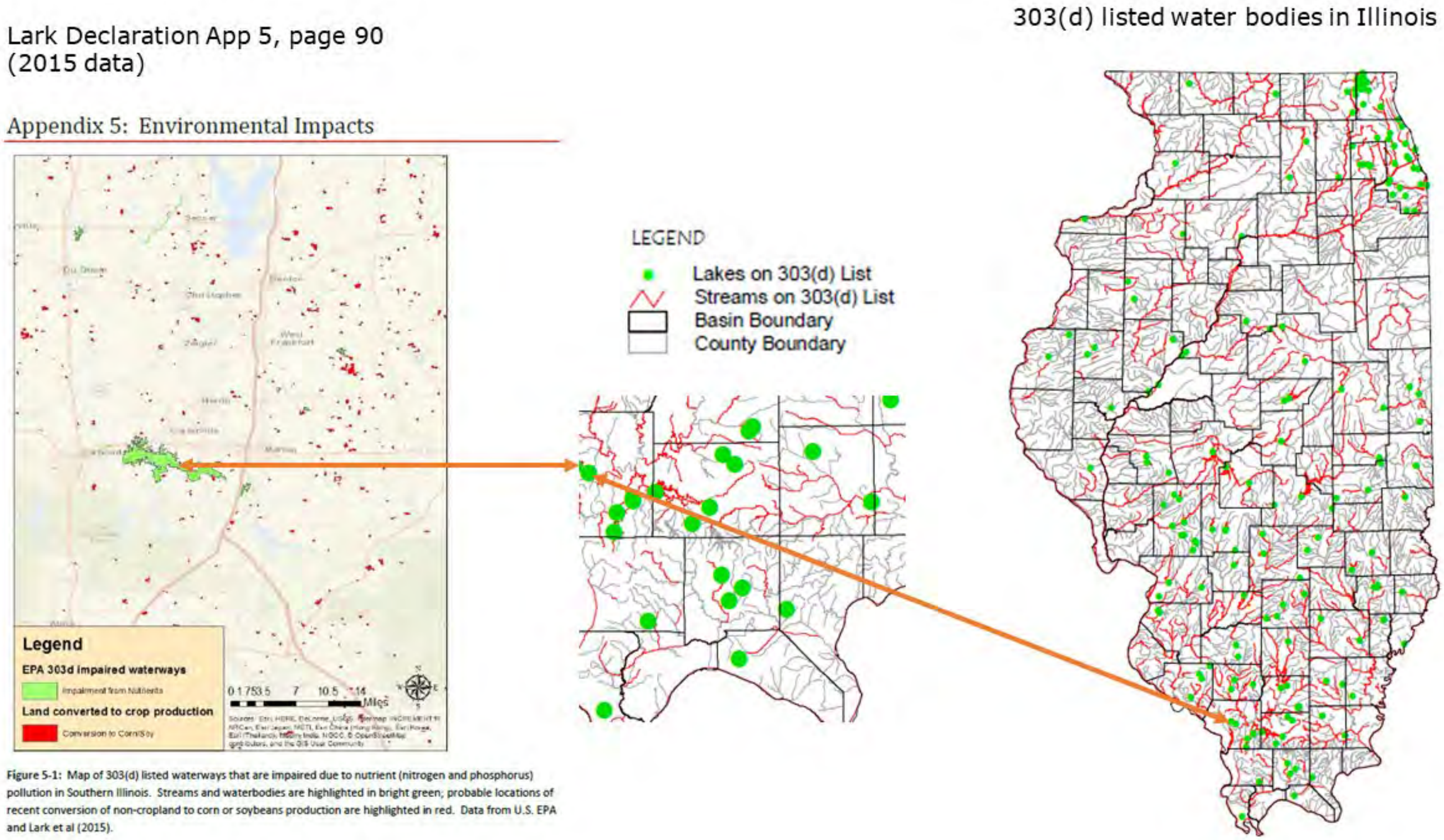
Source: USGS n.d.

Figure 14. Gulf sturgeon critical habitat and the Gulf of Mexico dead zone in 2019; the largest dead zone recorded



SOURCE: https://www.noaa.gov/media-release/gulf-of-mexico-dead-zone-is-largest-ever-measured by (Courtesy of N. Rabalais, LSU/LUMCON)

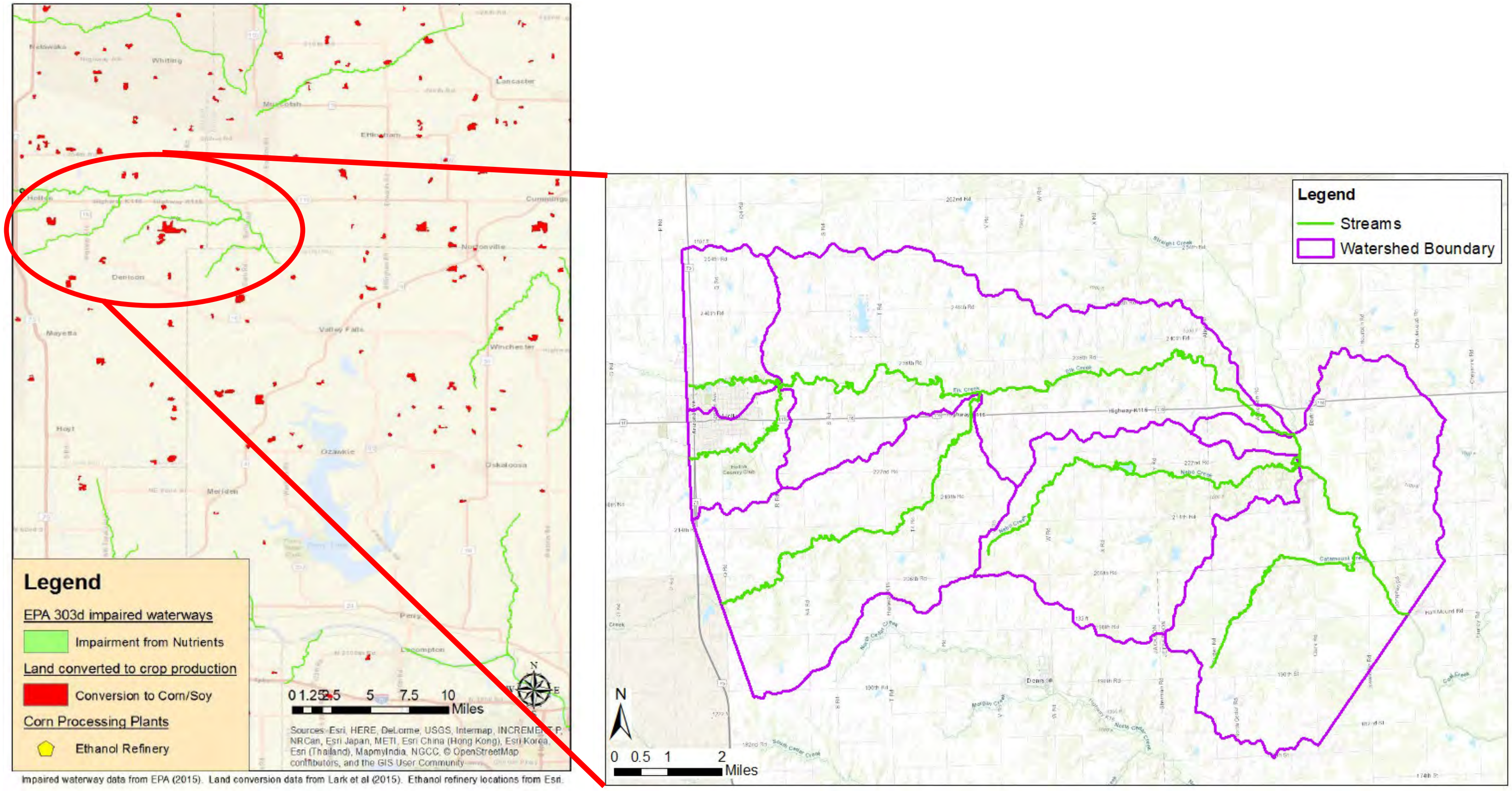
Figure 15. 303(d) maps for 2002 (as produced by the State of Illinois) and the 2015 map presented in the Lark Declaration showing that a major water body near Carbondale has been impaired for more than 17 years—well before the RFS went into effect in 2008.



Appendix 5: Environmental Impacts

Figure 5-1: Map of 303(d) listed waterways that are impaired due to nutrient (nitrogen and phosphorus) pollution in Southern Illinois. Streams and waterbodies are highlighted in bright green; probable locations of recent conversion of non-cropland to corn or soybeans production are highlighted in red. Data from U.S. EPA and Lark et al (2015).

Figure 16. Watershed area selected for spatial analysis of presumed land conversion relative to 303(d) designated streams as identified in Figure 5-6 of the Lark Declaration



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri Japan, METI, Esri China (Hong Kong), Esri Korea, Esri (Thailand), MapmyIndia, NGCC, © OpenStreetMap contributors, and the GIS User Community

Impaired waterway data from EPA (2015). Land conversion data from Lark et al (2015). Ethanol refinery locations from Esri.

Figure 17. Google Earth Images for the period 1991 through 2018 for fields adjacent to a 303(d) impaired water body identified in Figure 5-6 from the Lark Declaration as having been converted from grassland to corn or soy after 2008

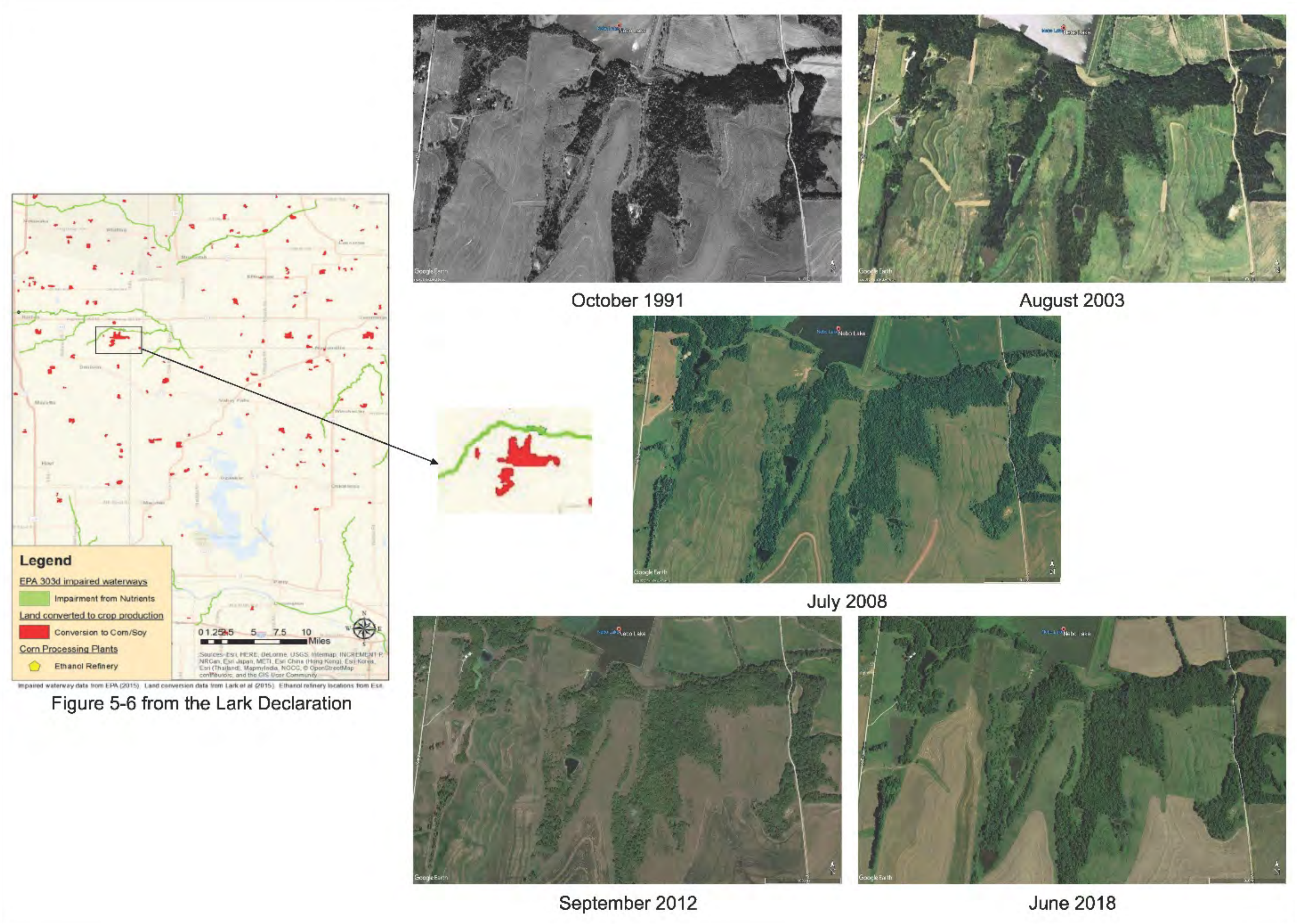


Figure 5-6 from the Lark Declaration

October 1991

August 2003

July 2008

September 2012

June 2018

Exhibit List

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Volume 2

Exhibit Number	Title of Exhibit
1	Environmental Health & Engineering, Inc., *Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards* (Feb. 3, 2022)
2	Life Cycle Associates, LLC, *Review of GHG Emissions of Corn Ethanol under the EPA RFS2* (Feb. 4, 2022)
3	Net Gain, *Analysis of EPA's Proposed Rulemaking for 2020, 2021, and 2022 RVOs, Regarding Land Use Change, Wetlands, Ecosystems, Wildlife Habitat, Water Resource Availability, and Water Quality* (Feb. 3, 2022)
4	*Comments of Drs. Fatemeh Kazemiparkouhi, David MacIntosh, Helen Suh*, EPA-HQ-OAR-2021-0324 (Feb. 3, 2022)
5	Stillwater Associates, LLC, *Comments to EPA on 2020-2022 RFS Rule, Prepared for Growth Energy* (Feb. 4, 2022)
6	Stillwater Associates LLC, *Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017* (July 11, 2016)
7	Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012)
8	Growth Energy, *Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations*, Docket # EPA–HQ–OAR–2020–0448 (Apr. 19, 2021)
9	Petroleum Equipment Institute, *UST Component Compatibility Library*
10	Association of State and Territorial Solid Waste Management Officials, *Compatibility Tool*
11	Air Improvement Resource, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2022* (Nov. 16, 2021)
12	Renewable Fuels Association, *Contribution of the Ethanol Industry to the Economy of the United States in 2020* (Feb. 2, 2021)
13	ABF Economics, *Economic Impact of Nationwide E15 Use* (June 2021)
14	Jarrett Renshaw & Chris Prentice, *Exclusive: Chevron, Exxon seek 'small refinery' waivers from U.S. biofuels law*, Reuters (Apr. 12, 2018)
15	Stillwater Associates LLC, *Potential Increased Ethanol Sales through E85 for the 2019 RFS* (Aug. 17, 2018)

Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 4

Tufts University | School of Engineering
Department of Civil and Environmental Engineering

February 3, 2022

Docket Number: EPA-HQ-OAR-2021-0324

Comments of Drs. Fatemeh Kazemiparkouhi,[1] David MacIntosh,[2] Helen Suh[3]
[1] Environmental Health & Engineering, Inc., Newton, MA
[2] Environmental Health & Engineering, Inc., Newton, MA and the Harvard T.H. Chan School of Public Health, Boston, MA
[3] Tufts University, Medford, MA

We are writing to comment on issues raised by the proposed RFS annual rule, the Draft Regulatory Impact Analysis (December 2021; EPA-420-D-21-002), and the supporting Health Effects Docket Memo (September 21, 2021; EPA-HQ-OAR-2021-0324-0124), specifically regarding the impact of ethanol-blended fuels on air quality and public health. We provide evidence of the air quality and public health benefits provided by higher ethanol blends, as shown in our recently published study[1] by Kazemiparkouhi et al. (2021), which characterized emissions from light duty vehicles for market-based fuels. Findings from our study demonstrate ethanol-associated reductions in emissions of primary particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO), and to a lesser extent total hydrocarbons (THC). Our results provide further evidence of the potential for ethanol-blended fuels to improve air quality and public health, particularly for environmental justice communities. Below we present RFS-pertinent findings from Kazemiparkouhi et al. (2021), followed by their implications for air quality, health, and environmental justice.

Summary of Kazemiparkouhi et al. (2021)

Our paper is the first large-scale analysis of data from light-duty vehicle emissions studies to examine real-world impacts of ethanol-blended fuels on regulated air pollutant emissions, including PM, NOx, CO, and THC. To do so, we extracted data from a comprehensive set of emissions and market fuel studies conducted in the US. Using these data, we (1) estimated composition of market fuels for different ethanol volumes and (2) developed regression models to estimate the impact of changes in ethanol volumes in market fuels on air pollutant emissions for different engine types and operating conditions. Importantly, our models estimated these changes accounting for not only ethanol volume fraction, but also aromatics volume fraction, 90% volume distillation temperature (T90) and Reid Vapor Pressure (RVP). Further, they did so

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[1] https://doi.org/10.1016/j.scitotenv.2021.151426

under both cold start and hot stabilized running conditions and for gasoline-direct injection engines (GDI) and port-fuel injection (PFI) engine types. Key highlights from our paper include:

- ***Aromatic levels in market fuels decreased by approximately 7% by volume for each 10% by volume increase in ethanol content*** (Table 1)**.** Our findings of lower aromatic content with increasing ethanol content is consistent with market fuel studies by EPA and others (Eastern Research Group, 2017, Eastern Research Group, 2020, US EPA, 2017). As discussed in EPA's Fuel Trends Report, for example, ethanol volume in market fuels increased by approximately 9.4% between 2006 and 2016, while aromatics over the same time period were found to drop by 5.7% (US EPA, 2017).

  We note that our estimated market fuel properties differ from those used in the recent US EPA Anti-Backsliding Study (ABS), which examined the impacts of changes in vehicle and engine emissions from ethanol-blended fuels on air quality (US EPA, 2020). Contrary to our study, ABS was based on hypothetical fuels that were intended to satisfy experimental considerations rather than mimic real-world fuels. It did not consider published fuel trends; rather, the ABS used inaccurate fuel property adjustment factors in its modeling, reducing aromatics by only 2% (Table 5.3 of ABS 2020), substantially lower than the reductions found in our paper and in fuel survey data (Kazemiparkouhi et al., 2021, US EPA, 2017). As a result, the ABS's findings and their extension to public health impacts are not generalizable to real world conditions.

Table 1. Estimated market fuel properties

Fuel ID	EtOH Vol (%)	T50 (^{o}F)	T90 (^{o}F)	Aromatics Vol (%)	AKI	RVP (psi)
E0	0	219	325	30	87	8.6
E10	10	192	320	22	87	8.6
E15	15	162	316	19	87	8.6
E20	20	165	314	15	87	8.6
E30	30	167	310	8	87	8.6

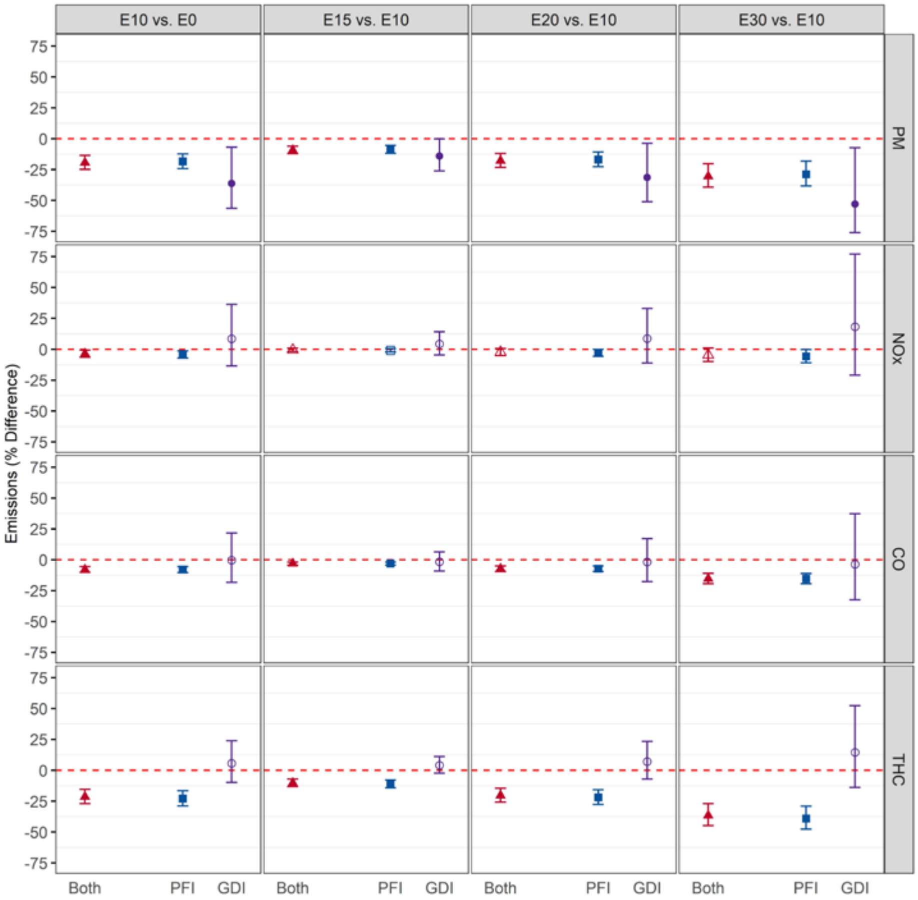
Abbreviations: EtOH = ethanol volume; T50 = 50% volume distillation temperature; T90 = 90% volume distillation temperature; Aromatics=aromatic volume; AKI = Anti-knock Index; RVP = Reid Vapor Pressure.

- ***PM emissions decreased with increasing ethanol content under cold-start conditions.*** Primary PM emissions decreased by 15-19% on average for each 10% increase in ethanol content under cold-start conditions (Figure 1). While statistically significant for both engine types, PM emission reductions were larger for GDI as compared to PFI engines, with 53% and 29% lower PM emissions, respectively, when these engines burned E30 as compared to E10. In contrast, ethanol content in market fuels had no association with PM emissions during hot-running conditions.

  Importantly, our findings are consistent with recent studies that examined the effect of ethanol blending on light duty vehicle PM emissions. Karavalakis et al. (2014), (2015), Yang et al. (2019a), (2019b), Schuchmann and Crawford (2019), for example, assessed the influence of different mid-level ethanol blends – with proper adjustment for aromatics – on the PM emissions from GDI engines and Jimenez and Buckingham (2014) from PFI engines. As in our study, which also adjusted for aromatics, each of these recent studies found higher ethanol blends to emit lower PM as compared to lower or zero ethanol fuels.

Together with these previous studies, our findings support the ability of ethanol-blended fuels to offer important PM emission reduction opportunities. **Cold start PM emissions have consistently been shown to account for a substantial portion of all direct tailpipe PM emissions from motor vehicles**, with data from the EPAct study estimating this portion to equal 42% (Darlington et al., 2016, US EPA, 2013). The cold start contribution to total PM vehicle emissions, together with our findings of emission reductions during cold starts, suggest that a **10% increase in ethanol fuel content from E10 to E20 would reduce total tailpipe PM emissions from motor vehicles by 6-8%.**

Figure 1. Change (%) in cold-start emissions for comparisons of different ethanol-content market fuels[a]



[a] Emissions were predicted from regression models that included ethanol and aromatics volume fraction, T90, and RVP as independent variables

- **NOx, CO and THC emissions were significantly lower for higher ethanol fuels for PFI engines under cold-start conditions**, but showed no association for GDI engines (Figure 1). CO and THC emissions also decreased under hot running conditions for PFI and for CO also for GDI engines (results not shown). [Note that NOx emissions for both PFI and GDI engines were statistically similar for comparisons of all ethanol fuels, as were THC emissions for GDI engines.] These findings add to the scientific evidence demonstrating emission reduction benefits of ethanol fuels for PM and other key motor vehicle-related gaseous pollutants.

Implications for Public Health and Environmental Justice Communities

The estimated reductions in air pollutant emissions, particularly of PM and NOx, indicate that increasing ethanol content offers opportunities to improve air quality and public health. As has been shown in numerous studies, lower PM emissions result in lower ambient PM concentrations and exposures (Kheirbek et al., 2016, Pan et al., 2019), which, in turn, are causally associated with lower risks of total mortality and cardiovascular effects (Laden et al., 2006, Pun et al., 2017, US EPA, 2019, Wang et al., 2020).

The above benefits to air quality and public health associated with higher ethanol fuels may be particularly great for environmental justice (EJ) communities. EJ communities are predominantly located in urban neighborhoods with high traffic density and congestion and are thus exposed to disproportionately higher concentrations of PM emitted from motor vehicle tailpipes (Bell and Ebisu, 2012, Clark et al., 2014, Tian et al., 2013). Further, vehicle trips within urban EJ communities tend to be short in duration and distance, with approximately 50% of all trips in dense urban communities under three miles long (de Nazelle et al., 2010, Reiter and Kockelman, 2016, US DOT, 2010). As a result, a large proportion of urban vehicle trips occur under cold start conditions (de Nazelle et al., 2010), when PM emissions are highest. Given the evidence that ethanol-blended fuels substantially reduce PM, NOx, CO, and THC emissions during cold-start conditions, it follows that ethanol-blended fuels may represent an effective method to reduce PM health risks for EJ communities.

Summary

Findings from Kazemiparkouhi et al. (2021) provide important, new evidence of ethanol-related reductions in vehicular emissions of PM, NOx, CO, and THC based on real-world fuels and cold-start conditions. Given the substantial magnitude of these reductions and their potential to improve air quality and through this public health, our findings warrant careful consideration. Policies that encourage higher concentrations of ethanol in gasoline would provide this additional benefit. These policies are especially needed to protect the health of EJ communities, who experience higher exposures to motor vehicle pollution, likely including emissions from cold starts in particular, and are at greatest risk from their effects.

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Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 5

Comments to EPA on 2020-2022 RFS Rule

Prepared for

Growth Energy

By

Stillwater Associates LLC

Irvine, California, USA

February 4, 2022

™ Stillwater Associates

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Disclaimer

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1 2022 Potential Ethanol Production

EIA lists the U.S. ethanol nameplate production capacity for 2020 at 17.38 billion gallons per year[1]. How much of this ethanol production capacity can be used is primarily a function of the available feedstock, corn, and the conversion capacity of ethanol plants. We consider three different approaches to determine the real world maximum potential ethanol production in 2022: historical maximum, previous year, and potential expansion.

The highest year of ethanol production was 2018, when 16.061 billion gallons of ethanol were produced domestically.[2] In 2021, it is estimated that 14.87 billion gallons of ethanol were produced.[3] We believe that both of these figures represent conservative estimates of how much ethanol could reasonably be produced in 2022. The 2021 volume was suppressed substantially by low demand for transportation fuel in response to the Covid-19 pandemic. And neither figure accounts for the continuing growth in the productivity of U.S. corn growers or the steady improvements in the efficiency of U.S. corn ethanol plants. As explained below in greater detail, these developments have allowed U.S. ethanol production to continuously increase their production capability without requiring increasing corn acreage or adversely impacting the supply of corn available for other domestic non-ethanol demands or export markets. In fact, we conclude that, accounting for these developments, 15.565 billion gallons could be produced domestically in 2022.

While the 15.565 billion gallons of ethanol for 2022 in Table 4 seems like an upper limit on ethanol production in 2022, it is in fact limited by the decision to keep the planted acres constant the decision to keep the portion of corn used for ethanol constant, and the representation of new technology implementation as a straight line. The reality is that market forces are always in play. A positive future market outlook may cause more acres to be planted in corn that year. It may cause plant maintenance to be delayed until next year. A very promising technology may be implemented earlier and to a larger extent than typical technology is implemented. Table 4 and the other tables in that section represent average conditions which can be increased or decreased by each farmer or ethanol production facility's market outlook. Indeed, as noted, the actual ethanol production in 2018 exceeded our projection for 2022 by a substantial margin, at a time when yield rates and conversion efficiency were lower than they are now.

1.1 Corn Supply

Review of U.S. corn production data through the Fall 2021 harvest shows that yields per harvested acre have continued their long-term growth trend. Figures 1 and 2 below illustrates annual per-harvested-acre yields and annual planted corn acres as reported by USDA[4]; Figure 1 presents the long-term trend since 1936 and Figure 2 focuses on 2006 through 2021. The dashed red line in Figure 2 indicates the average annual corn plantings from 2008 through 2021 was 90.8 million acres; this is below the 93.5 million corn acres planted in 2007, the last crop planted prior to enactment of EISA 2007.

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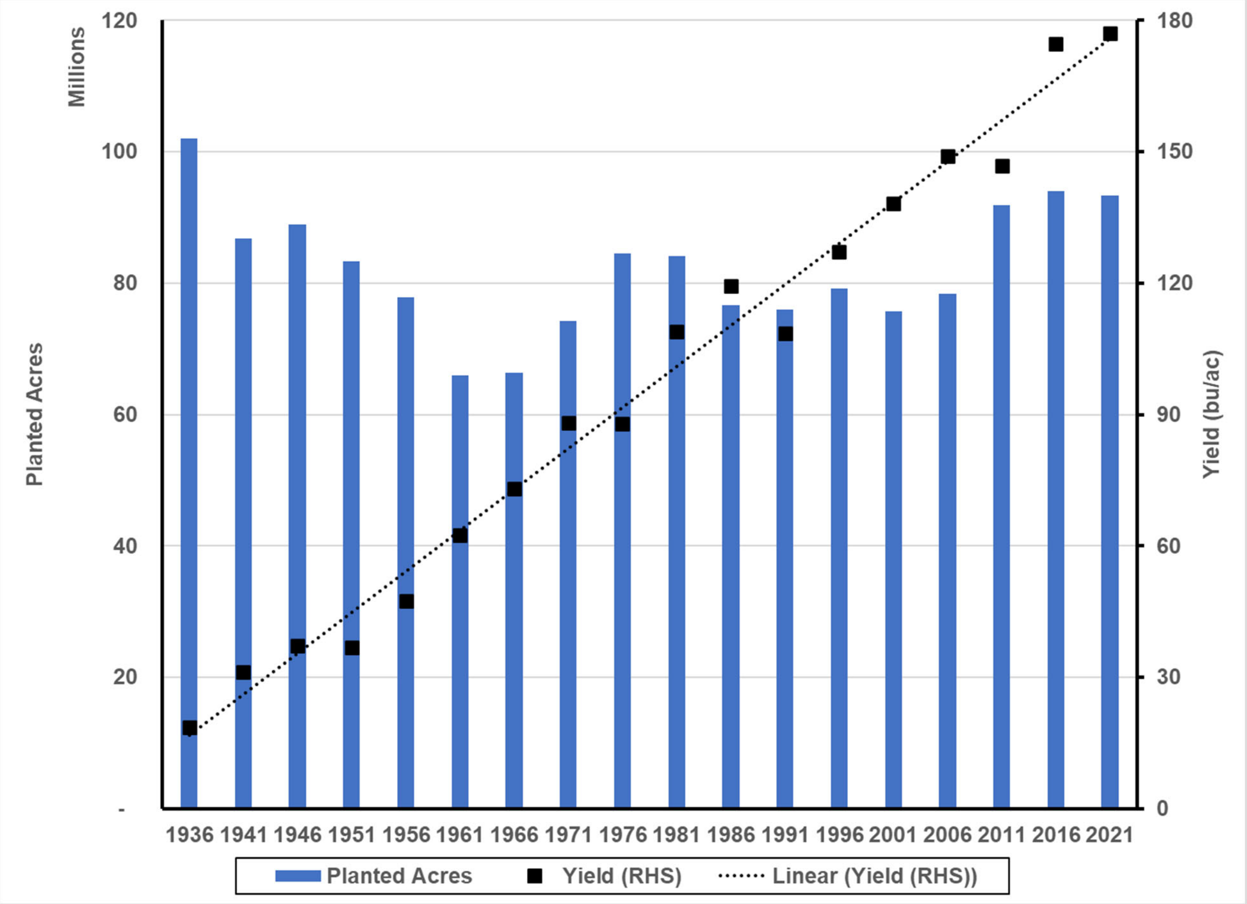
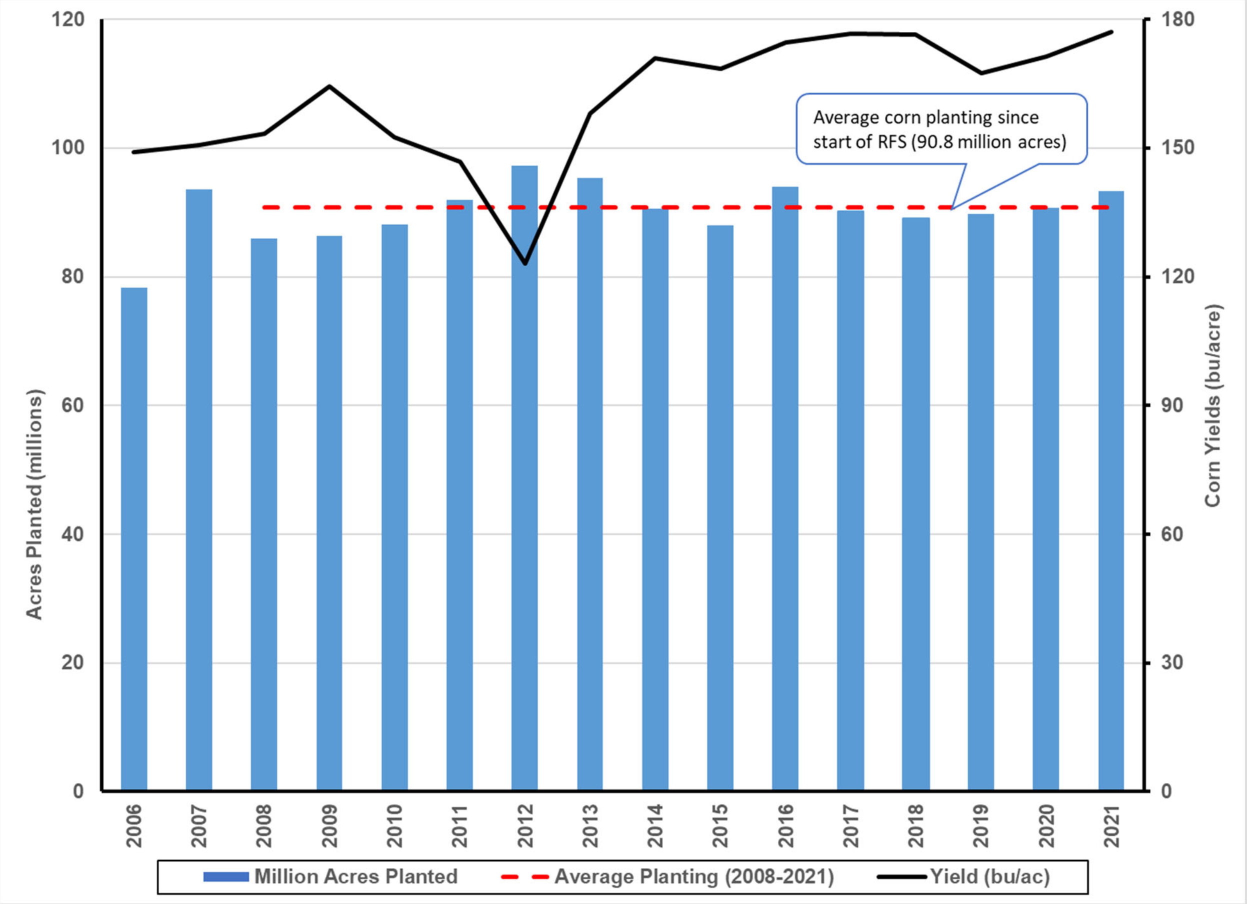
[1] https://afdc.energy.gov/data/10342, U.S. Ethanol Plants Capacity and Production
[2] https://afdc.energy.gov/data/10342, U.S. Ethanol Plants Capacity and Production
[3] http://ethanolproducer.com/articles/18648/eia-reduces-2021-2022-ethanol-production-forecasts
[4] USDA QuickStats, https://quickstats.nass.usda.gov/.

Figure 1. U.S. Corn Acres and Yield (1936-2021)



Source: *USDA, Stillwater analysis*

Figure 2. U.S. Corn Acres Planted and Yield (2006-2021)



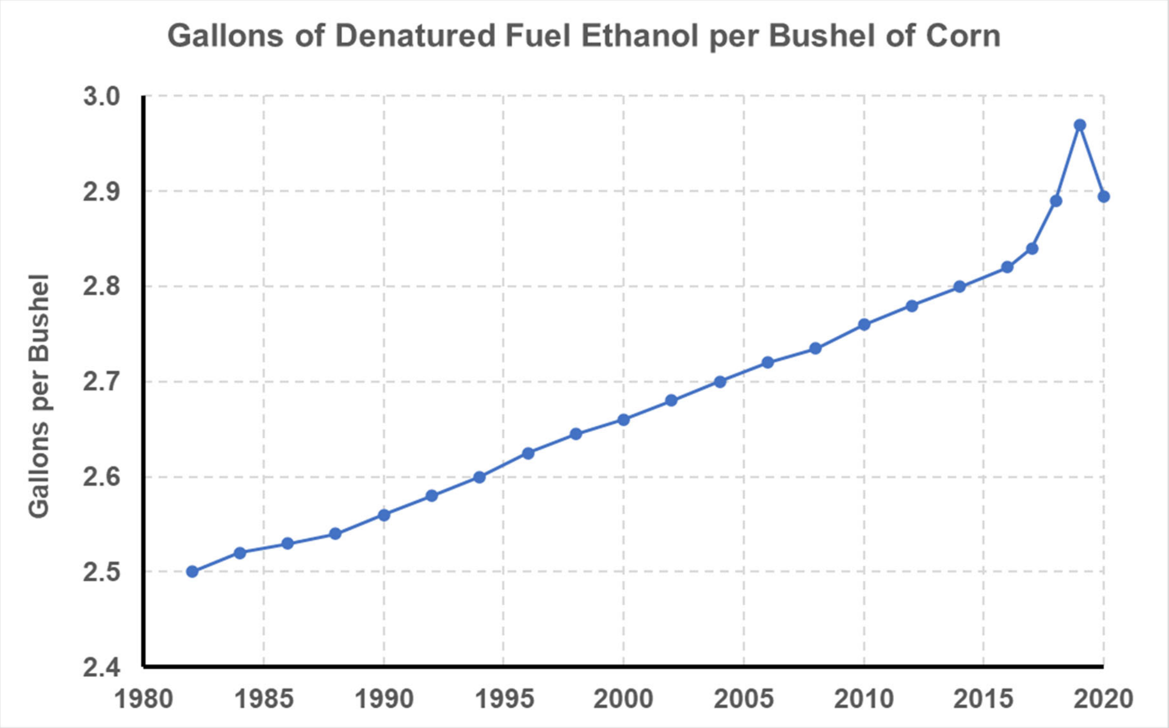
Source: *USDA, Stillwater analysis*

Since 2008, U.S. corn yields have grown from 153.3 bushel per harvested acre ("bu/ac") to 177.0 bu/ac in 2021, an increase of 1.8 bu/ac each year. This is nearly the same pace as the 1.9 bu/ac each year in the 85 years since 1936. Normally to be consistent with this durable trend, we would estimate that in 2022, the corn yield will be 178.8 bu/ac. However, this value is based on 177.0, which is itself a projection. To be conservative we have decided to keep the 2022 projection of corn yield at 177.0.

1.2 Ethanol Production

In addition to this steadily increasing trend in corn yields, the yield of ethanol from corn processed at U.S. ethanol plants has also steadily increased (according to data from USDA). These data, illustrated in Figure 3 below, indicate that yields have increased at a rate of over 0.010 gallons of denatured fuel ethanol (DFE) per bushel of corn each year from 1982 through 2020 and this rate has accelerated to over 0.012 gallons of DFE per bushel of corn each year from 2006 through 2020. These increases can be attributed to innovation enabled by growing industry operating experience and steady improvements in both the engineering designs of ethanol plants and the efficiency of the yeasts used in the fermentation process. Extrapolating the long-term trend (an average yield increase of 0.0101 gallons per bushel per year since 1982) illustrated in Figure 3 allows us to estimate that the reported industry-average ethanol yield of 2,894 gallons of ethanol per bushel of corn in 2020 would increase to 2.904 gallons of ethanol per bushel in 2021 and 2.914 gallons per bushel in 2022. As a result, the 3,049 million bushels of corn which produced 9,309 million gallons of DFE in 2008 would yield 9,919 million gallons of DFE at current yields, a 7% increase.

Figure 3. Improvement in Yields at U.S. Corn Ethanol Plants



Source: *USDA QuickStats, Stillwater analysis*

1.3 Computation of Achievable Ethanol Supply

Combining each of the elements above, it is possible to estimate how much corn could be used for ethanol production in 2022—and hence how much ethanol could be produced—while continuing to supply the growing domestic market demands for corn required for all other uses (estimated based on the 10.9% growth in U.S. population since 2007) and maintaining corn exports at the same volume as 2007.

As a first step in this analysis, we can estimate the amount of corn which can be produced on the same number of planted acres as used in the 2007 market year.[5] This analysis is presented in Table 1 below. For purposes of this analysis, we assume that U.S. farmers plant 93.5 million acres of corn in the Spring of 2022, which is equal to the acreage planted in 2007. For the 2007 market year, we use USDA data reported in their World Agriculture Supply Demand Estimate (WASDE) report for January 2010. Importantly, the ratio of harvested acres to planted acres was about 92.5% in 2007, higher than 91.3% average for the most recent 10 years. We also assume that U.S. farmers will harvest 91.3% of the planted acreage, which is the average harvest rate over the past decade. Accordingly, we estimate that 85.4 million acres could be harvested in Fall 2022. Applying the yield of 177.0 bu/ac, we estimate an achievable 2022 corn crop of 15,116 million bushels.

Then to assess how much of that corn would be available for domestic use, we add corn imports (USDA estimates 25 million bushels for 2022) and subtract corn exports (using the most recent USDA figure of 2,437 million bushels in 2020/2021.) The net result is that the U.S. could have 12,704 million bushels of corn available for all domestic uses in 2022.

The other major demands for corn are for feed, food, seed, and non-ethanol industrial uses. Accordingly, assessment of how much corn is potentially available for ethanol production needs to also consider domestic demand for these other markets. Many factors influence corn demand in each of these markets.

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[5] The market year for corn runs from September 1st through August 31st. Thus, the 2007/08 market year begins with harvesting the corn planted in the Spring of 2007 (before EISA was enacted in December 2007) and ends prior to the harvest of the corn crop planted in the Spring of 2008.

Table 1. Potential 2022 Corn Harvest using 2007/08 Planted Acres and Current Yields

Market Year	2007/08	Estimated 2022/23 with 2007/08 Acres
Area Planted (million acres)	93.5	93.5
Area Harvested (million acres)	86.5	85.4
Yield (bushels per acre harvested)	150.7	177.0
Production (million bushels)	13,038	15,116
Corn Imports (million bushels)	20	25
Less Corn Exports (million bushels)	(2,437)	(2,437)
Available Corn Supply (million bushels)	10,621	12,704

***Source**: USDA, Stillwater analysis*

For the purposes of this analysis, we will assume that growth in U.S. population, which is projected to be 10.9% from 2008 to 2022, can be used as a proxy for overall demand growth.[6] Annual data on U.S. population as reported by the U.S. Census Bureau for 2007 through 2021 and U.S. population for 2022 as estimated by the United Nations[7] is summarized in Table 2.

Table 2. U.S. Population as Estimated by the United Nations

Year	Population as of December 31st
2007	301,903,167
2008	304,718,000
2009	307,373,750
2010	309,731,983
2011	311,918,250
2012	314,120,641
2013	316,266,088
2014	318,534,859
2015	320,822,902
2016	323,095,500
2017	325,142,676
2018	326,882,088
2019	328,460,928
2020	331,236,261
2021	332,182,892
2022 (forecast) *	334,805,269
*U.N. Forecast	

***Source**: U.S. Census Bureau, Macrotrends.net*

In estimating supply of corn for feed, it is also necessary to consider the feed co-products produced at ethanol plants (both wet mills and dry mills). The ethanol production process only utilizes the starch contained in the corn; all the protein, fiber, and minerals, along with much of the oil[8] are contained in the co-products[9] which are highly valued as feed. Production data for these coproducts is available from USDA

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[6] Other factors would include changing consumer dietary preferences (impacting feed demand for cattle, swine and poultry) and economic growth (impacting consumer demand for a wide range of products).

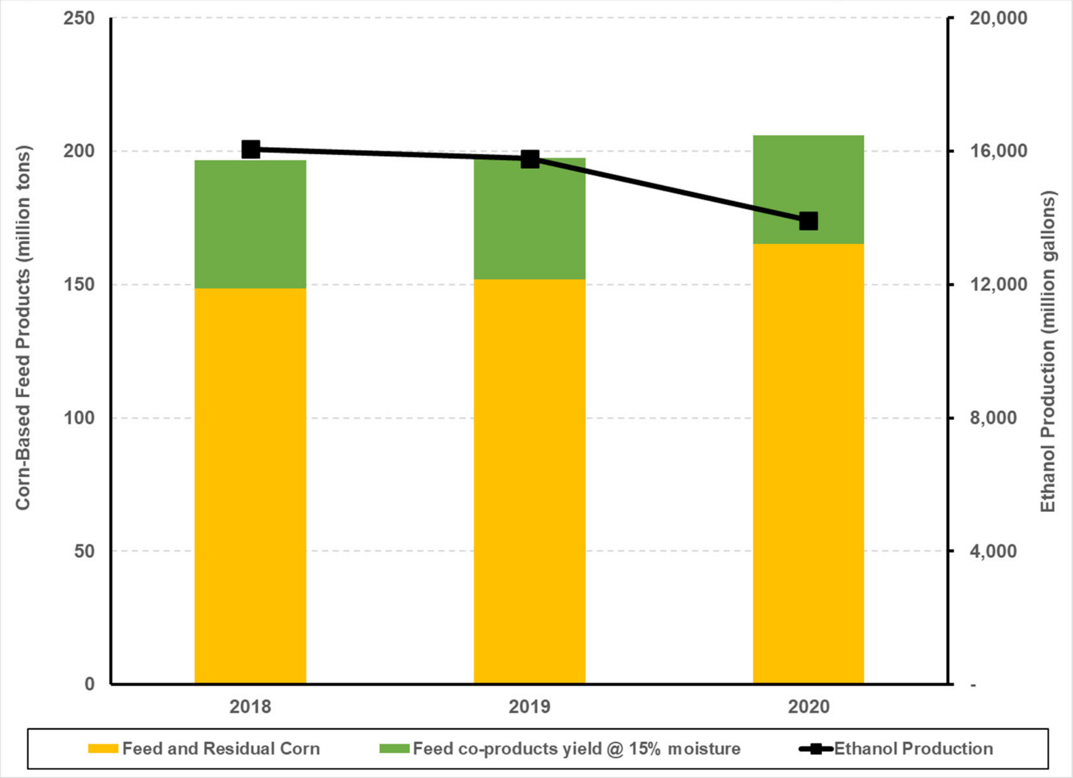
[7] Available at https://www.macrotrends.net/countries/USA/united-states/population

[8] A portion of the corn oil is separated out at most corn ethanol plants for use in applications other than feed. This corn oil product is, thus, excluded from this analysis of feed co-products.

[9] These co-products include distillers' grains and syrup produced at dry mills and corn gluten meal and corn gluten feed produced at wet mills.

in their monthly Grain Crushings and Co-Products Production report and Annual Summary[10] with annual data released in March of the following year. Figure 4 below illustrates, for the most recent three years, the combination of corn used for feed, as reported by USDA in their monthly World Agriculture Supply and Demand Estimate (WASDE) reports and feed co-products as reported in their Grain Crushings and Co-Products Production reports. This is compared to the corresponding annual ethanol production data and it can be seen that the large decrease in ethanol production in 2020 had only a minimal effect on feed availability.

Figure 4. U.S. Ethanol Production and Corn-based Feed Availability



Source: *USDA, Stillwater analysis*

The next step in our analysis is to project current U.S. corn demand for uses other than ethanol production. USDA breaks down domestic corn demand into two categories – “Feed and Residual” (F&R) and “Food, Seed, and Industrial” (FS&I). USDA then breaks out fuel ethanol demand from the broader FS&I total. For our analysis, we will divide domestic non-ethanol corn demand into F&R and “Other FS&I” (i.e., the FS&I minus corn used for ethanol production). Complete analysis of the demand for feed, however, needs to include the feed co-products of ethanol production in addition to the direct use of corn for feed; we label this as Total Corn-based Feed.[11]

For this analysis, we assume that growth in domestic demand for Total Corn-based Feed and Other FS&I since 2007 can be estimated based on the growth in U.S. population since 2007. Estimation of the maximum ethanol production in 2022/23 which leaves sufficient corn to satisfy the U.S.’s growing demand for Total Corn-based Feed and Other FS&I is illustrated in Table 3 below. From the calculations in Table 1, we have projected 12,704 million bushels of corn to be available in the U.S. during 2022/23 to supply all domestic uses. From this, we subtract the 1,476 million bushels of corn required to satisfy demands for Other FS&I (calculated from the reported demand in 2007/08 and the growth in U.S. population). This leaves 11,228 million bushels of corn available to supply F&R plus ethanol production. Per USDA, Total Corn-based Feed

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[10] https://usda.library.cornell.edu/concern/publications/v979v304g?locale=en

[11] E.g., DDGS and corn gluten meal.

demand in the U.S. in 2007/08 was 6,839 million bushels which included 5,913 million bushels of corn and 926 million bushels of Feed Co-Products from ethanol production.[12]

Adjusting for population growth since 2007/08, the U.S. is estimated to demand 7,514 million bushels of Total Corn-based Feed in 2022/23. Allocating those 7,514 million bushels between corn and co-products requires an iterative calculation based on 17 pounds of co-products per bushel of corn used in ethanol production and a projected ethanol yield of 2.914 gallons per bushel in 2022/23 based on extrapolation of the yearly industry yield trend since 1982. Using these yields, production of 15,565 million gallons of ethanol in 2022/23 would be expected to consume 5,341 million bushels of corn and produce 1,621 million bushels of Feed Co-Products. This leaves an estimated 5,892 million bushels of corn available for use as F&R. These 5,892 million bushels of corn for F&R plus the 1,621 million bushels of Feed Co-Products adds up to the 7,514 million bushels of estimated demand for Total Corn-based Feed.

Table 3. Calculation of Maximum Ethanol Production in 2022/23

Marketing Year	2007/08	Projected 2022/23
U.S. Population	300,608,429	334,805,269
Corn Available for Domestic Use (million bushels)	10,621	12,704
Other FS&I (million bushels)	1,338	1,470
Corn Available for Feed and Ethanol (million bushels)	9,283	11,234
Feed and Residual (million bushels)	5,913	--
Estimated Feed Co-Products (million bushels)	926	--
Total Corn-based Feed (million bushels)	6,839	7,514
Estimated Feed Co-Products from 15.565 billion gallons of ethanol production		1,621
Required Corn to supply F&R Demand (million bushels)		5,892
Corn Available for ethanol production		5,341
Ethanol production at 2.914 gallons/bushel (billion gallons)		15.565

***Source**: USDA, Stillwater analysis*

Table 4 below recaps the above allocation of corn volume in 2022/23 which produces 15.565 billion gallons of ethanol while planting the same number of acres planted in corn in 2007, keeping U.S. corn exports even with 2007/08, and supplying estimated growth in domestic demand for all other uses of corn.

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[12] Based on an average yield of 17 pounds per bushel of corn used for ethanol production, corrected to 15% moisture content.

Table 4. Summary of Corn Supply and Demand Calculations

Market Year	2007/08	Projected 2022/23
Corn Supply (million bushels)		
Corn Produced	13,038	15,116
Corn Imports	20	25
Corn Exports	(2,437)	(2,437)
Total Domestic Corn Supply	10,621	12,704
Corn Demand (million bushels)		
Feed and Residual	5,913	5,892
Food, Seed & Industrial	4,387	6,811
Ethanol for fuel	*3,049*	*5,341*
Other Food, Seed & Industrial	*1,338*	*1,470*
Total Domestic Corn Demand	10,300	12,704
Surplus/(Shortage)	321	--
Ethanol Production (billion gallons)	9.3	15.565
Ethanol Yield (gallons/bushel)	2.735	2.914
Feed Co-Products (mmillionbushels)	926	1,621
Feed Co-Product Yield (pounds per bushel) @ 15% moisture	17	17

Source*: USDA, Stillwater analysis*

2 E85 and E15 Consumption Capacity

In EPA's RFS proposal for 2022, they state: "We do not anticipate that growth in the use of higher ethanol blends through 2022 will increase rapidly enough to result in significantly greater volumes of ethanol consumption in the U.S.[13]" This is dubious since in recent years governmental efforts such as USDA's Blender Infrastructure Program and Higher Blends Infrastructure Incentive Program have significantly added to E85 and E15 infrastructure. Much of this infrastructure will be underutilized if future RFS's do not encourage increased usage of E85 and E15.

2.1 E85

E85 consumption capacity is a function of two factors: (a) E85 dispensers and (b) E85-compatible vehicles.

2.1.1 E85 Dispenser Capability

The AFDC reports that there are currently 4,125 stations selling E85.[14] A report by Stillwater in 2018 estimated that these E85 stations would average 1.8 dispensers per station in 2022 that are already in service providing E85 and thus that are compatible with and approved for use with E85.[15] Therefore, in 2022, there will be about 7,425 E85 dispensers.

Each dispenser can dispense a typical volume of 45,000 gallons per month of E85, containing 33,300 gallons of ethanol per month. Therefore, the maximum E85 throughput capacity of the 7,425 existing E85 dispensers is 4.0 billion gallons of E85 containing 3.0 billion gallons of ethanol.[16] [17] EIA projects that 320 million gallons of E85 will be used in 2022 (See Figure 5, year 2022). Given 7,425 existing E85 dispensers, there is, therefore, the existing capability to dispense an additional 3.68 billion gallons of E85 containing 2.72 billion gallons of ethanol. That would in turn contain about 2.36 billion incremental gallons of ethanol, i.e., gallons beyond the ethanol in the E10 that would be replaced by the additional E85.

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[13] https://www.epa.gov/sites/default/files/2021-12/documents/rfs-2020-2021-2022-rvo-standards-nprm-2021-12-07.pdf, page 27

[14] https://afdc.energy.gov/fuels/ethanol_locations.html#/analyze?country=US&fuel=E85

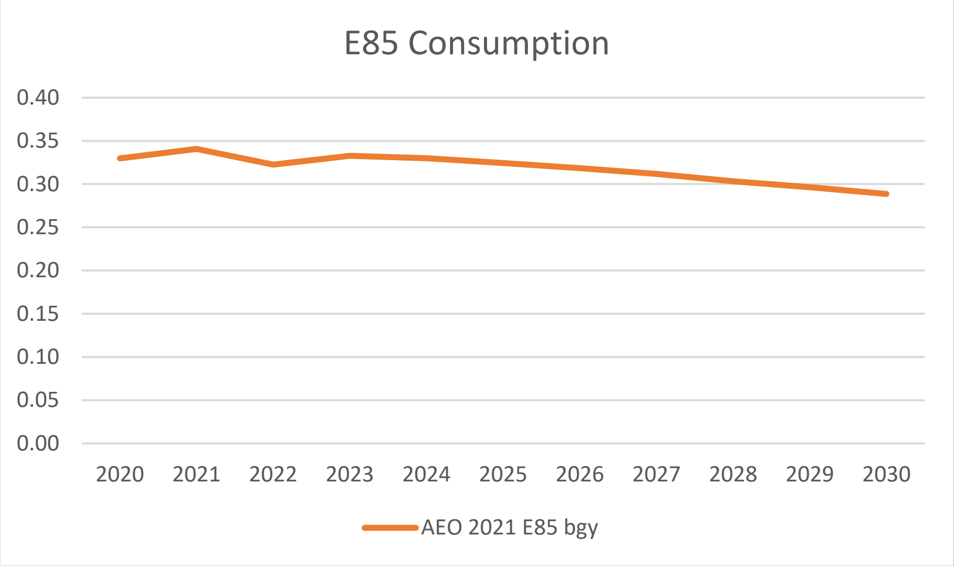
[15] **Potential Increased Ethanol Sales through E85 for the 2019 RFS, August 17, 2018**, Prepared for Growth Energy by Stillwater Associates LLC, Table 2

[16] 7,425 dispensers X 45,000 gallons per month X12 months = 4.0 billion gallons

[17] 4.0 billion gallons of E85 X .74 gallons of ethanol per gallon of E85 = 3.0 billion gallons of ethanol

Citing 2020 data, EPA states that there are only about 3,947 stations at the end of 2020.[18] In an effort to examine a more conservative case, we assume that there are only 3,947 stations and that each station only has a single dispenser. In this case, the maximum E85 throughput capacity of these 3,947 dispensers is 2.31 billion gallons of E85 containing 1.71 billion gallons of ethanol. [19] [20] Again assuming that 320 million gallons of E85 will be used in 2022, there would be the existing capability to dispense an additional 1.99 billion gallons of E85 containing 1.47 billion gallons of ethanol. That would in turn contain about 1.27 billion incremental gallons of ethanol, i.e., gallons beyond the ethanol in the E10 that would be replaced by the E85.[21]

Figure 5. E85 Consumption projected in AEO 2021[22]



EPA's own estimate of the use of E85 in 2022 implies even lower utilization of existing E85 distribution infrastructure. EPA relies on three estimates of E85 usage from 2020: 297, 206, and 202 million gallons[23]. Using the largest value of 297 million gallons implies a utilization rate of 13% if there are 3,947 dispensers. This utilization rate would be 7.4 % if there are 7,425 dispensers.

Each 5-percentage point increase in utilization rate would provide in an additional 116 million gallons of E85, containing 85 million incremental gallons of ethanol, if there 3,947 dispensers and would provide an additional 200 million gallons of E85, containing 148 million incremental gallons of ethanol, if there 7,425 dispensers.

2.2 E85-compatible vehicles

Another constraint on E85 is that E85 can only be used in FFVs so FFV capacity to use E85 needs to be examined. In 2022, there will be about 20.4 million E85-compatible vehicles based on EIA's estimates from AEO 2021. These vehicles could use *588* gallons per year of E85, containing *435* gallons of ethanol (based on the projected number of vehicle miles driven).[24]

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[18] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013KOG.pdf, page 192

[19] 3,947 dispensers X 45,000 gallons per month X12 months = 2.31 billion gallons

[20] 2.31 billion gallons of E85 X .74 gallons of ethanol per gallon of E85 = 1.71 billion gallons of ethanol

[21] 1.99 billion gallons of E85 X .64 gallons of ethanol per gallon of E85 = 1.27 billion gallons of ethanol

[22] https://www.eia.gov/outlooks/aeo/

[23] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013KOG.pdf, page 38, Figure 1.7.1-2

[24] If a typical vehicle goes 12,000 miles per year. 12,000 miles divided by 25.4 miles per gallon (US fleet average in footnote 6 above) results in 472 gallons of E10 or 588 gallons of E85 needed each year., using the factor 1.22 to convert E10 to E85.

2.2.1 FFV

The latest Annual Economic Outlook from the EIA, AEO 2021, projects the number of ethanol-flex fueled vehicles (FFVs) expected to be in use to be about 20.4 million[25]. Again, EIA estimates that about 320 million gallons of E85 will be used in 2022, see Figure 5. When this is divided by the 20.4 million FFVs, it calculates out to be 15.7 gallons of E85 per FFV per year. Given that the average FFV is expected to travel about 12,000 miles per year and could use an estimated 588 gallons per year of E85 per FFV, this shows that there is a very large upside potential for E85 sales which can be reached with the existing E85 infrastructure.[26,27] If the 20.4 million FFVs used only E85, the maximum existing consumption capacity of E85 would be 12.65 billion gallons per year of E85 containing 9.38 billion of ethanol. Each 5% increment of E85 usage by FFVs would use 588 million gallons of E85 containing about 376.32 million incremental gallons of ethanol over E10.

Table 4 below shows that in 2022 15.565 bg of ethanol could be produced with no changes in the total farmland used for growing corn. EPA states that their proposed RFS would use 13.788 bg of ethanol[28]. This would leave 1.777 bg of ethanol which would be unused by the RFS. If that unused ethanol were instead used in E85, a total of 2.401 bg of additional E85 could be produced. Dispensing those additional gallons of E85 would increase total E85 consumption to 2.741 billion gallons, raising dispenser utilization to 68.5%, with the 7,800 dispensers, or 137% (the dispensers would be completely utilized dispensing 1.99 bg of E85), with 3,700 dispensers. With this 2.741 bg of E85 being consumed, the FFV fleet would be 21.7% fueled with E85.

2.3 Combining E85 Infrastructure and FFVs

As noted, EIA, in Figure 5, projects E85 consumption of 320 million gallons in 2022, which calculates to an average of 15.7 gallons of E85 use for each of the 20.4 million FFVs in operation in 2021. Making the reasonable assumption that the FFV vehicles are distributed in proximity to the E85 stations, 320 mg for the FFV fleet or 15.7 gallons per FFV represents only an 8.0% utilization rate of dispensers and 3% utilization rate of vehicles. [29] [30] So, there is clearly a huge opportunity to increase the use of E85 given existing infrastructure. The main barrier is pricing of E85 relative to E10.

There is sufficient existing E85 station infrastructure to dispense 4.0 bgy of E85 (3.0 bgy of ethanol). There are sufficient FFVs to consume this E85 volume (100% dispenser utilization) while filling FFVs with E85 only 35% of the time. The number of FFVs will not constrain major increases in E85 sales. As noted above, even devoting all additional ethanol production to E85 use (2.741 billion gallons) would raise existing-dispenser utilization to only 68.5% and FFV utilization to only 21.7%. It appears that market forces and pricing will continue to be the key factors impeding significant E85 growth. If EPA desires increased usage of ethanol, E85 sales offer more ethanol volume per gallon of fuel sold than any other option.

2.4 E15

2.4.1 E15 Dispensers

The Biofuels Infrastructure Program (BIP) had plans to install 4,880 blender pump dispensers capable of handling E15/E85 in 1486 stations by the end of 2018[31]. This calculates out to 3.3 dispensers per station. Other programs such as Prime the Pump and Higher Blends Infrastructure Incentive Program have added

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[25] https://www.eia.gov/outlooks/aeo/data/browser/#/?id=49-AEO2021&cases=ref2021&sourcekey=0, Table 39

[26] https://www.epa.gov/automotive-trends/highlights-automotive-trends-report

[27] 12,000 miles divided by 25.4 miles per gallon (US fleet average in footnote 6 above) results in 472 gallons of E10 or 588 gallons of E85.

[28] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013KOG.pdf, page 51, Table 2.1-1

[29] 320 million gallons divided by 4.0 billion gallons of E85 capacity equals 8.0% utilization.

[30] 17 gallons divides by 588 gallons of E85 used by an FFV every year is 3% utilization

[31] https://www.fsa.usda.gov/programs-and-services/energy-programs/bip/index, state table

additional stations and dispensers to reach the 2,300 stations that EPA references in the RIA.[32] It will be assumed that all these stations also average 3.3 dispensers per station.

2.4.2 E15 Infrastructure

E15 is a relatively new fuel and E15 station and sales data is not regularly reported by government agencies. In the draft RIA for this proposal, EPA presents a figure which shows approximately 2300 E15 stations as of January 2021.[33] Stillwater has estimated that that these stations will average 3.3 dispensers per station offering E15 by 2022 (i.e., dispensers that are compatible with and approved for use with E15.[34] These 7,540 dispensers can handle about 4.1 billion gallons of E15 containing 0.205 billion gallons of ethanol can be dispensed in 2022. [35] [36]

Since E15 is not allowed the 1 psi waiver that applies to E10, the above station throughputs must be adjusted for 8.5 months instead of the 12 months used above. This reduces the distribution potential for E15 in 2022 to about 2.9 billion gallons containing 0.145 billion gallons of incremental ethanol above the E10 it would replace. If this infrastructure handles 1.2 billion gallons of E15 in 2022, then 1.7 billion gallons of E15 dispensing capacity is not being utilized. This represents 59% of the E15 capacity that is unutilized and 41% utilization of E15 dispensing capacity.

EPA in the RIA expresses some concerns about E15. One concern is that all existing or new hardware must be compatible with E15, new underground tanks must also be approved for E15, and it is expensive for station owners to pay for upgrading their hardware. The second concern is retailer liability for E15 damage and the additional cost associated with verifying E15 compatibility. These concerns are irrelevant to the analysis of the throughput capacity thus far, which is limited to the *existing* E15 infrastructure, i.e., infrastructure that is already acquired, compatible with E15 (by definition), and approved for use with E15. And with respect to the expansion of E15 infrastructure, EPA's concerns are misplaced or overstated. The manufacturers of nearly all dispensers have warranted them for E15 for many years, and most new dispensers made since 2012 have met the UL 87A requirements for E15. Because stations typically upgrade their pumps at high volume stations every 12 years, the population of E15 stations will continue to increase, and for little additional cost because the upgrade cycles would occur anyway regardless of a desire to expand E15 infrastructure.

EPA raises concerns in the RIA page 196 that being classified as E15 compatible is not the same as being approved for E15 use. EPA points in particular to underground tanks and pipes. This point did not bother EPA when creating Figure 6 In any event, EPA's concern about approval is very misleading and overstated. First, E15 underground tanks are generally unnecessary for the expansion of E15 delivery capacity because most E15 today is produced by blender pumps, which do not need E15-certified tanks. Indeed, EPA admits this on page 195 of the RIA: "the majority of service stations offering E15 today do so through blender pumps which can produce E15 on demand for consumers through the combination of E10 (or E0) and E85…"[37] Thus for most E15 stations the underground tank requirements for E15 storage do not apply. With a blender pump there is no E15 in contact with pipes or tanks as the E15 is produced in the dispenser. Second, although underground tanks are not upgraded as frequently as dispensers and can be more expensive than dispensers, the additional burden of obtaining approval to use a new E15-compatible underground system is negligible

2.4.3 E15 Compatible Vehicles

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[32] Figure 6.4.3-2: Number of Retail Service Stations Offering E15, page 196

[33] https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013KOG.pdf, Figure 6.4.3-2: Number of Retail Service Stations Offering E15, page 196

[34] Potential Increased Ethanol Sales through E85 for the 2019 RFS, August 17, 2018, Prepared for Growth Energy by Stillwater Associates LLC, Table 2

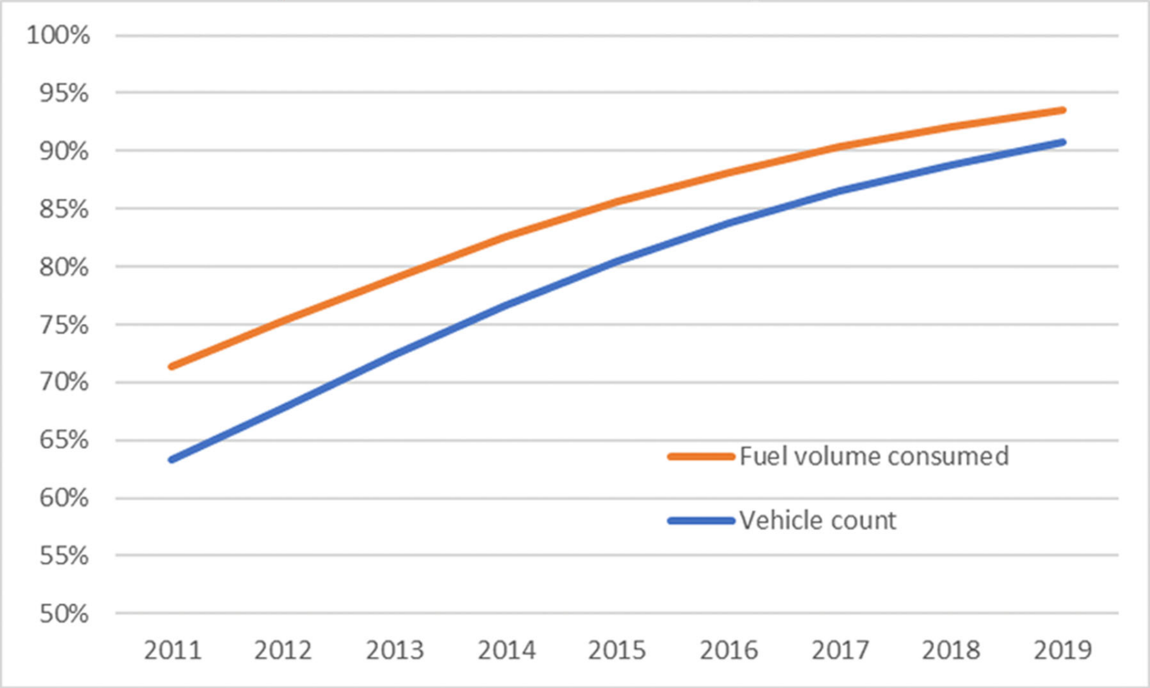
[35] 2,300 stations X 3.3 dispensers X 45,000 gal/disp/mo X 12 = 4.1 billion gallons

[36] 4.1 bg E15 X 0.05 gal etoh/ gal E15 = 0.205 bg etoh

[37] Draft Regulatory Impact Analysis: RFS Annual Rules (EPA-420-D-21-002, December 2021), page 194

As Figure 6 shows the vehicle pool is approaching the point where EPA claims that more than 90% of the vehicles are compatible with E15 (not counting FFVs, which can also use E15) and the noncompatible vehicles use less than 5% of the fuel used by the vehicle fleet.[38] As time moves on, these vehicles will become a smaller and smaller problem. Even in 2022, the capability for most of the nation's vehicles to use E15 far exceeds the small volumes of E15 available for this use.

Figure 6. MY2001 Or Later Fraction of In-Use Vehicle Fleet and MY 2001 or Later Fraction of In-Use Gasoline Consumption



Source: *EPA*

2.5 Combining E85 and E15 Capabilities

As can be seen from the E85 and E15 infrastructure analyses above in 2022 the additional ethanol capabilities of the E85 infrastructure, 2.72 bgy of incremental ethanol, vastly exceeds the capabilities of the current E15 infrastructure at 0.145 incremental bgy of ethanol per year. However, both sets of infrastructure can contribute to the goal of using more ethanol in the form of E85 or E15 with a total of 2.865 bgy of ethanol.

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[38] Draft Regulatory Impact Analysis: RFS Annual Rules (EPA-420-D-21-002, December 2021), page 199

3 E85 Pricing

In general, there is a lack of good data with information on E85 sales, production, and pricing. However, the Clean Cities Alternative Fuels Price Report is a fair source for E85 pricing data.[39] It is a quarterly report that collects samples of E85 prices by U.S. Department of Energy (DOE) PADDs for 15 days each quarter. These prices are averaged and then compared to E10 gasoline prices in the same PADD areas. The report also adjusts the E85 prices for energy content relative to E10 on a gasoline gallon equivalent (GGE) basis.

The most recent report was for October 2021 and the E85 and gasoline average prices from that report are shown in Table 5. The average E85 price nationally for October 2021 was $2.73 per gallon compared to $3.25 for E10 gasoline. These prices and the difference in prices of -$0.52 are about the same as most of the areas of the country except for New England and California. New England has an E85 price that is $0.32 above gasoline and California E85 is priced nearly $1.00 below California reformulated gasoline. This implies that in New England E85 sellers are not pricing competitively compared to gasoline on an energy basis but in California the market pricing is very competitive to E10 gasoline.

Table 5. E85 and Gasoline Average Prices by Region October 2021

Region	E85 Prices ($/gal)	Gasoline Prices ($/gal)	Price Difference
New England	$3.55	$3.23	$0.32
Central Atlantic	$2.68	$3.16	-$0.48
Lower Atlantic	$2.68	$3.08	-$0.40
Midwest	$2.69	$3.08	-$0.39
Gulf Coast	$2.52	$2.82	-$0.30
Rocky Mountain	$3.05	$3.54	-$0.49
West Coast	$3.35	$4.34	-$0.99
National Average	$2.73	$3.25	-$0.52

The Clean Cities Alternative Fuels Price Report also converted the E85 prices to a gasoline equivalent price by adjusting for the lower energy content of E85. A factor of 70% was used for adjusting the ethanol gallon energy content to a gasoline energy content equivalent. It was also assumed that E85 had on average 70% ethanol. EIA uses 74% in its E85 calculations. These GGE prices are shown in Table 6.[40] As can be seen, in all cases the E85 fuel was priced higher than gasoline on an energy equivalent basis. California alone seems to have E85 priced nearly equal to gasoline on an energy basis. The rest of the country has E85 prices that are adjusted to reflect some of the reduced energy, but it appears that stations in these areas are attempting to keep around half of the cost of the energy difference for themselves. This may reflect that many states have mandates for FFV and E85 usage in state and government fleets and the E85 retailers adjust their prices only enough to maintain some portion of the non-mandated E85 market.

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[39] https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_october_2021.pdf, Table 8

[40] https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_october_2021.pdf, Table 17a

Table 6. E85 and Gasoline Average Prices by Region (GGE) October 2021

Region	E85 Prices ($/GGE)	Gasoline Prices ($/gal)	Price Difference
New England	$4.62	$3.23	$1.39
Central Atlantic	$3.48	$3.16	$0.32
Lower Atlantic	$3.48	$3.08	$0.40
Midwest	$3.50	$3.08	$0.42
Gulf Coast	$3.28	$2.82	$0.46
Rocky Mountain	$3.96	$3.54	$0.43
West Coast	$4.36	$4.34	$0.02
National Average	$3.55	$3.25	$0.30

There is little doubt that 2020 and 2021 gasoline and E85 prices reflect the large drop in transportation fuel demand caused by the Covid-19 epidemic, but the pandemic's effect may have been similar with respect to each type of fuel. In order to examine E85 pricing during a more normal time period, the same two tables used above have been copied from the Clean Cities Alternative Fuels Price Report for October 2019.[41] In 2019, the national average E85 price was $2.28 per gallon and the national average gasoline price was $2.68 per gallon. These prices are lower than the October 2021 prices and reflect an average of $0.40 less for E85 than for E10 gasoline. In 2019, New England had E85 priced above gasoline just as in 2021 and California again had the lower E85 prices relative to gasoline.

Table 7. E85 and Gasoline Average Prices by Region for October 2019

Region	E85 Prices ($/gal)	Gasoline Prices ($/gal)	Price Difference
New England	$2.85	$2.69	$0.16
Central Atlantic	$2.34	$2.45	-$0.11
Lower Atlantic	$2.26	$2.46	-$0.20
Midwest	$2.18	$2.49	-$0.31
Gulf Coast	$2.07	$2.25	-$0.18
Rocky Mountain	$2.27	$2.73	-$0.46
West Coast	$3.08	$3.93	-$0.85
National Average	$2.28	$2.68	-$0.40

Table 8 shows the 2019 GGE adjusted prices for E85.[42] The results are very similar to the results for 2021. Again, California was the only region that came close to pricing E85 at parity with E10, but it still priced E85 above E10 on an energy-equivalent basis.

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[41] https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_oct_2019.pdf, Table 7

[42] https://afdc.energy.gov/files/u/publication/alternative_fuel_price_report_oct_2019.pdf, Table 17a

Table 8. E85 and Gasoline Average Prices by Region (GGE) October 2021

Region	E85 Prices ($/GGE)	Gasoline Prices ($/gal)	Price Difference
New England	$3.70	$2.69	$1.01
Central Atlantic	$3.04	$2.45	$0.59
Lower Atlantic	$2.94	$2.46	$0.48
Midwest	$2.83	$2.49	$0.34
Gulf Coast	$2.69	$2.25	$0.44
Rocky Mountain	$2.95	$2.73	$0.22
West Coast	$4.00	$3.93	$0.07
National Average	$2.96	$2.68	$0.28

From looking at Tables 6 and 8, it appears that since 2019 and even through the Covid epidemic, E85 has consistently been priced above E10 gasoline on an energy equivalent basis on average in all regions of the country. If we assume that E85 purchasers are completely rational, it is obvious why utilization of E85 has not been higher: consumers recognize that it is too expensive. By and large, only price-insensitive E85 purchasers, such as those that are mandated to use E85 in their state, or through Federal mandate, or for fleet fueling for FFVs, purchase E85. Additionally, there are likely some consumers that are committed to E85 for non-economic reasons, who are also relatively price-insensitive; these can include corn farmers, those involved in ethanol production, and environmentalists. These groups of price-insensitive consumers have likely been the primary market for E85 retailers so far. Because they are few in number and not growing rapidly, the use of E85 has also not been growing much. In order to substantially increase the use of E85, it must be marketed to general consumers, who are highly price sensitive when purchasing fuel. And therefore, E85 must be priced at or below parity with E10 on an energy-equivalent basis. Put another way, retailers have been marketing E85 as a premium niche product, seeking high margins on low volume, but to take advantage of the infrastructure to markedly increase E85 use, they would need to market it as a mass-market low-cost, high-volume commodity.

In sum, the only real barrier to increasing the use of E85, and thereby the concentration of ethanol in the nation’s fuel supply, is the relative pricing of E85 to E10. E85 has consistently been priced more expensive than E10 and most consumers are highly sensitive to this premium. The solution, then, is to lower the relative price of E85 to E10. The RFS provides a direct mechanism to achieve this: higher RFS standards tighten the supply of RINs, increasing their price. Higher RIN prices translate into greater discounts relative to E10. And because E85 has such a higher concentration of ethanol, it can achieve a greater discount through higher RIN prices.

4 Encouraging Increased Use of Higher-Ethanol Blends

The RFS is designed to allow the lowest priced renewable biofuel to meet the demand for the conventional renewable biofuel requirement. Many parties believe that the conventional renewable biofuel category is designated to provide a mandate for ethanol D6 RINs but this category can be met by using any renewable biofuel allowed under the RFS. As a result, meeting this category’s requirements is based on acquiring the least expensive marginal RINs.

The marginal RIN is defined as the type of RIN which provides the lowest cost option for RFS-Obligated Parties to comply with the last increment of their annual obligation. This builds upon the assumption that an obligated party will seek to comply with its obligations in the most cost-effective manner available to it; thus, it will use the overall lowest cost option first to comply with as much of its obligation as possible and then, successively, utilize higher cost options in order of increasing cost to the extent needed to satisfy its total obligation for a year. As the RFS is comprised of four nested obligations, assessment of the marginal RIN is more complex than the assessment of the marginal supplier in most other market contexts.

Identifying the marginal RIN is useful as a tool for predicting the market response to potential changes to RFS policies.

Without the value of the D6 RIN export ethanol is more expensive than domestic RFS ethanol, so that anytime ethanol is desirable for RFS compliance, the market will first divert from exports. Put differently, anyone choosing to export U.S. ethanol chooses to lose the value of the D6 RIN he could get if he could use the ethanol domestically. This is important because it means that we have 1.3-1.5 billion or more gallons of ethanol, with existing land use and production capacity, ready to use domestically if the right price signals are sent through the RFS[43] [44]. There is no need to worry about marginal land use effects or marginal price effects for corn or food.

5 Market Challenge in Meeting Original 2020 Percentage Standards

EPA originally finalized the annual volume obligations and the corresponding percentage standards for the four RFS renewable fuel categories in February 2020.[45] The volumes and corresponding percentage standards are presented in Table 9 below. As each Obligated Party's obligations under the RFS are set by applying the percentage standards to the sum of their gasoline and diesel supply to the 49-state RFS market,[46] the finalization of the 2020 percentage standards enabled them to calculate their obligations and act to acquire all RINs needed for compliance with each their year-to-date obligations every day for the rest of 2020. Accordingly, when Obligated Parties closed their books for 2020, they were able to precisely know their obligations and take appropriate actions to secure any remaining shortfall in their required number of 2019 and 2020 RINs.

Table 9. RFS Final 2020 Volume Standards and Percentage Standards, February 2020

Fuel Category	2020 Final Volume Standard (billion gallons)	2020 Final Percentage Standards
Cellulosic biofuel	0.59	0.34%
Biomass-based diesel	2.43*	2.10%
Advanced biofuel	5.09	2.93%
Renewable fuel	20.09	11.56%
Undifferentiated Advanced Biofuels (Implied)	1.445	0.83%
Conventional Biofuels (Implied)	15.00	8.63%

*Established in the 2019 final rule (83 FR 63704, December 11, 2018)

In calculating the final percentage standards for 2020, EPA used data provided by EIA in their Short-Term Energy Outlook (STEO) for October 2019 and estimated the volume of small refinery volumes to be granted exemptions based on actual exemptions granted annually for 2016 through 2018. These volumes, originally published in Table VII.C-1 of the 2020 Final Rule are reproduced in Table 10 below along with the revised volumes in the December 2021 proposed rule.

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[43] https://www.fas.usda.gov/ethanol-2020-export-highlights

[44] https://www.fas.usda.gov/ethanol-2019-export-highlights

[45] Renewable Fuel Standard Program: Standards for 2020 and Biomass-Based Diesel Volume for 2021 and Other Changes, 85 FR 7016, February 6, 2020.

[46] Gasoline and diesel supplied to Alaska do not generate RFS obligations.

Table 10. Values for Terms in Calculation of the Final 2020 Standards (billion gallons)

		Value for 2020 Standards	
Term	**Description**	**February 2020 Final Rule**	**December 2021 Proposal**
RFVCB	Required volume of cellulosic biofuel	0.59	0.51
RFVBBD	Required volume of biomass-based diesel a	2.43	2.43
RFVAB	Required volume of advanced biofuel	5.09	4.63
RFVRF	Required volume of renewable fuel	20.09	17.13
G	Projected volume of gasoline	142.68	123.25
D	Projected volume of diesel	55.30	50.49
RG	Projected volume of renewables in gasoline	14.42	12.63
RD	Projected volume of renewables in diesel	2.48	2.15
GS	Projected volume of gasoline for opt-in areas	0	0
RGS	Projected volume of renewables in gasoline for opt-in areas	0	0
DS	Projected volume of diesel for opt-in areas	0	0
RDS	Projected volume of renewables in diesel for opt-in areas	0	0
GE	Projected volume of gasoline for exempt small refineries	4.24	0.00 – 4.80
DE	Projected volume of diesel for exempt small refineries	3.02	0.00 – 3.39

[a] The BBD volume used in the formula represents physical gallons. The formula contains a 1.5 multiplier to convert this physical volume to ethanol-equivalent volume.

In their proposed rule for volume requirements for 2020, 2021, and 2022, EPA proposes to revise the final volumes and percentage standards for 2020 on the basis that – [47]

> *Since we promulgated those standards, several significant and unanticipated events occurred that affected the fuels markets in 2020. The two most prominent of these events were:*
>
> - *The COVID–19 pandemic and the ensuing fall in transportation fuel demand, especially the disproportionate fall in gasoline demand relative to diesel demand, which significantly reduced the production and use of biofuels in 2020 below the volumes we anticipated could be achieved, and*
> - *The potential that the volume of gasoline and diesel exempted from 2020 RFS obligations through small refinery exemption (SREs) will be far lower than projected in the 2020 final rule.*[48]

To evaluate the impact of these factors on obligated parties, we compare EPA's February 2020 Final Volume obligations for each of the four RFS categories with the volume obligations calculated by applying 2020 actual volumes to the finalized 2020 Percentage Standards (with and without inclusion of EPA's current estimates for exempted gasoline and diesel volumes) and to EMTS data for net 2020 RIN generation and 2020 RIN Separations (excluding separation for export). [49] [50] [51] These comparisons, which do not include any usage of carryover RINs, are presented in Table 11 below. This analysis shows that the inherent flexibilities in the RFS due to the use of percentage standards, the availability of cellulosic waiver credits (CWCs) to meet shortfalls in cellulosic biofuel availability, and the nested structure of the RFS obligations means that actual separations of 2020 vintage RINs were sufficient to sufficient to satisfy the cellulosic biofuel, biomass-based diesel, and advanced biofuel obligations for 2020 as previously finalized.[52] Additionally, net RIN generation for the Renewable fuels category was more than sufficient to enable compliance with the previously finalized 2020 Renewable Fuel obligation if EPA's estimate for small refinery exemptions (SREs) in 2020 is accurate, thus use of carry-over RINs to cover the shortfall in 2020 conventional RIN separation is appropriate.

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[47] Renewable Fuel Standard (RFS) Program: RFS Annual Rules, 86 FR 72436, December 21, 2021.

[48] RFS Annual Rules, Sub-Section I.B., December 21, 2021

[49] 4.80 billion gallons of gasoline and 3.39 billion gallons of diesel as indicated in the rightmost column of Table 6.

[50] Defined by EPA as the total number of RINs generated minus the number of invalid RINs generated.

[51] RINs associated with export volumes are not eligible for use in meeting RFS volume obligations. EIA data indicates that 1,317 million gallons of ethanol were exported from the U.S. in 2020. These would have been available to supply the domestic U.S. market if required for RFS compliance.

[52] While a portion of 2020 vintage RIN separations occurred in 2021, this analysis has not taken credit for the portion of 2019 vintage RIN separations which occurred in 2020.

Table 11. Volume Obligations (2020 Final Rule) Compared to the Actual Volume Obligations (with and without EPA's estimate of SREs) and RIN Generation

Fuel Category	2020 Final Volume Standard (billion gallons)	Actual Volume Obligations with 2020 Percentage Standards, no SRE	Actual Volume Obligations with 2020 Percentage Standards, est SRE	2020 Net RIN Generation	2020 RIN Separation
Cellulosic biofuel	0.59	0.54	0.51	0.51	0.50
Biomass-based diesel	2.43	2.15	2.04	2.88	2.48
Advanced biofuel	5.09	4.66	4.42	5.33	4.66
Renewable fuel	20.09	18.38	17.43	18.26	17.06

***Source**: EIA, Stillwater analysis*

To understand the influence of EPA's estimate for SREs in their calculation of the 2020 Final Percentage Standards in February 2020, we recomputed these values with the gasoline and diesel exempt volume projections both set to zero. This effectively increases the denominator used in calculating the percentage standards. This revised calculation ("2020 Percentage Standards, no SREs") is compared to the February 2020 calculation ("2020 Final Percentage Standards") in Table 12 below.

Table 12. Recalculation of 2020 Percentage Standard with no SREs

Fuel Category	2020 Final Volume Standard (billion gallons)	2020 Final Percentage Standards	2020 Percentage Standards, no SREs
Applicable Volume (bgal)	--	173.82	181.08
Cellulosic biofuel	0.59	0.34%	0.33%
Biomass-based diesel	2.43	2.10%	1.34%
Advanced biofuel	5.09	2.93%	2.81%
Renewable fuel	20.09	11.56%	11.09%
Undifferentiated Advanced Biofuels (Implied)	1.445	0.83%	0.80%
Conventional Biofuels (Implied)	15	8.63%	8.28%

***Source**: EPA, Stillwater analysis*

These alternative percentage standards are next used to compute what the 2020 volumes would have been had EPA accurately projected both transportation fuel use and SREs for 2020. These calculations are presented below in Table 13 and can be compared with Table 12 above. With this alternative calculation, it can be seen that cellulosic biofuels RIN generation (0.51 billion) and RIN separation (0.50 billion) both fell slightly short of the actual volume obligation of 0.52 billion RINs. RIN separations in this calculation exceed the actual volume obligations for both biomass-based diesel and advanced biofuels. Renewable fuels separations, at 17.06 billion fall short of the actual volume obligation of 17.64 billion. However, we see that 2020 net RIN generation, at 18.26 billion significantly exceeded the actual volume obligation – this tells us that sufficient RINs were generated to meet the 2020 standards as originally finalized if the EPA's 2020 estimation of SREs is removed from the analysis.

Table 13. 2020 Actual Volume Obligations calculated with revised percentage standards (with and without EPAs current estimate of SREs)

Fuel Category	2020 Final Volume Standard (billion gallons)	Actual Volume Obligations with 2020 Percentage Standards, no SRE	Actual Volume Obligations with 2020 Percentage Standards, est SRE	2020 Net RIN Generation	2020 RIN Separation
Cellulosic biofuel	0.59	0.52	0.49	0.51	0.50
Biomass-based diesel	2.43	2.06	1.96	2.88	2.48
Advanced biofuel	5.09	4.47	4.24	5.33	4.66
Renewable fuel	20.09	17.64	16.73	18.26	17.06
Undifferentiated Advanced Biofuels (Implied)	1.445	1.27	1.20	0.29	0.31
Conventional Biofuels (Implied)	15	13.17	12.49	12.93	12.40

Source: *EIA, Stillwater analysis*

5.1 RFS Impacts on Imports and Exports of Petroleum and Ethanol

To examine the impact of the RFS on imports and exports of petroleum (crude oil and products) and ethanol, we will review data available from EIA. A key element of this analysis begins with EIA's assessment of U.S. ethanol production capacity and production. These data are summarized in Table 14 below. EIA reports U.S. fuel ethanol production capacity annually as of January 1st of each year; the most recent data available are for January 1, 2021.[53] EIA also reports monthly fuel ethanol production.[54] The ratio of the two gives us the annual capacity utilization which we measure in percent; the average utilization achieved in the years immediately preceding Covid-19, 2018 and 2019, was 95%. Assuming that the industry can regularly operate at 95% of capacity and that U.S. ethanol capacity remains unchanged from the 17.546 billion gallons per year cited by EIA at the beginning of 2021, this suggests that the U.S. ethanol industry has the capability to produce at a rate of 16.669 billion gallons per year if sufficient supplies of corn are available and if there is demand for the product.[55]

Table 14. U.S. Annual Ethanol Production and Capacity

Year	Annual Capacity (million gallons)	Monthly Capacity (million gallons)	Annual Production (million gallons)	Annual Utilization (%)
2018	16,542	1,379	16,091	97%
2019	16,908	1,409	15,778	93%
2020	17,378	1,448	13,941	80%
2021 (estimated)[56]	17,546	1,462	14,716	84%
Potential 2022[57]	17,546	1,462	16,669 (@ 95% utilization)	95% (assumed)

Source: *EIA, Stillwater analysis*

Figure 7 below illustrates the monthly supply and demand for U.S. ethanol from 2018 through October 2021. As seen in this chart, monthly production (orange line) averaged 95% of capacity (blue line) in 2018 and 2019. Capacity utilization dropped to a low of 49% in April 2020 due to the impacts of the pandemic and operating rates have only recovered to 84% of capacity in 2021 (based on data for January through October). Domestic demand (green bars) for March through October of 2021 has nearly recovered to pre-Covid levels of about 1.2 billion gallons per month while export volumes (light gray bars) continue to be below pre-pandemic levels. The black line on the chart corresponds to the finalized implied conventional biofuels obligation of 15 billion gallons per year (1250 million gallons per month) for 2018 through 2020;

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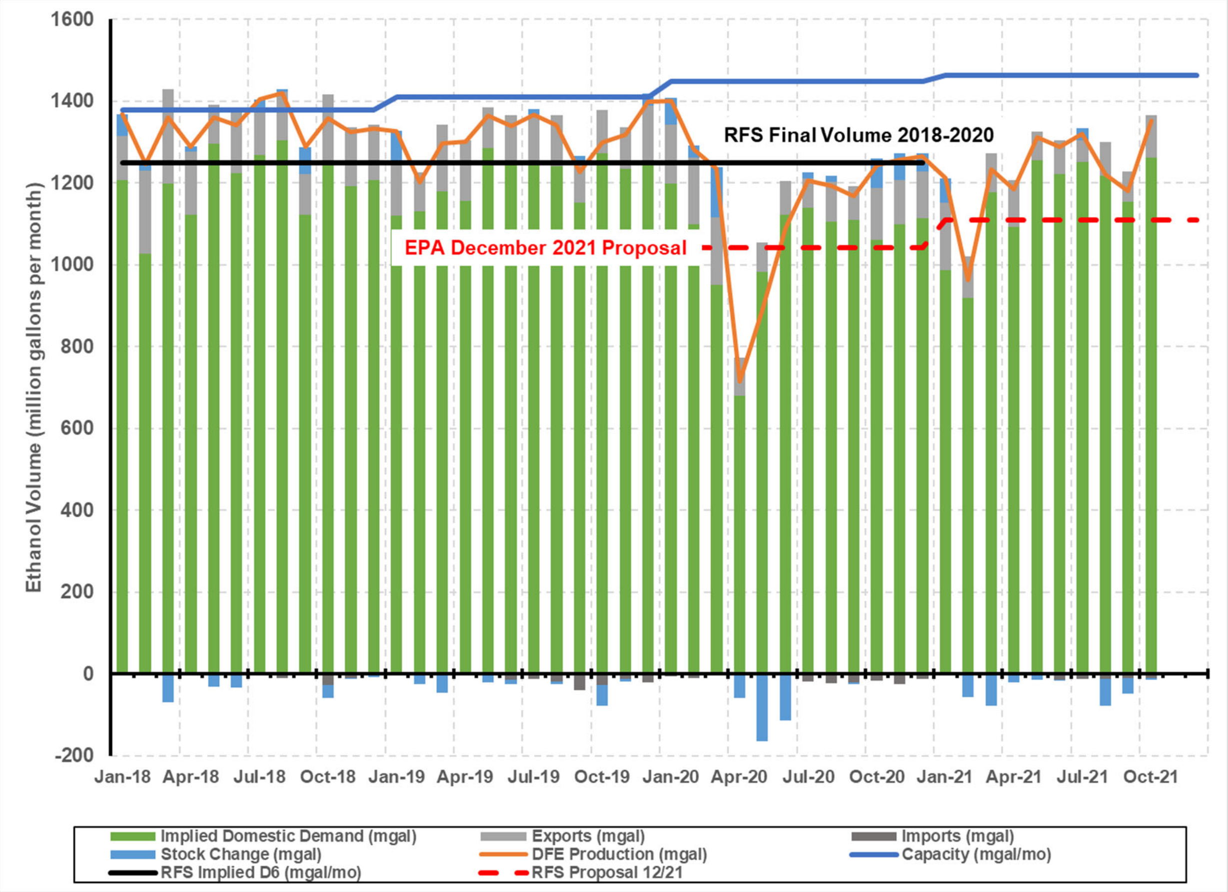
[53] https://www.eia.gov/petroleum/ethanolcapacity/
[54] https://www.eia.gov/dnav/pet/pet_pnp_oxy_dc_nus_mbbl_m.htm
[55] https://www.eia.gov/petroleum/ethanolcapacity/
[56] Annual production estimated based on data through October 2021.
[57] Assumes no change in operable capacity since January 1, 2021.

while domestic ethanol demand in 2020 was clearly below this level, pre-pandemic ethanol demand averaged near this target.[58] The dashed red line represents the 2020 and 2021 volumes in EPA's December 2021 proposal. In summary, these data demonstrate that the U.S. ethanol industry has significant unused capacity which could be used to supply as much as about 16.7 billion gallons per year of ethanol for the U.S. fuels market.[59]

Figure 7. Monthly U.S. Ethanol Supply, Demand and RFS Volume Standards (2018-2021)



***Source**: EIA, Stillwater analysis*

Exports continue to play a major role in U.S. petroleum and ethanol markets. Figure 8 below illustrates the recent trends in U.S. exports of crude oil, petroleum products, and ethanol. U.S. crude oil exports pre-pandemic were increasing steadily from over 42 million barrels per month in January 2018 to a high of 112 million barrels in March 2020; since the onset of the pandemic, they have varied in the range of about 80 to 100 million barrels per month. U.S. exports of petroleum products (including gasoline, diesel fuel, and other products) generally ranged around 100 million barrels per month pre-pandemic, dropped to a low of 58 million barrels in May 2020, and then rapidly recovered to a range of 80-90 million barrels per month since mid-2020. In contrast, U.S. ethanol exports are considerably smaller and have been generally declining since 2018 – from an average of 3,400 barrels per month in 2018 to an average of 2,300 barrels per month in 2021 (January through October). This decline in ethanol exports since before the pandemic is attributable to restrictive trade policies implemented by China and Brazil, two of the largest markets for U.S. ethanol exports.

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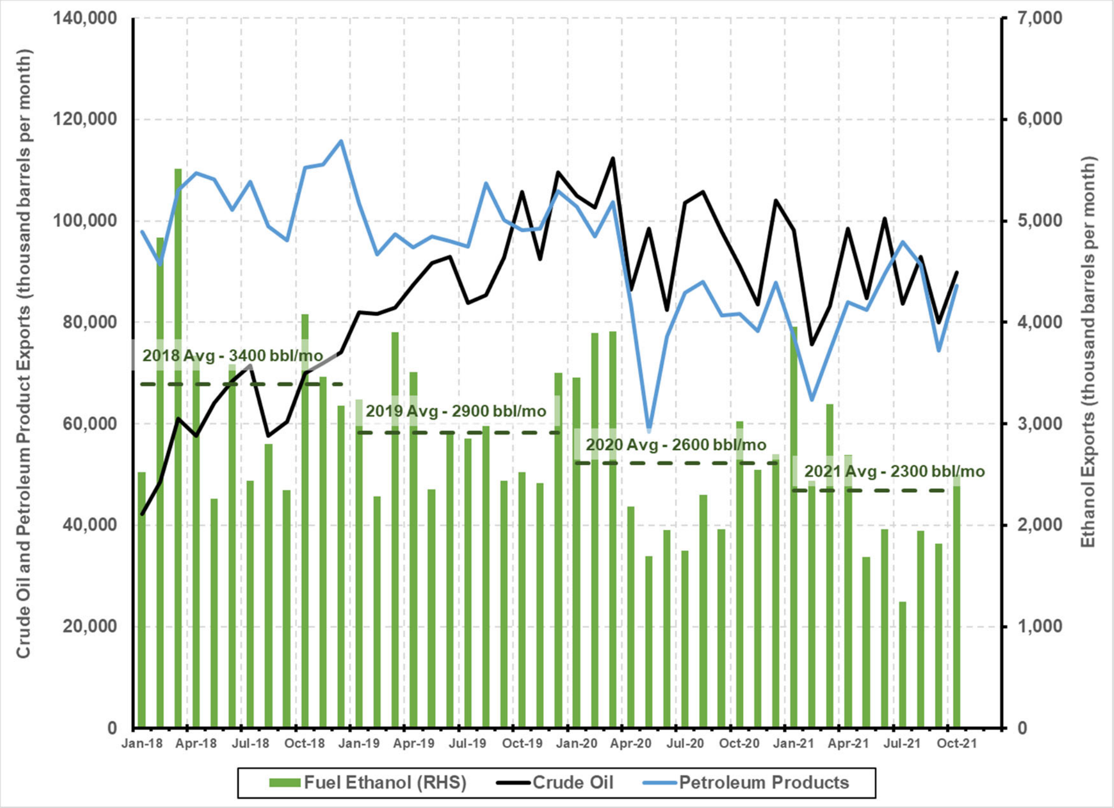
[58] The actual RFS obligation scales with annual gasoline and diesel demand each year. As discussed in Section 5 page 25 of this report, this regulatory scaling mechanism effectively eliminates any need for EPA to reduce the obligation volumes for 2020 as they currently propose.

[59] Based on current nameplate capacity of 17.5 billion gallons per year and the 95% sustained capacity utilization achieved in 2018 and 2019.

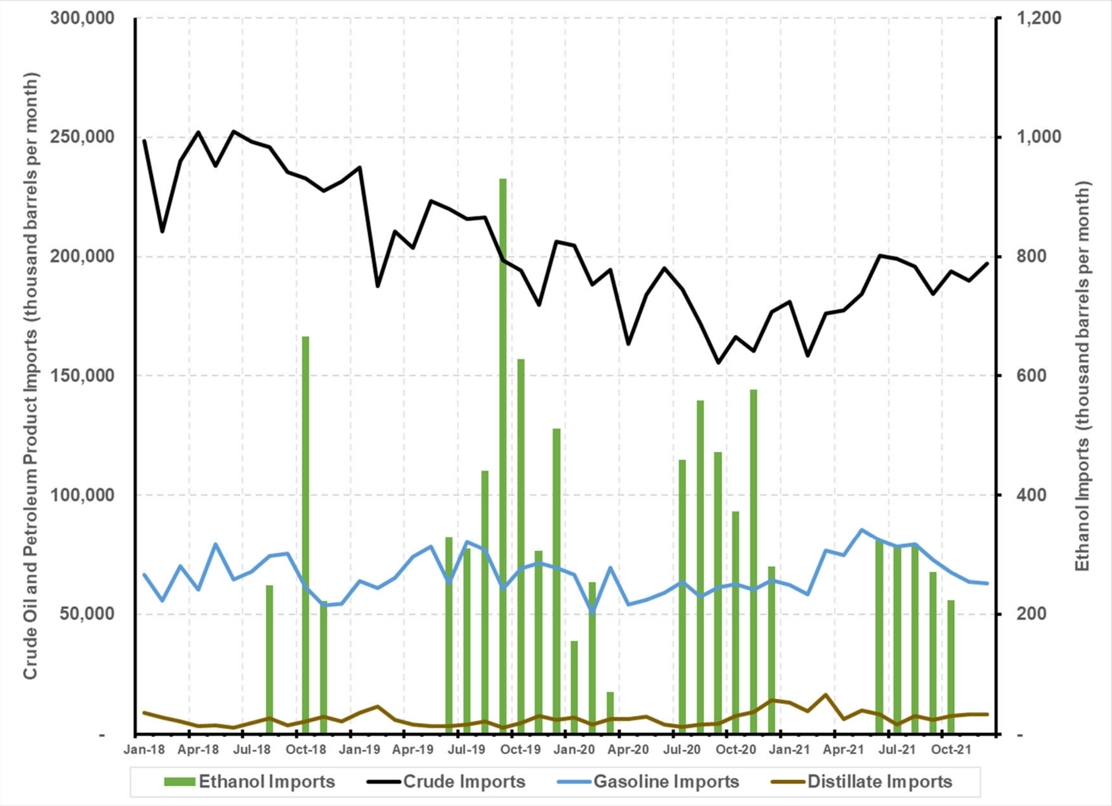
Figure 8. Monthly U.S. Exports of Crude Oil, Petroleum Products, and Ethanol (2018-2021)



***Source**: EIA, Stillwater analysis*

Looking at U.S. Imports, as shown in Figure 9 below, shows a somewhat different pattern than U.S. exports reviewed above. Crude oil imports are roughly double the amount of crude oil exports, with recent highs of 250 million barrels per month during the summer of 2028 followed by a gradual decline to a recent low of 155 million barrels in September 2021 because of growing U.S. production and exports and the loss in domestic demand with the pandemic. Since September 2021, crude imports have risen to recent levels near 200 million barrels per month. During this time period, U.S. gasoline and diesel imports have been relatively steady, averaging nearly 67 million barrels per month and 6.5 million barrels per month, respectively. U.S. ethanol imports during this time period have been small and irregular, comprised primarily of opportunistic imports of Brazilian sugarcane ethanol during Brazil's harvest season and directed primarily towards California's LCFS market where the low carbon intensity is highly valued. Over the time frame shown, ethanol imports averaged less than 0.2 million barrels per month.

Figure 9. Monthly U.S. Imports of Crude Oil, Gasoline, Diesel, and Ethanol (2018-2021)



Comparing exports and imports, the U.S. remains a large net importer of crude oil and a net exporter of petroleum products. The U.S. is also the world's largest ethanol exporter with net exports declining in recent years due to the combined effects of trade frictions with China and Brazil and the impacts of Covid-19. With the U.S. ethanol industry operating well below capacity, it has the capability of significantly increasing supply to U.S. and international markets if current regulatory and trade barriers were relaxed.

Based on the above analysis, increasing the implied RFS obligation for conventional biofuels would be expected to increase demand for domestic ethanol production. As U.S. ethanol plants are currently operating below demonstrated capacity, this increase can be accommodated without the need for the U.S. to reduce its current level of exports. As U.S. ethanol imports are currently small, opportunistic, and driven by LCFS value it is unlikely that increased RFS obligations would result in material increases of ethanol imports. With higher levels of ethanol in the U.S. gasoline pool, petroleum refineries would be expected to re-optimize between lower rate (reducing U.S. crude imports) and increased net exports of petroleum products (reducing crude demand in the rest of the world) depending on short-term market conditions. Regardless of how the U.S. refining industry were to re-optimize, global GHG emissions would be reduced.

6 EPA Cost Analysis of Ethanol Costs

In the RIA, EPA has projected an increased cost for ethanol in 2022.[60] Table 7.4-1 in the RIA projects a 3% increase in corn ethanol prices for 2022 and Table 7.5-1 sets the price increase at $0.14 per bbl of corn. Historically, the process of producing corn and ethanol have gotten more efficient each year. If this is coupled with a drop in gasoline demand and the resulting drop in demand for blending ethanol, it would be expected for corn and ethanol prices to drop slightly rather than increase as EPA is proposing.

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[60] Draft Regulatory Impact Analysis: RFS Annual Rules (EPA-420-D-21-002, December 2021), page 214

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 6

Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017

Prepared for

Growth Energy

By

Stillwater Associates LLC

Irvine, California, USA

July 11, 2016

Stillwater Associates

Disclaimer

Stillwater Associates LLC prepared this report for the sole benefit of Growth Energy.

Stillwater Associates LLC conducted the analysis and prepared this report using reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of presentation. Changes in factors upon which the report is based could affect the results. Forecasts are inherently uncertain because of events that cannot be foreseen, including the actions of governments, individuals, third parties and competitors. NO IMPLIED WARRANTY OF MERCHANTABILITY SHALL APPLY.

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Executive Summary

Congress legislated both the 2005 Renewable Fuel Standard (RFS) and the updated 2007 Standard (RFS2) as a mechanism to mandate the phasing in of renewable biofuels into U.S. transportation fuels. On an annual basis, the administering agency, the U.S. Environmental Protection Agency (EPA), is expected to propose and finalize new volume obligations for the four RFS categories of cellulosic biofuels; advanced biofuels, biomass-based diesel and total renewable biofuels. Ethanol has become the predominant biofuel used to meet three of the four RFS2 categories. Ethanol can be used in transportation fuel when it is blended with gasoline at various levels. The most popular of these has been E10, which is 10 percent ethanol and 90 percent petroleum blendstocks. Ethanol can also legally be blended as E15, a blend of up to 15 percent ethanol, or as E85. E85 can contain 51 to 83 percent ethanol blended with petroleum blendstocks or natural gasoline. E85 can only be used in Flexible Fueled Vehicles (FFVs). FFVs comprise about eight percent of the nation’s transportation vehicle fleet.

As the RFS2 mandates for ethanol have risen, the nation has begun to approach the so-called E10 blendwall, that point at which nearly all of the nation’s gasoline has been blended at the 10 percent ethanol level. To get around the E10 blendwall, it is necessary to find pathways to blend more than 10 percent ethanol into ever larger portions into the nation’s gasoline pool. E15 and E85 are the primary pathways to increase ethanol consumption beyond 10%.

In its latest RFS2 proposal for 2017, EPA has proposed standards that result in modest increases in ethanol usage but has discounted the additional contribution from E85 and E15. Growth Energy has requested that Stillwater Associates examine the distribution infrastructure for pathways to potentially increase the supply of E15 and E85 at the retail station level. Stillwater has considerable experience in the transportation fuels distribution space.

Stillwater evaluated the current state of fuels distribution, from the supply source though the pipeline and terminal network to the service station and to the consumer. For E85, Stillwater found that there are enough E85 stations and E85 dispensers in the U.S. to substantially increase the volumes of ethanol used in transportation fuels. The simplest case where E85 throughput is increased in the roughly 3,100 existing E85 stations with no new hardware required can increase E85 sales by 1.674 billion gallons per year (bgy) and increase ethanol usage by 1.108 bgy if EPA would only provide sufficient economic incentives to current FFV owners using E10. This is very low hanging fruit in terms of increasing renewable fuels usage.

Stillwater analyzed the reasons for the current low consumption of E85 and found that E85 needs to sell below its energy parity value compared to E10 in order to increase sales to price conscious E10 consumers. Stillwater found that EPA’s recently established and currently proposed RFS renewable standards fall short of providing a sufficient driving force to increase D6 RIN value to the point where E85 prices can be set far enough below energy parity with E10 to establish a tipping point where larger E85 sales volumes enable even lower E85 prices to the consumer.

Stillwater also found that ethanol volumes can be increased significantly through the use of E15 or E85 by making relatively modest investments to expand the infrastructure for delivering E85 or E15.

1 The Objective of the Study

On May 31, 2016, the EPA issued a notice of proposed rulemaking on the 2017 Renewable Fuel Standards and the biomass-based diesel standard for 2018. For 2017, EPA is proposing standards based on an assumption that the maximum reasonably achievable volume of ethanol usage is approximately 0.2 bgy above the E10 blendwall most of which is E85. Growth Energy has requested that Stillwater Associates evaluate whether more volumes of incremental ethanol are reasonably achievable through E85 and E15 if EPA were to require additional ethanol above the E10 blendwall through implementation of the RFS.

In this report, Stillwater assesses the ability of the fuel system to deliver greater volumes of E85 right now. We then analyze the potential pathways for expanding infrastructure for selling E85 or E15. Stillwater prioritizes low-cost solutions for expansion. Stillwater also analyzes the financial dynamics of the market to determine what kind of incentives are needed to spur the necessary investment in upgraded infrastructure, and develops a market segmentation model that illuminates what is needed from RFS volume requirements and the RIN market to create those incentives.

Stillwater did NOT examine the actual production capacity of ethanol manufacturing facilities but will assume that sufficient domestic production is available to fulfill the incremental supply. Additionally, Stillwater did assume that model year 2001 and later U.S. automobile and truck fleets are capable of using E15 and that original equipment manufacturer warranty issues will not impede renewable fuel consumption. Support, or lack thereof, from the oil industry is assumed to be out of scope for the purposes of this report.

2 E85 Analysis

In the E85 portion of this analysis, Stillwater first identifies the potential increases in E85 sales volumes through existing stations. We then assess the cost of expanding E85 distribution capacity by additional E85 dispensers at existing E85 stations and at E10-only stations, and estimate the magnitude of the possible expansion. Next Stillwater analyzes the investment costs in terms of rates of return and the need for increased margins from the point of adding a single new dispenser. The margins required to achieve desirable rates of return are minimal if the new dispenser is fully utilized but they increase if the dispenser has low E85 throughput, suggesting a strong incentive for high RIN prices and high corresponding E85 discounts. Then Stillwater models the behavior of several segments of E85 customers and discovers that E85 has seldom been priced sufficiently below energy parity with E10 to attract price-sensitive E10 customers, which constitute by far the largest segment of the market. It appears that there is a tipping point in E85 price below which E85 sales volumes can increase rapidly. Finally, Stillwater discusses the ethanol-E85 supply chain and how RINs and ethanol price reductions move through the supply chain.

2.1 Case 1: Incremental Ethanol Consumption Through Existing E85 Infrastructure

Existing infrastructure is capable of delivering volumes of E85 far beyond what EPA has proposed. The ability to deliver E85 is a function of three factors:

1. The number of E85 stations;
2. Dispenser throughput; and
3. The location of stations relative to vehicles that can use the fuel, i.e., flex-fuel vehicles (“FFVs”).

We address each in turn.

Stations. According to EPA, there were 3,126 E85 stations in the United States as of March 2016.[1] By the time 2017 begins, that figure will certainly be higher as a result of additional upgrades and various programs targeted to increase the availability of E85, such as BIP (USDA's Biofuel Infrastructure Partnership) and the "Prime the Pump" program. EPA notes that BIP is expected to have added 1,486 E85 stations by the end of 2016. Therefore, we can assume that there will be at least 4,612 E85 stations at the start of 2017. But to make our analysis extremely conservative, we will assume that there are 3,100 E85 stations at the start of 2017. Further, that figure will undoubtedly increase over the course of 2017. We address the potential for infrastructure expansion in 2017 later; for now, and again to develop the most conservative analysis, we will assume for present purposes that the number of E85 stations does not increase during 2017 but rather remains at 3,100 for the entire year.

Dispenser throughput. In an influential study entitled "Feasibility and Cost of Increasing U.S. Ethanol Consumption Beyond E10," leading researchers Bruce Babcock and Sebastien Pouliot examined an E85 service station in Minnesota and found that it sold almost 50,000 gallons in one month.[2] Accordingly, they assume that the average E85 station can deliver 45,000 gallons of E85 per month. That assumption accords with a rule of thumb in gasoline marketing that the average station will sell two million gallons of fuel per year with four dispensers (2 hoses each). That standard converts to just about 42,000 gallons per month per dispenser.

More careful analysis confirms Babcock and Pouliot's finding and the rule of thumb, but further shows that they are very conservative and reflect a model in which there is minimal customer wait time at the pump. We assume for purposes of this discussion that the average E85 station has one E85 dispenser, located on a fueling island allowing two vehicles access at the same time with one fueling hose on each side of the island. For safety reasons, the EPA has established a rule that limits the rate at which gasoline or methanol is pumped into motor vehicles—the "flow rate"—to 10 gallons per minute.[3] While every dispenser has its own self-contained pumping mechanism, it is designed to be shared by both attached hoses, allowing one dispenser to fuel two vehicles simultaneously. While flow rates vary service station to station, and then by dispenser, we assume conservatively for purposes of this discussion a flow rate of just three gallons per minute, assuming two vehicles are using the dispenser at the same time. The average volume of gasoline purchased per transaction (which may or may not completely fill the vehicle gasoline tank) is approximately 12 gallons, which at a flow rate of three gallons per minute would result in the average fueling not exceeding four minutes. We then assume conservatively that it takes four minutes for the just-fueled vehicle to leave the fueling island and the next vehicle to situate at the dispenser after a modest time gap (though we think it could reasonably take as little as two minutes), yielding an eight-minute fueling cycle per vehicle. At that rate, each hose on the fuel dispenser could service 7.5 vehicles per hour, for a total of 15 vehicles per hour per dispenser. While a typical service station is open 24 hours per day (usually set by contractual terms), approximately 75 of its fuel sales take place over a 12-hour peak period with very little taking place during the late evening or early morning hours. Therefore, we assume that drivers fill up at the maximum rate during the 12 peak hours, and that that defines 75% of the daily throughput for the dispenser. Specifically, using the typical fueling volume of 12 gallons per transaction, a single E85 fueling dispenser with two hoses would dispense 180 gallons of fuel during each of the peak hours of operations per day, which works out to 2,160 gallons during the entire peak window, 2,873 gallons total per day, and 86,184 gallons total per month, assuming that daily sales are ratable through a 30-day month (i.e., that the same volume is sold daily—an assumption that likely has only marginal effect on the results). This analysis shows that the average station with a single E85 dispenser could deliver approximately twice the volume of E85 that Babcock and Pouliot assumed and that the rule of thumb suggests.

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[1] EPA's count is likely too low. According to e85prices.com, there are about 3,450 E85 stations today.

[2] Babcock, Bruce A., Pouliot, Sebastien. *Feasibility and Cost of Increasing U.S. Ethanol Consumption Beyond E10.* Iowa State University Center for Agricultural and Rural Development - CARD Policy Briefs. January 2014. http://www.card.iastate.edu/publications/dbs/pdffiles/14pb17.pdf

[3] EPA. *Transportation and Air Quality.* http://www.epa.gov/oms

For purposes of the rest of this report, we will therefore assume (consistent with Babcock and Pouliot's finding) a very conservative throughput of 45,000 gallons per dispenser per month.

FFVs. According to the U.S. Department of Energy's (DOE) Alternative Fuels and Advanced Vehicles Data Center (AFDC), there are more than 17.4 million FFVs on U.S. roadways today. In fact, that figure is likely higher—almost 21 million, according to a recent report by Air Improvement Resource, Inc.

Total incremental consumption capacity. Finally, we consider how much ethanol can be consumed through this system as E85 above the amount of ethanol that can be consumed as E10, i.e., the existing system's capacity to deliver and consume incremental ethanol as E85. For purposes of this discussion, we assume, as EPA does, that E85 contains 74% ethanol but adds the equivalent of 66.2% ethanol over the gallon of E10 that the E85 displaces (specifically, EPA states every gallon of ethanol use in excess of E10 requires 1.51 gallons of E85).

Assuming 3,100 E85 stations each with a single E85 dispenser distributing 45,000 gallons of E85 per month, this system can distribute about 139.5 million gallons of E85 per month, or 1.674 billion gallons of E85 per year. That is far higher than the 200-300 million gallons of E85 that EPA assumed for 2017. And it equates to about 1.108 billion gallons of incremental ethanol per year.

There is no reason to find that the fleet would be unable to consume that entire capacity of E85. The recent report by Air Improvement Resource finds that the existing FFV fleet of 21 million can consume about 17.13 billion gallons of E85 per year.[4] Even if AFDC's smaller fleet size is used, it could still amply consume all the E85 that could be delivered by the existing infrastructure.

The only remaining question with respect to the capacity of the existing system to deliver and consume E85 is whether the FFVs are proximate to E85 stations. To assess this, we return to the Babcock and Pouliot paper. Prior to that paper, studies and papers by other authors had simply attempted to extrapolate potential E85 sales using linear models based upon E10 consumption rates. Such analysis is off target, since FFVs are the only vehicles that can use E85 fuel. Babcock and Pouliot used detailed data extracts for the geographical distribution of FFVs across the U.S. down to the zip code level, and the corresponding data of existing E85 service stations with infrastructure already in place. Assuming that station throughput (as noted) was 45,000 gallons of E85 per month, that there were 14.6 million FFVs on the road, that there were 3,000 E85 stations nationwide, and that FFVs would buy E85 from stations within a 10-mile radius, Babcock and Pouliot determined that 1.2-1.3 billion gallons of E85, containing one billion gallons of ethanol, could be consumed in a year. Their result of 1.2-1.3 billion gallons of E85 is of course less than the 1.674 billion gallons of E85 computed above. But since they conducted their study in 2013, the number of E85 stations and the number of FFVs have increased, thus increasing the likelihood that an FFV is within 10 miles of an E85 station, and so it is likely that if the Babcock and Pouliot analysis were re-run using today's figures, the result would be much higher and closer to the full 1.674 billion gallons of E85 of throughput capacity. In other words, the Babcock and Pouliot results reflect a very conservative estimate of the volume of E85 and incremental ethanol that could be reasonably consumed in 2017.

In sum, there is no doubt that much more than one billion gallons of E85 could be consumed nationally in 2017 using existing E85 infrastructure.

2.2 Case 2: Expanding Infrastructure to Deliver E85 in 2017

In this section, we examine low-cost ways to expand infrastructure for delivering E85 to consumers in 2017.

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[4] Air Improvement Resource, Inc. *Analysis of Ethanol-Compatible Fleet for Calendar Year 2017.* July 11, 2016.

Cost to add an E85 dispenser at an existing E10-only station. There are two principal pieces of infrastructure needed to deliver E85: the dispenser and the underground storage tank.

There are two basic kinds of dispensers: blender pumps, which cost about $20,000; and E85 pumps, which cost about $15,000.

According to a report by the National Renewable Energy Laboratory (NREL) called "E85 Retail Business Case,"[5] there are three methods for an existing service station to obtain the necessary tank to introduce an E85 dispenser:

1. Mid-grade conversion - The retailer cleans an existing (E10) tank and replaces or retrofits associated non-compatible piping and other equipment. This applies to cases where stations have a third tank for mid-grade that can be replaced by a blending valve (for regular and premium to make mid-grade), cases where stations have an extra regular grade tank, or cases where diesel is replaced because the sales are deemed negligible.
2. New tank - The retailer installs a new underground storage tank and retrofits or replaces associated non-compatible piping and other equipment. In this case, the retailer retains the sales of regular and premium fuel.
3. Premium conversion - The retailer fills the premium-grade tank with E85 after cleaning it and replacing associated non-compatible piping and other equipment. This case applies to stations that blend their mid-grade rather than draw it from a designated mid-grade tank, so the retailer can no longer offer either mid-grade or premium-grade gasoline once the tank is converted.[6]

With the movement to E10, most E10 stations have tanks that are capable of holding E85. As set forth in more detail in an NREL report, all steel tank manufacturers have issued signed letters indicating compatibility with E100, as have fiberglass tanks manufactured in the last ten years.[7] The only potential issue would be older fiberglass tanks, where compatibility and manufacturer approval for use depends on age, manufacturer, and whether the tank is single- or double-walled.[8]

Particularly since EPA promulgated its recent underground storage tank rule, EPA has increased efforts to ensure stations have documentation to show that the tank is approved. This may be a concern for older stations. However, in the past two years, tank and equipment manufacturers have made strides toward updating their records for older equipment design and the types of materials used and supplying this information to the station owners. In fact, EPA's rule has created a cottage industry of consultants willing to help the station owner meet the documentation requirements for EPA, fire marshal, and insurance purposes. While this service comes with a cost, it is generally cheaper than replacing the equipment and Stillwater's cost estimates should cover these expenses.

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[5] Johnson, C. and Melendez, M. *E85 Retail Business Case: When and Why to Sell E85.* NREL. December 2007. http://www.afdc.energy.gov/pdfs/41590.pdf

[6] DOE EERE. *Clean Cities – Building Partnerships to Reduce Petroleum Use in Transportation.* http://www1.eere.energy.gov/cleancities/

[7] Moriarty, K., Yanowitz, J., *E15 and Infrastructure*, NREL. May 2015. http://www.afdc.energy.gov/uploads/publication/e15_infrastructure.pdf

[8] There is no specific limit on how long a tank can last until it must be replaced. Tanks now have leak detection and corrosion monitoring, so they can be monitored and replaced before failure. Under the right conditions many tanks last 30 years or longer, but there are some locations where a tank is unlikely to last for 20 years.

Method 1 is the lowest-cost path and the one we focus on. NREL has estimated the cost of the underground work associated with Method 1 as $15,000, and thus $30,000 to complete the conversion, i.e., including the new E85 dispenser.[9]

Cost to add an E85 dispenser at an existing E85 station. Adding another E85 dispenser to an existing E85 station is cheaper because the only expense is the new dispenser—$15,000 if it is an E85 dispenser. The station will already have the necessary tank and associated piping and equipment.

Taking advantage of the natural replacement cycle. Whether upgrading an E10-only station or an existing E85 station, the effective cost can be reduced by taking advantage of the typical replacement cycle. Gasoline stations generally replace their dispensers every seven years.[10] Upgrading infrastructure to support E85 in conjunction with ordinary infrastructure replacement reduces the upgrade cost to its marginal cost over the regular replacement cost. Since the cost of an E10 dispenser is $10,000, the marginal cost of the upgrades described above can be reduced by this amount.

The consumption that could be supported simply by taking advantage of the ordinary replacement cycle to upgrade to E85 is sizeable. There are about 155,000 stations in the United States, which means that about 22,140 stations are replacing their dispensers every year. Of course, not all the replacement occurs on January 1; it is spread over the year. Assuming that this replacement cycle occurs ratably over the year, i.e., at a constant rate, 1,845 stations replace their dispensers every month. If EPA sent a strong signal to the market through the RFS and even one third of these already-upgrading stations upgraded to offer E85 with one dispenser, then that would mean an additional 7,380 stations offering E85 at the end of 2017, or (assuming ratable installation over the year) the equivalent of an additional 3,690 stations operating for all of 2017. Given the throughput discussed above of 45,000 per dispenser per month those stations could deliver an additional approximately two billlion gallons of E85 over the course of 2017.

It is reasonable to assume that the industry could hit the ground running on January 1, 2017, because the final 2017 RFS rule would give it a one-month lead time to prepare.

Existing activity to expand E85 infrastructure. Expansion of E85 infrastructure is already underway. As noted above, EPA expects the BIP program to add 1,486 E85 stations. Through BIP and “Prime the Pump,” many large independent chains are working to significantly increase the number of E85 stations, including Sheetz, Kum & Go, Murphy USA, Protec Fuel, Thorntons, MAPCO, Minnoco, Cenex, and RaceTrac. And other chains that have worked to expand E85 capabilities significantly include Speedway, Kwik Trip, Spinx, Rebel Oil, Break Time (MFA), MFA Oil, Meijer Gas, Super Pantry, Bosselman's Pump & Pantry, Kroger, Petro Serve USA, and Road Ranger.

2.3 Transporting Additional E85

While the distribution system must move four gallons of E85 for every three gallons of gasoline, most of the E85 will move from local ethanol production facilities or ethanol tanking facilities to the stations by truck. E85 is primarily blended at ethanol plants in the Midwest and mostly trucked to E85 stations that are close to the ethanol production facilities. Trucking assets will require some redeployment (from product terminals to ethanol plants or ethanol storage facilities) but this should not be a constraint on the distribution system. Rebalancing these truck transportation requirements results in little change to the overall number of trucks. Because the ethanol distribution system is already handling substantial ethanol volumes through E10, significant increases in ethanol consumption are possible without much impact on the gasoline or ethanol distribution system.

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[9] Moriarty, K., Johnson, C., Sears, T. and Bergeron, P. *E85 Dispenser Study*. NREL. December 2009. http://www.afdc.energy.gov/pdfs/47172.pdf

[10] Stillwater estimate. See Section 5.5.1 for details.

The station tankage for E85 should also not be a concern. Even for small stations, the station's largest tank is sized to move about 85 percent of the volume (regular gasoline) through the two dispensers in a day. If this becomes tight, the station will simply move to twice a day deliveries of E85.

E85 is primarily blended at ethanol plants in the Midwest and mostly trucked to E85 stations that are close to the ethanol production facilities. Because the ethanol distribution system is already handling substantial ethanol volumes through E10, significant increases in ethanol consumption are possible without much impact on the gasoline or ethanol distribution system.

3 Economics of E85 Infrastructure Changes

3.1 Single Station Single Dispenser Economics

The best way to examine the economics of E85 is through the eyes of a single station adding an E85 dispenser. This analysis will be for a station that already has three or more gasoline tanks. By adding E85 none of the current grades are lost, so the current station economics continue with the added margins from the new E85 to offset the added required investments.

Since dispensers are replaced about every seven years, we assume a project with a seven-year life. We examined three scenarios, described above:

1. Adding an E85 dispenser to an existing E85 station on the replacement cycle, which has an initial investment of $5,000;
2. Adding an E85 dispenser to an existing E85 station off the replacement cycle, which has an initial investment of $15,000;
3. Adding an E85 dispenser to an E10-only station off the replacement cycle, which has an initial cost of $30,000.

Using our assumption that a dispenser will move 45,000 gallons per month, we further assume that the new E85 dispenser will move 540,000 million gallons per year and 3.78 million gallons over the seven-year investment period.

We examine the economics with two rates of return: 10%, which is a reasonable target for independent stations; and 15%, which is a reasonable target for a large corporation.

In Table 3.1, a simple breakeven analysis of Scenario 1 reveals that the station needs to make 0.13 cents per gallon additional margin to recover the initial investment, an additional margin of 0.33 cents per gallon to earn a 10% return, and 0.38 cents per gallon to earn a 15% return. Given that these required margins are far less than one cent per gallon, the station owner should have little hesitation making this investment in E85, assuming that he believes there will be reasonable demand to fully utilize his E85 dispenser. We explain in more detail below the reasons to believe that this throughput can be achieved in light of demand patterns and the stations' optimal gross margin analysis.

Table 3.1 - Single Dispenser Economics for addition of second E85 Dispenser at Existing E85 station on replacement cycle

		FULLY UTILIZED E85 DISPENSER		
INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 5,000	7	3,780,000		0.13
$ 5,000	7	3,780,000	10%	0.33
$ 5,000	7	3,780,000	15%	0.38

Table 3.2 - Single Dispenser Economics for addition of a second E85 Dispenser at Existing E85 station off replacement cycle

		FULLY UTILIZED E85 DISPENSER		
INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 15,000	7	3,780,000		0.40
$ 15,000	7	3,780,000	10%	0.98
$ 15,000	7	3,780,000	15%	1.14

Table 3.2 shows the results under Scenario 2, where a second E85 dispenser is added at an existing E85 station *off* replacement cycle, i.e., paying the full cost for the upgrade rather than just the marginal cost. The $15,000 cost for adding a second dispenser at existing E85 stations represents 0.40 cents per gallon on a simple breakeven basis, 0.98 cents per gallon for a 10% rate of return, and 1.14 cents per gallon for a 15% rate of return. While these margin increases are around one cent per gallon and slightly higher, this should still be an easy investment decision for the station owner to make. The only assurance that a station owner would need under these circumstances, is that there will be sufficient demand for E85.

Table 3.3 - Single Dispenser Economics for addition of a new E85 Dispenser at Existing E10 station off replacement cycle

		FULLY UTILIZED E85 DISPENSER		
INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 30,000	7	3,780,000		0.79
$ 30,000	7	3,780,000	10%	1.96
$ 30,000	7	3,780,000	15%	2.29

Table 3.3 shows the results under Scenario 3, where an E85 dispenser is added at an existing E10-only station off replacement cycle. The $30,000 cost for adding a new E85 dispenser represents 0.79 cents per gallon on a simple breakeven basis, 1.96 cents per gallon for a 10% rate of return, and 2.29 cents per gallon for a 15% rate of return. These margin increases required are above the one cent per gallon threshold used by station owners and as such would require serious decision making by the station owner. The station owner would have to expect to capture additional RIN value through higher E85 margins or attract additional new volumes to make this kind of investment.

Tables 3.1, 3.2, and 3.3 demonstrate the E85 economics if the dispenser is fully utilized. What do the economics look like at less than full utilization? Table 3.4 shows not surprisingly that the station needs double the margin increase if the dispenser is only half utilized. Thus the station owner deciding to add an E85 dispenser must worry not only about the additional margin needed to pay off his investment but also about how much each dispenser is used.

Table 3.4 - Single Dispenser Economics under scenario 3 where the new E85 dispenser added at the previously E10-only station has 50% dispenser utilization

		50% UTILIZED E85 DISPENSER		
INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 30,000	7	1,890,000		1.59
$ 30,000	7	1,890,000	10%	3.91
$ 30,000	7	1,890,000	15%	4.58

Table 3.5 below reveals some insights about existing E85 stations. Again using Scenario 3, this table shows that at low throughputs the margin required to pay off investments is in the $0.20 per gallon range. It could be said that station owners are not gouging the E85 customer or failing to pass on enough of the RIN value but are simply holding on to the high E85 margin because it is needed to pay off their investment due to the very low E85 throughput per station.

Table 3.5 Single Dispenser Economics for addition of a new E85 Dispenser at Existing E10 station (off replacement cycle) with 10% dispenser utilization

		10% UTILIZED E85 DISPENSER		
INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 30,000	7	378,000		7.94
$ 30,000	7	378,000	10%	19.56
$ 30,000	7	378,000	15%	22.89

4 How to Increase Sales at Existing E85 Stations

Past characterizations of E85 consumers have assumed they are a single group that follow standard economic rules. Here, we explore a logical segmentation of E85 customers to better explain observed demand patterns versus price, then extend this model by estimating gross margin in the supplier-retailer chain to explain observed retail pricing behavior. In the current pricing situation between gasoline, ethanol, and RIN prices, dealers and retailers are pricing E85 higher than energy parity with E10 because this price level generates the largest gross margin. A combination of higher RIN price and lower ethanol-relative-to-gasoline price can change this optimum price point to increase E85 sales volume dramatically from current levels. The RIN price required to increase sales volume in the short to mid-term by changing pricing behavior and over the long term by providing incentives to build E85 fueling infrastructure is calculated below. EPA can create the environment for this E85 growth by setting 2017+ obligations for ethanol high enough to sustain these necessary RIN values.

4.1 Customer Segmentation

The different sloped lines obtained by Korotney in “Correlating E85 Consumption Volumes with E85 Price” are in part due to different geographies, but are also likely to be due to different types of potential customers who react differently to price. For example, demand in California appears to have no response at all to price. This is inconsistent with behavior of the typical price-seeking consumer. Also, all other states show a small but steady increase in demand for E85 when prices are higher than energy parity with E10. (See Appendix.) A purely price-seeking consumer who is aware of this would not purchase E85 until it was priced at or below energy parity. In fact, there are a number of reasons to believe that such a price-seeking consumer would only start to increase E85 consumption when the price is somewhat below parity due to the inconveniences of refueling more often and traveling farther to find E85, which is currently only sold at about 2% of retail sites. Variations in E85 energy content (since ethanol content varies from 51% to 81%) also complicates the decision, so the consumer may also require a bit more of a discount.

To account for these issues, we have developed a working hypothesis based on our extensive experience with the retail gasoline market on how to segment E85 customers in a way to better account for the observed buying behavior. Our estimates of the customer breakdown can be summarized as in the following table:

Table 4.1 – Estimates of Customer Breakdown

Segment	**Description**	**% of FFV Owners**	**% of Current E85 Demand**	**Total US Vol. Demand Available, (mgy)**	**Vol. Per site per mo.**	**Price Point**	**Notes**
Committed	Either Brand or contractually obligated to consume.	0.5%	30%	50	1,400	Doesn't matter	Includes federal, state and municipal fleets or businesses who have committed to E85.
Believers	Believe it's the right thing to do. Will consume if price approaches energy parity.	3%	60%	300	8,400	Sliding scale that increases from 5 to 25% discount from E10	Supporters of renewable fuel, some farmers or other corn proponents. Also could be car renters who fill up before returning FFVs.
Mass Consumers	Price takers will consume when economical, including price, convenience and risk.	93.5%	10%	93500	262,000	Sliding Scale from 25% to 50% discount from E10	Most consumers try to buy the best fuel for the money, but are influenced by other issues too.
Disbelievers	Will not consume, regardless of price.	3%	0%	0	0	Begins only at steep discounts of 40% or more	No need to consider this group.

Some corroboration of this model is provided by EIA data which show that federal and state fleets consumed nearly 44 million gallons of E85 in 2014, which is about 27% of estimated total consumption[11,12].

It is important to realize that there are many ways to segment fuel customers along completely different dimensions. Also note that the distribution will vary by geography, and the number of consumers in each segment can only be roughly estimated. However, despite these limitations, this structure accounts for many observations of demand response to price, and enables additional investigation of phenomena at the dealer-customer interface.

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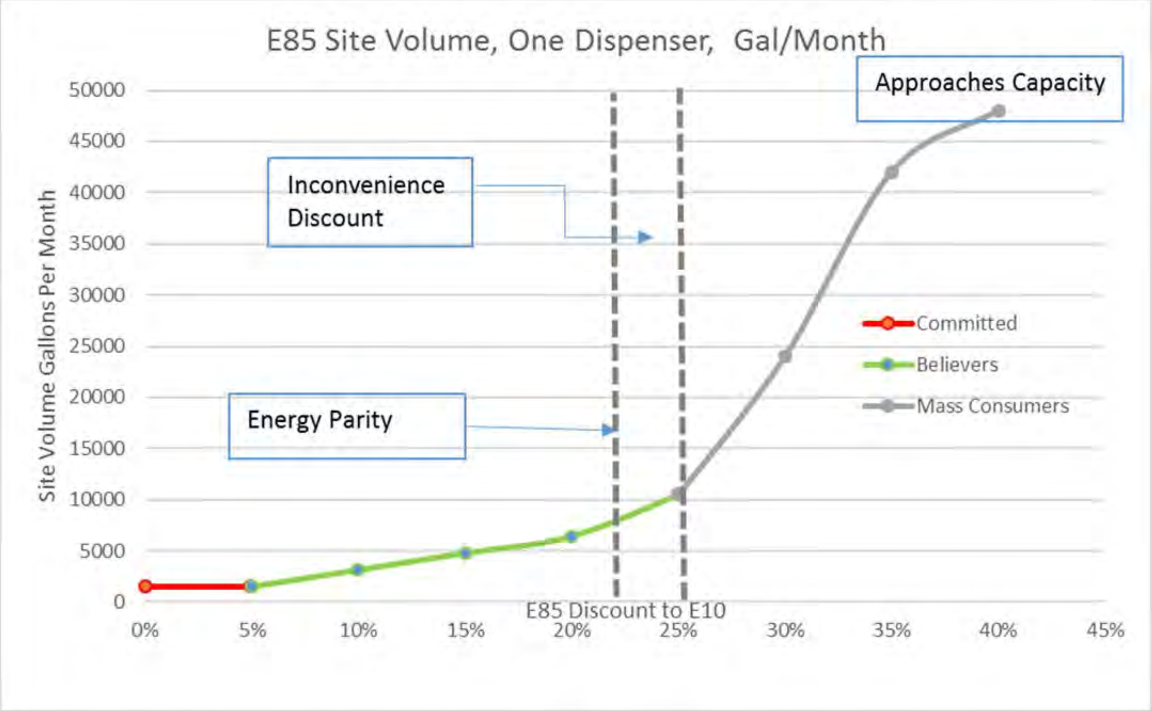
[11] EIA. *Federal Fleet Fuel Consumption Data*. http://federalfleets.energy.gov/performance_data#waivers

[12] EIA. *State Fleet and Fuel Data.* http://www.eia.gov/renewable/afv/users.cfm?fs=a&ufueltype=e85

This model leads to a volume curve for a one-dispenser E85 site which has a customer base representing the U.S. as a whole to look something like this:

Figure 4.1 – E85 Site Volume, One Dispenser



To test how reasonable these results are, consider how the left half of this curve looks like the regression analyses for each of the five states analyzed in Korotney's analysis.[13] California looks like the very far left part of the curve only because so much of the demand there is by consumers committed to its use. The other four states look very much like the part of the curve shown for the Believers with small positive slopes. The overall slope of this part of the curve is consistent with Korotney's results. Consider the demand response we attribute to Mass Consumers on the right hand side of the curve. If E85 were discounted by 35% to E10, only 15% of the owners of FFVs (or 16% of those we are calling Mass Consumers) would be needed to create demand ten times larger than today's typical demand of less than 5,000 gallons per month. Based on the work by Babcock and Pouliot in 2013 (with lower station counts and a small FFV fleet than exist today), more than 30% of FFVs are located within five miles of an E85 station, so attracting half of these local FFVs with E85 discounted to only 65% of E10 price seems very reasonable if not conservative.

Drawing from our experience in the industry, we also believe that the right-hand side of the curve is reasonable, assuming that the discounts shown persisted in a sustained pricing environment (e.g., as would occur if EPA meaningfully changed how it implemented the RFS). In our experience, customers are very price-sensitive. For example, we have seen evidence of significant customer movement when different retailers engage in price wars over gasoline. Similarly here, once the inconvenience of E85 is compensated for below energy parity, we would expect retailers to market the price savings and for FFV owners to take advantage of them. Indeed, if E85 were discounted by 35% to E10, only 15% of the owners of FFVs (or 16% of those we are calling Mass Consumers) would be needed to create demand ten times larger than today's typical demand of less than 5,000 gallons per month. As stated above, based on the work by Babcock and Pouliot, more than 30% of FFVs are located within five miles of an E85 station (and 55% of FFVs are located within ten miles).

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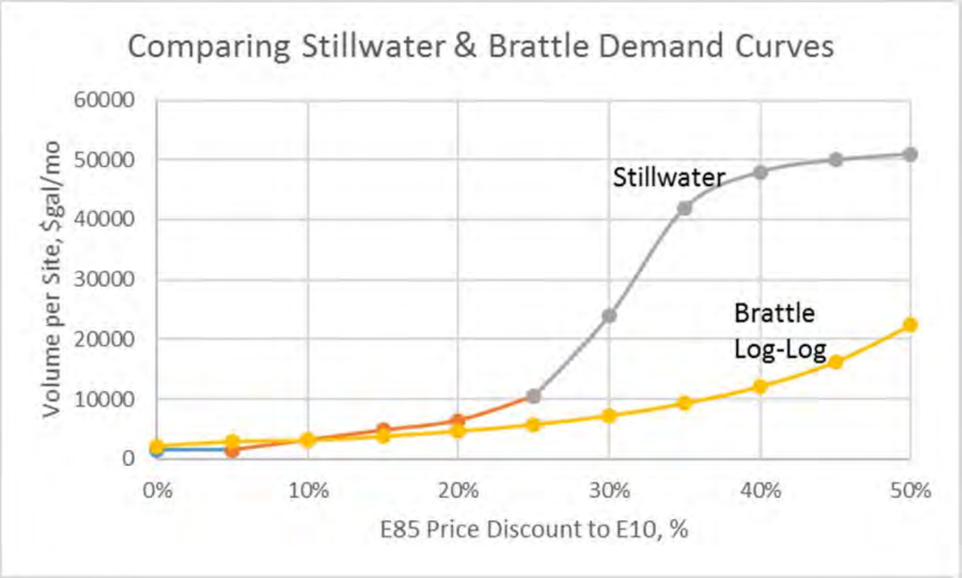
[13] "Memo to docket on Correlating E85 consumption volumes with E85 price," memorandum from David Korotney to EPA Air Docket EPA-HQ-OAR-2015-0111.

The graph below contrasts Brattle's[14] log-log curve with Stillwater's assessment:

Figure 4.2 Comparing Stillwater and Brattle Demand Curves



Note how similar the curves are in the range below the point of E85 energy parity which occurs at an E85 discount of about 22% to E10. These should agree at this point because there are ample observations of consumer behavior to correlate it with price. The area where the two demand curves diverge is where there is not enough data to discern price behavior. Accordingly, the Brattle demand curve is a reasonable extrapolation of the existing data that show the beginning of change near energy parity. However, Stillwater's customer segmentation analysis predicts that there should be a distinct change in demand response to price as the price discount to E10 increases below energy parity because price seeking customers begin to see better value, and we believe these are the vast majority of FFV owners.

There is another difference between these curves that is important to realize. To achieve strong demand at E85 discounts of 30% or more to E10 there are two key requirements. First, local FFV owners will need to know where to find the E85 site. Second, FFV owners will need to know that E85 will be consistently priced at levels that make it attractive relative to E10. We believe this level is 25-30% below E10, but in reality it is related to other factors including general price level, local competition for E85 sales, and local concentration of FFVs. Consumers will not drive around looking for the single local E85 site if it is often more expensive to use than E10.

Next, we examine the incentives that fuel suppliers and retailers have for pricing E85 by looking into the gross margin available to them. We'll first consider the situation with recent prices with the Stillwater demand curve and later generalize the predictions for a range of prices with the use of Brattle's log-log price curve.

4.2 Gross Margins

If dealers will not discount E85 by more than 25% relative to E10, how does this matter? To explore this issue, we have created a simple model of retail pricing to estimate gross margins in

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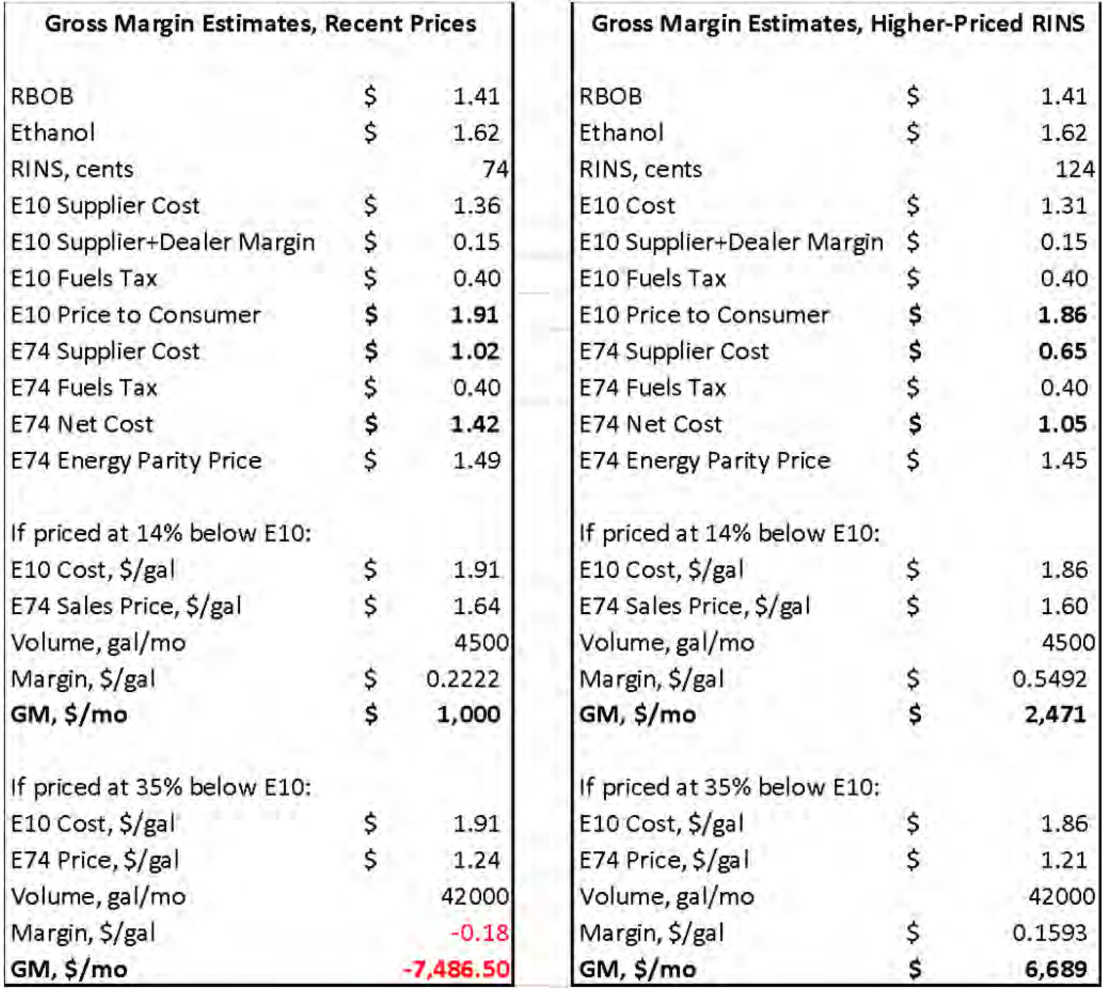
[14] **Peeking Over the Blendwall** An Analysis of the Proposed 2017 Renewable Volume Obligations The Brattle Group July 11,2016

the supply chain with the following assumptions (using 2016 average prices in Los Angeles through June as a proxy):

- Ethanol Price = $1.62/gallon
- Gasoline (BOB) Price = $1.41/gallon
- Ethanol RIN Price = 74 cents
- Supplier E10 Margin to Retailer = 5 cents per gallon (cpg)
- Retailer E10 Margin = 10 cpg
- E85 volumes according to the above curve
- Gross margin calculated across fuel supplier and retailer
- Fuels tax = 40 cpg*[15]

Using these assumptions, we calculate E85 gross margins for two cases shown on the left priced at 14% and 35% discounts to E10. On the right we do the same calculations but with the RIN price increased from 74 to 124 cents.

Figure 4.3 – E85 Gross Margin Estimates



Gross Margin Estimates, Recent Prices		
RBOB	$	1.41
Ethanol	$	1.62
RINS, cents		74
E10 Supplier Cost	$	1.36
E10 Supplier+Dealer Margin	$	0.15
E10 Fuels Tax	$	0.40
E10 Price to Consumer	**$**	**1.91**
E74 Supplier Cost	**$**	**1.02**
E74 Fuels Tax	$	0.40
E74 Net Cost	**$**	**1.42**
E74 Energy Parity Price	$	1.49
If priced at 14% below E10:		
E10 Cost, $/gal	$	1.91
E74 Sales Price, $/gal	$	1.64
Volume, gal/mo		4500
Margin, $/gal	$	0.2222
GM, $/mo	**$**	**1,000**
If priced at 35% below E10:		
E10 Cost, $/gal	$	1.91
E74 Price, $/gal	$	1.24
Volume, gal/mo		42000
Margin, $/gal		-0.18
GM, $/mo		**-7,486.50**

Gross Margin Estimates, Higher-Priced RINS		
RBOB	$	1.41
Ethanol	$	1.62
RINS, cents		124
E10 Cost	$	1.31
E10 Supplier+Dealer Margin	$	0.15
E10 Fuels Tax	$	0.40
E10 Price to Consumer	**$**	**1.86**
E74 Supplier Cost	**$**	**0.65**
E74 Fuels Tax	$	0.40
E74 Net Cost	**$**	**1.05**
E74 Energy Parity Price	$	1.45
If priced at 14% below E10:		
E10 Cost, $/gal	$	1.86
E74 Sales Price, $/gal	$	1.60
Volume, gal/mo		4500
Margin, $/gal	$	0.5492
GM, $/mo	**$**	**2,471**
If priced at 35% below E10:		
E10 Cost, $/gal	$	1.86
E74 Price, $/gal	$	1.21
Volume, gal/mo		42000
Margin, $/gal	$	0.1593
GM, $/mo	**$**	**6,689**

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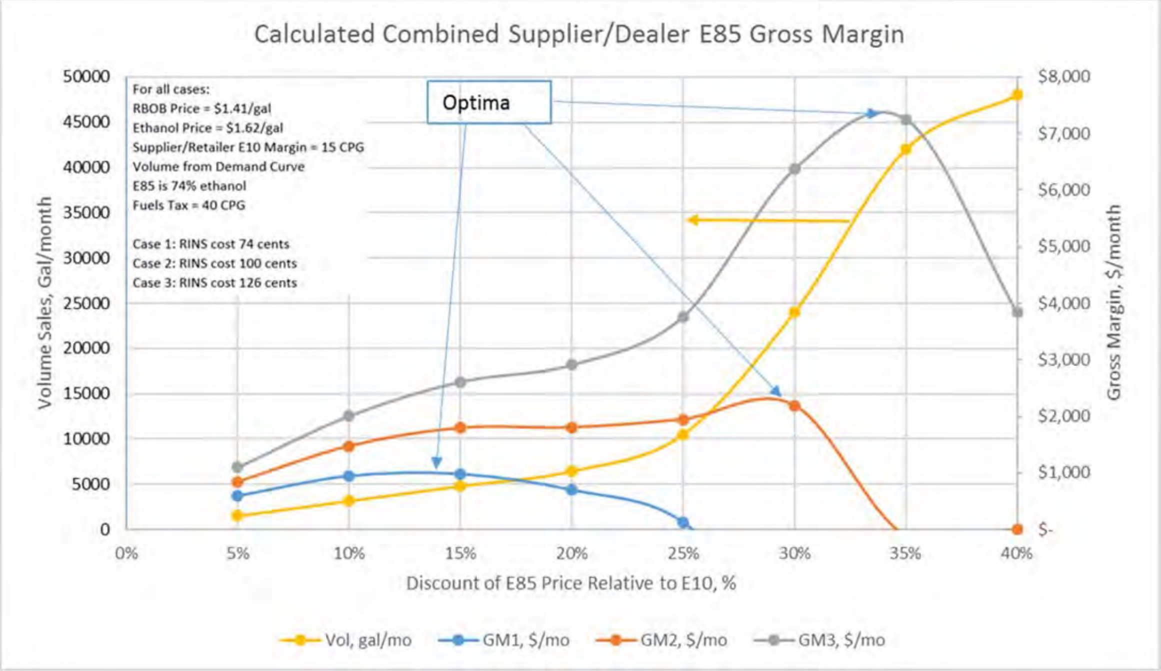
[15] (Fuels taxes vary dramatically by state, and in many states are lower for E85 than for E10.[15] Here we assume a moderate volumetric tax of 40 cents on every gallon of fuel. This penalizes E85 relative to E10 since the 22% higher volume of E85 needs to be purchased results in 22% higher taxes per mile driven. If the fuels tax is implemented as a sales tax based on a percent of sales price and E85 is priced below energy parity to E10, then it actually favors E85 slightly.) The following link: http://www.ncsl.org/research/transportation/taxation-of-alternative-fuels.aspx#one for the National Council of State Legislatures lists much of the data on state taxes.

The first case shows a gross margin (“GM”) of $1,000/month for pricing above energy parity at a 14% discount to E10 price. It also shows a negative margin at a much steeper discount of 35% relative to E10 because the dealer would have to price below cost in order to attract the price seeking consumers. Clearly, E85 cannot be economically priced below energy parity with these price assumptions. In the second case, all of the assumptions are identical except that RINs are priced much higher at 124 cents. In this case, the gross margin increases 170% with the deeper discount because the increased volume more than overcomes the decreased margin per gallon sold. Note that the optimum E85 sales price with higher RIN prices (and constant RBOB prices) is significantly lower. With only a change in RIN price, the dealer can profitably increase gross margin by selling more E85 at a much lower price. Also note that this increase in E85 sales can occur without increases in retail infrastructure. Last, note that this also results in more competitive E85 pricing without more E85 competition. This happens because E85 becomes price competitive with E10 so that consumers with FFVs will choose to fill with E85 because it less expensive for them.

While the E85 dealer may lose some of his E10 business to E85, because only 2% of retail sites have E85 it is more likely that he will increase overall site volume and profitability by attracting FFVs that were being filled at competitors’ sites. It may be pointed out that this is the gross margin across the fuel supplier and retailer, so that the retailer may not be able to set his price at the joint optimum. However, both supplier and marketer have incentives to find this price point even if the margin is not shared equally. The additional benefit to the retailer from increased site traffic further increases the chances of finding a price point that results in increased sales volumes.

We repeated calculations like those above to estimate GM as a function of price point and the impact of RIN prices in the 2016 price environment, as shown in the following figure:

Figure 4.4 – Calculated Combined Supplier/Dealer E85 Gross Margin



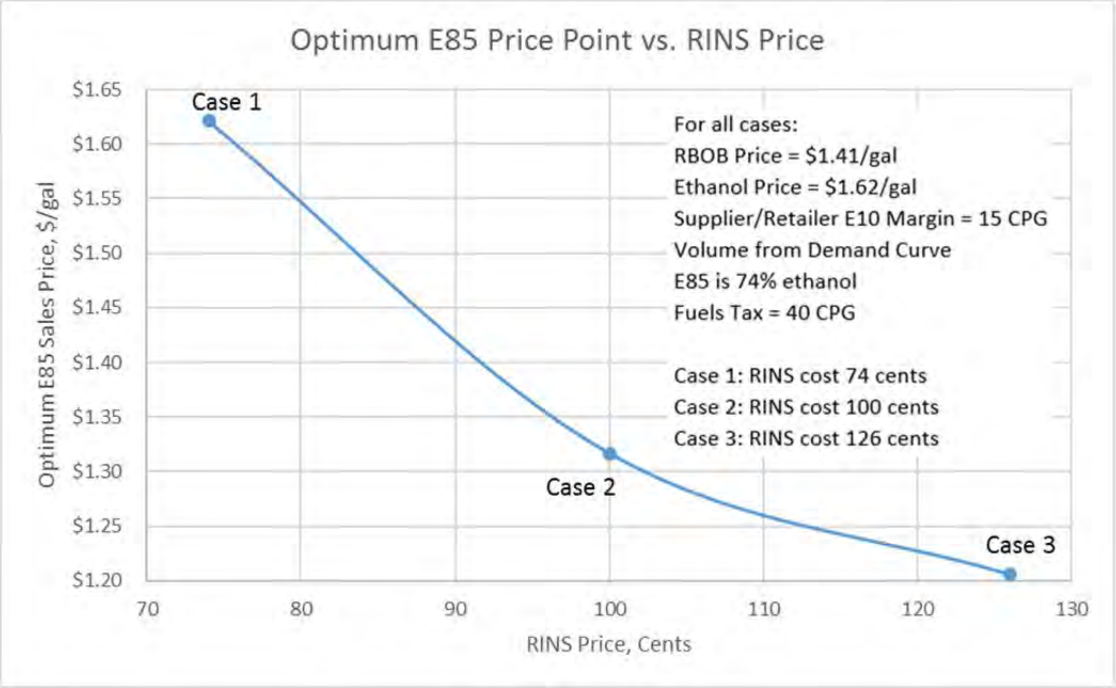
For all cases:
RBOB Price = $1.41/gal
Ethanol Price = $1.62/gal
Supplier/Retailer E10 Margin = 15 CPG
Volume from Demand Curve
E85 is 74% ethanol
Fuels Tax = 40 CPG

Case 1: RINS cost 74 cents
Case 2: RINS cost 100 cents
Case 3: RINS cost 126 cents

The yellow line is the volume curve derived from the customer segmentation analysis. The blue line shows the GM curve that an E85 retailer would expect in the assumed pricing environment. The 2016 environment, with ethanol priced above gasoline, is difficult for E85 marketing. Margins tend to be low and with RINs priced at 74 cents, the E85 price point that optimizes gross margin is very close to the 14% below E10 observed recently. This indicates that E85 marketers are pricing to maximize gross margin as we would expect, and gives another validation for the structure of this model. This figure also shows that GM increases with RIN price and that optimum GM increases even more with higher RIN prices when the sales price is discounted more heavily.

Increasing the RIN price from 74 to 100 cents results in a doubling of GM with five times the sales volume. Increasing the RIN price further to 126 cents results in nine times both the gross margin and sales volume with reduced E85 sales prices. The trend is shown in the graph below:

Figure 4.5 – Optimum E85 Price Point vs. RINs Price



This analysis demonstrates that high RIN prices increase E85 gross margins, providing incentives to build E85 infrastructure. They also (interestingly) provide incentives to price more competitively and sell substantially more volume in the short term. So E85 sales volumes can increase substantially in both the short term and the long term if RIN prices can be maintained at a specific level that is a function of the RIN price, and the relative price of ethanol to RBOB, and fuels tax rate. The RIN price needed to provide the right incentives for increased E85 sales varies with gasoline and ethanol prices as shown in the next section.

One last note on value pricing is that it has at times been very successful in the fuels market. ARCO was very successful for decades at pricing below other majors. At one point in time, a 5 cpg discount in street price was enough to enable an average volume per site that was double the industry as a whole. This enabled dealers to amortize fixed costs over twice the volume of competitors and resulted in increased site traffic that improved the profitability of AM/PM brand convenience stores located on ARCO sites. Today, an example of a successful value priced retail site is Costco, which has an average volume many times that of an average gasoline station. Value has been, and continues to be (along with quality, convenience, and others), one of the dimensions of differentiation in the retail fuel space. While these examples do not indicate what the price response to E85 will be, they do demonstrate that there are many consumers who are price conscious.

4.3 What RIN Price is Needed for Short Term Volume Growth

All of the calculations so far have been with a narrow range of fuel taxes, gasoline, ethanol, and RIN prices. In this section a wide range of these parameters will be used to show specifically what RIN price is needed so that the optimum retail price point is discounted by 30% relative to E10. With the Stillwater demand curve, this results in a site sales-volume increase of five times current average site volume when priced at a 14% discount to E10. Below are two graphs that show ethanol RIN price levels required using this simple model (the S curve from Figure 4.5) to increase E85 sales volumes by a factor of five from 4,800 gallons per month to 24,000 gallons per month.

Figure 4.6 – RINS Price that Causes E85 to be Priced at 30% Discount to E10 (Ethanol Price)

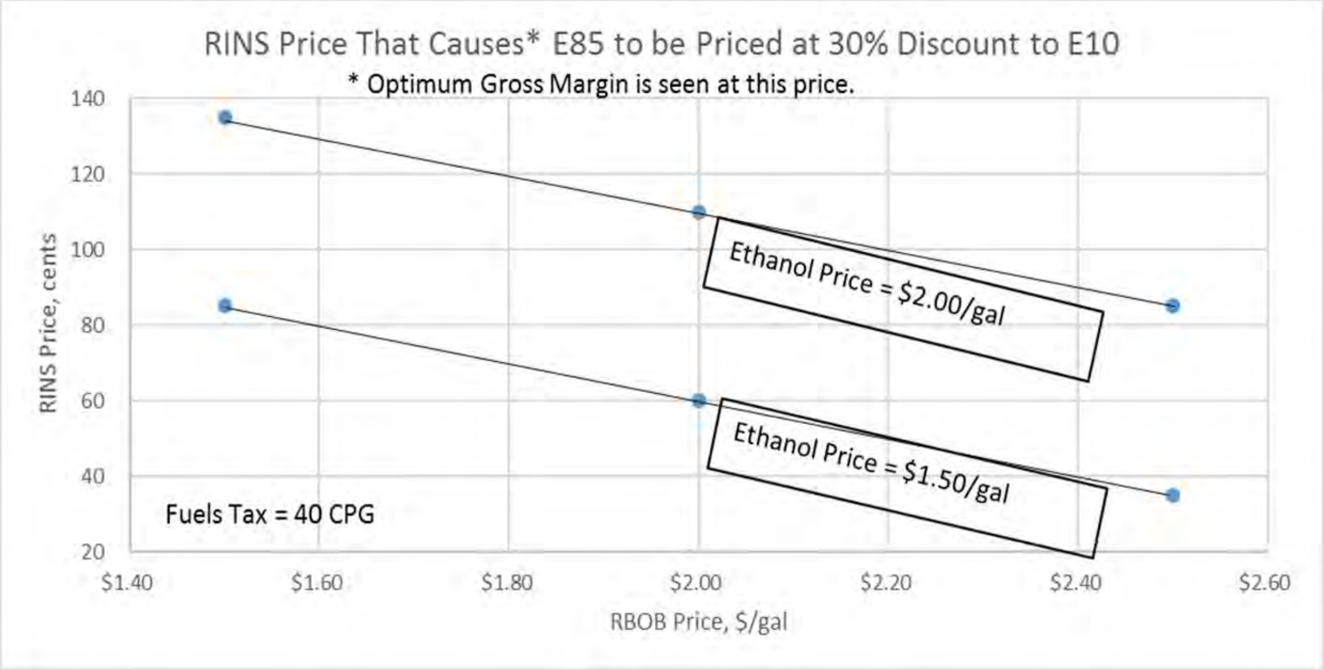
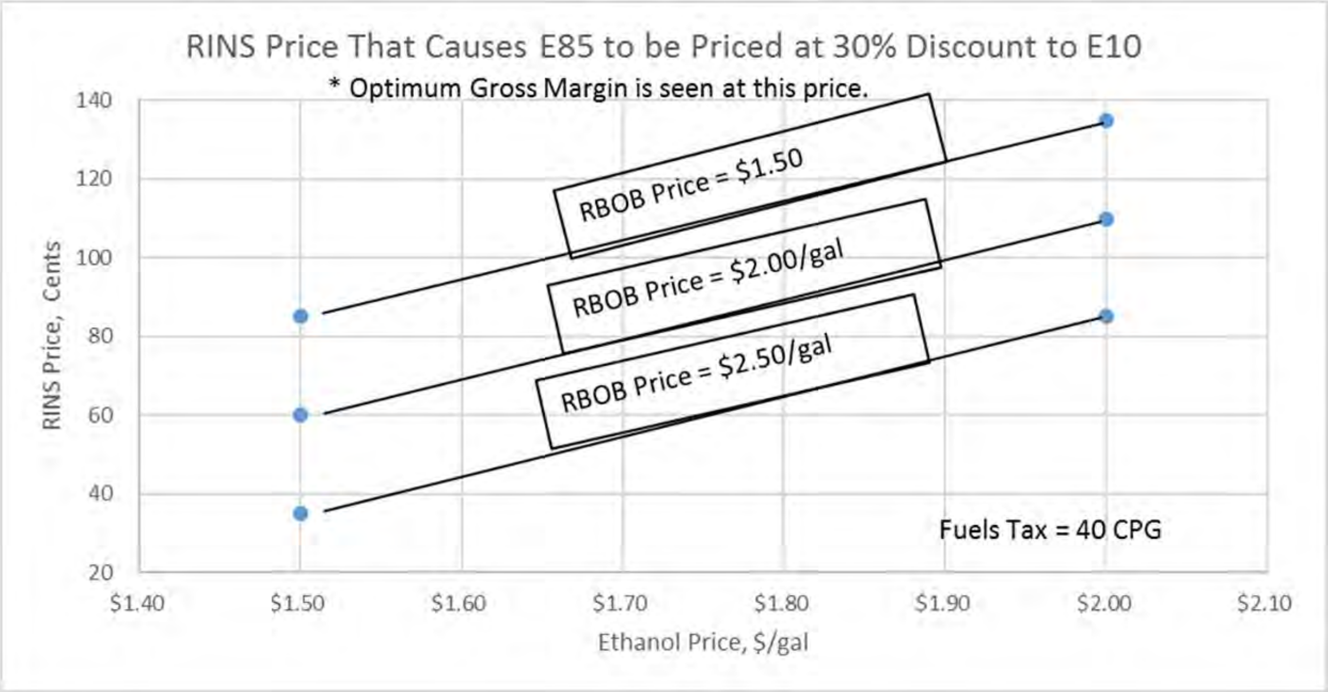
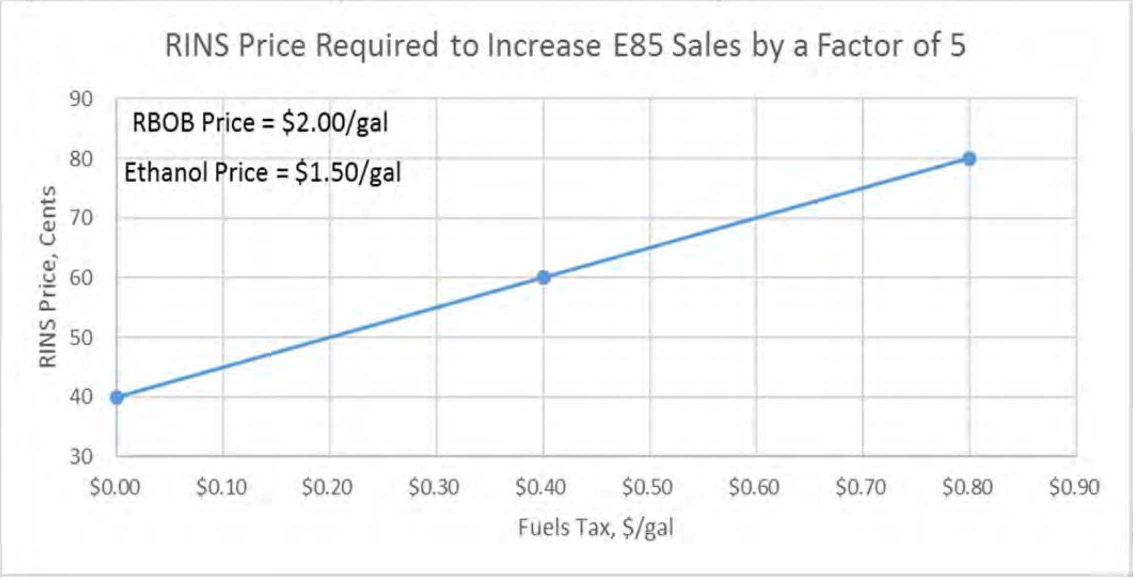


Figure 4.7 – RINS Price that Causes E85 to be Priced at 30% Discount to E10 (RBOB Price)



The graph below shows the impact of Fuels Tax level on RIN price required to increase E85 sales by a factor of five:

Figure 4.8 – RINs Price Required to Increase E85 Sales by a Factor of 5



From these analyses, we can make the following generalizations for what is needed to provide incentives to increase E85 sales by five times at existing infrastructure from current levels while holding the other parameters constant:

- A 50 CPG increase in gasoline price reduces RIN price needed by 25 cents.
- A 50 CPG increase in ethanol price increases RIN price needed by 50 cents.
- A 50 CPG increase in fuels tax increases RINS price needed by 25 cents.

The last key point here is that the RIN values needed to effect this type of behavior are in the range of $1.00 to $1.50. If gasoline prices return to their historical higher levels than ethanol, the price range is even lower.

These results are dependent on the demand curve used in the analysis. The next section briefly shows the impact of using a curve with lower demand response to price discounts

4.4 Impact of Different Demand Curves on Optimum Gross Margin

We repeated the analysis described in Section 4.2 using the Brattle log-log demand curve and summarize some of the key results in these two tables:

Figure 4.9 – Comparison of Stillwater and Brattle Log-Log Curves

Stillwater Curve Log-Log Curve			
RIN price, cents	Optimal Discount to E10, %	Volume per site, gal/mo	Passthrough, %
75	15%	4,800	89%
100	30%	24,000	108%
125	35%	42,000	98%
135	35%	42,000	92%
155	35%	42,000	81%
175	35%	42,000	73%

Brattle Log-Log Curve			
RIN price, cents	Optimal Discount to E10, %	Volume per site, gal/mo	Passthrough, %
75	5%	2,900	55%
125	5%	2,900	38%
135	25%	5,800	73%
145	30%	7,300	77%
155	35%	9,300	81%
175	45%	16,300	87%

(Note that the 108% pass-through when RIN prices are $1.00 reflects the fact that it became optimal for the dealer to discount E85 so much that it partially cut into the standard assumed retail margin.)

The first table shows results that were previously described. Notice how increasing RIN prices above 125 cents does not change the optimum site volume and cause RIN pass-through to decline. This is because the Stillwater price curve assumes that the station is approaching capacity so that the additional volume obtained by further discounting is not sufficient to offset the lower sales price. In other words, due to capacity constraints the demand curve is too shallow to provide sufficient incentive to lower price.

The second table using the Brattle demand curve shows RIN pass-through to decline with increased RIN price because of the same lack of demand response that would be observed when approaching site capacity. It is not until RINs are priced above 130 cents that GM increases enough to cause discounting, resulting is a large increase in RINs pass-through. The volume continues to increase with higher RIN prices because the demand curve gets continuously steeper, even if they continue to be much smaller than when using the Stillwater demand curve.

The lessons from this section are: gross margin optimization can effect higher E85 volumes for a range of demand responses; and the range of RIN prices needed to cause higher volumes is not much higher than those seen in the past.

5 E15 Analysis

In the E15 portion of this analysis, Stillwater describes the paths to expanding E15 infrastructure and assesses the cost of doing so. Next Stillwater analyzes the investment costs in terms of rates of return and the need for increased margins from the point of adding a single new dispenser. Finally, Stillwater discusses the present need to expand E15 much like E85 given that E15 is not currently available at the product terminal.

5.1 Expanding Infrastructure to Deliver E15 in 2017

Like E85, infrastructure for E15 could also be expanded in 2017 to support much higher volumes. We here examine the cost of adding E15 pumps, much as we did with E85 above. Key issues are, again, having compatible pumps, having compatible tanks, and taking advantage of the regular 7-year replacement cycle. Although the conversion process for E15 might be more complicated than for E85, station consultants are now appearing who will help stations get the required documentation and certifications for E15. The costs for these consultants is typically less than the cost for replacing the hardware and equipment, so Stillwater replacement cost estimates below would still be conservative relative to the cost of converting with the help of a station consultant.

5.2 The Time since the Last Dispenser Replacement is Important

Before 2010, E10 was limited to mainly the Midwest and most stations did not have to worry about ethanol compatibility. Even back then nearly all of the tanks were compatible with ethanol. However, many of the pipefittings and other systems were not ethanol compatible. Since that time E10 has become ubiquitous throughout the nation and most stations have become E10 compatible. For the most part E10 compatible equipment is also E15 compatible but many of the manufacturers have not taken all the steps to have their equipment completely certified or approved for E15, since it is not a commonly used fuel. Upgrade kits from the two dispenser manufacturers provide U/L certification for the dispenser and all the parts that are above the ground. Moreover, both dispenser manufacturers have stated that their dispensers are E15-compatible: Wayne has stated that all of their dispensers in the field are warranted for E15%; and Gilbarco has stated that all their dispensers since 2008 are compatible with E15%.

For the past two years, these manufacturers are now saying that they have determined that their E10 equipment is also E15 compatible or that some small gaskets, seals, hoses, etc. are all that have to be changed to become E15 compatible. There are still exceptions but they are diminishing and most of them can be fixed with upgrade kits (just like the dispensers) instead of having to replace the entire system. Key items that should be replaced with U/L E15 certified items or certified upgrade kits are the submersible turbine pump, the ball valve and the shear valve.

Stillwater has found that about every seven years, stations replace dispensers and upgrade any of the other supporting tank and piping systems if required. This means that stations that went through this upgrading within the last six years have already completed a majority of the steps to be E15 compatible. The dispensers in these stations will need to be upgraded to be E15 compatible and some of the tank support systems and the piping systems will need to be upgraded or replaced.

Stations that have not replaced their dispensers in the past six years are at risk of having older tank support systems and older piping systems and will have higher costs to upgrade or replace this hardware. Stations that have not replaced their dispensers in seven years should be replacing their dispensers in 2017 and, since E15 dispensers cost no more than E10 dispensers, these stations should have no additional dispenser costs. For these stations, the tank support systems and older piping systems will have the same costs as stations that have not replaced their dispensers in six years.

5.3 Station Costs to Upgrade to E15

Stations with two gasoline tanks that have been upgraded in the past six years or less and that are only converting from E10 to E15 would have to upgrade their two dispensers and would incur $1,000 in cost to modify any of the various tank systems. The total cost for these stations would be $5,000. Stations with two gasoline tanks that were upgraded seven years ago would have to make more modifications to the various tank systems and upgrade two dispensers for an additional $7,000. Total cost $11,000. Note that some of these stations may have already changed their tank systems and would only have a cost of $1,000. Table 5.1 shows the cost itemization for stations with two gasoline tanks.

Table 5.1 - Station Costs to Upgrade to E15 – Two Gasoline Tank Station

Two Gasoline tank station		
E15 Upgrade Costs		
6 years or less since last upgrade		
	2 E15 Upgrade kits+install	$ 4,000
	Piping & Tank system Changes	$ 1,000
	Total	**$ 5,000**
More than 6 years since last upgrade		
	2 E15 Upgrade kits+install	$ 4,000
	Piping & Tank system Changes	$ 7,000
	Total	**$ 11,000**
Would have upgraded in 2017		
	Piping & Tank system Changes	$ 7,000
	Total	**$ 7,000**

Stations with three or more gasoline tanks that have been upgraded in the past six years or less and that are only converting from E10 to E15 would have a $8,000 cost to upgrade their four dispensers and a $1,500 cost to modify the various tank systems. Total cost would be $9,500. Stations with three or more gasoline tanks that were upgraded six years ago would have to make more modifications to the various tank systems for an additional $8,000 plus the $8,000 cost to upgrade all four dispensers. Total cost $16,000. Note that some of these stations may have already changed their tank systems and would only have a cost of $1,500. Stations that were upgraded seven years ago would be replacing the dispenser and upgrading again in 2017 anyway. Since a new E15 dispenser has the same cost as an E10 dispenser, these stations have no dispenser costs to upgrade to E15. Their only costs are for piping and tank system changes, which is estimated at $8,000. Table 5.2 shows the costs for stations with three or more gasoline tanks.

Table 5.2 - Station Costs to Upgrade to E15 – Three Gasoline Tank Station

Three or more Gasoline tank station		
E15 Upgrade Costs		
6 years or less since last upgrade		
	4 E15 Upgrade kits+install	$ 8,000
	Piping & Tank system Changes	$ 1,500
	Total	**$ 9,500**
More than 6 years since last upgrade		
	4 E15 Upgrade kits+install	$ 8,000
	Piping & Tank system Changes	$ 8,000
	Total	**$ 16,000**
Would have upgraded in 2017		
	Piping & Tank system Changes	$ 8,000
	Total	**$ 8,000**

5.4 Costs for the Blender Pump Option

Stations with three or more gasoline tanks would have the option to install blender pumps that would give the station the option to offer E10, E15, E85 and perhaps E20 and E30. Also in cases where terminal blended E15 is not available, using a blender pump with E85 is the only available option (a circumstance discussed more below). The blender pump would cost $20,000 with $2,000 installation costs. Thus to install a blender pump and upgrade a single existing dispenser will have an additional cost of $22,000 for stations upgraded in the past six years and the same cost for stations with older upgrades. Of these older stations not upgraded in the past six years, half of them would be scheduled to replace their dispenser in 2017. The cost to these stations would only be the $10,000 blender pump cost above a regular dispenser.

One may be tempted to look at the lowest cost option. Using cost as the only criterion would seem to eliminate blender pumps but a business owner must also weigh the risks of their decisions. Adapting E10 dispensers to use E15 forces the station owner to be able to sell only E15 (and perhaps some E10 if not all dispensers are converted). Installing blender pumps in place of E10 pumps allows the station owner to sell E15, E85 and perhaps some other high ethanol grade; while still maintaining the ability to sell E10 grades. This kind of “cover your bets” approach has a lot of appeal to business owners. For this reason and because of terminal reluctance to sell blended E15, Stillwater believes that the installation of blender pumps will be the method of choice for stations wishing to get into the E15 or E85 business.

5.5 The Phase-In for 2017

Stillwater believes that with proper planning and notice, upgrades to E15 infrastructure could begin at the very beginning of 2017, with some initial attention. With the RFS rule being finalized at the end of November, December would be occupied by lining up engineering resources, hiring installation contractors and ordering replacement equipment and kits. Kits and parts need to be ordered and delivered and contractors lined up. It is necessary that the Fire Marshall be consulted and approval obtained. It is also necessary that EPA, OSHA, and state agencies be informed. Thus Stillwater assumes that no conversions are completed in 2016 and that the conversions are spread evenly over the appropriate time periods for the fuels being produced in 2017. While the first conversions may proceed slowly, it is expected that all the parties involved will quickly become proficient so that most of the conversions will be accomplished in a cookie cutter fashion. Assuming perfectly constant conversion across 2017 may be slightly optimistic because of the ramp-up time but we think the difference will be marginal. Note that some station owners have already gotten an early jump on their competitors and others may follow suit. As before, assuming ratable upgrades over 2017 equates to a constant number of pumps equal to about half the number of pumps that are eventually installed over the year.

5.5.1 E15 dispenser economics

Table 5.3 from the report shows three options for upgrading two E10 dispensers to E15 dispensers. Even using the most expensive of these options at $11,000 results in the rather modest margin increases shown in Table 5.3. Even to achieve a 15% rate of return only requires a modest increase of 0.342 cents per gallon.

Table 5.3 - Station Costs to Upgrade to E15 – Two Gasoline Tank Station

Two Gasoline tank station		
E15 Upgrade Costs		
6 years or less since last upgrade		
	2 E15 Upgrade kits+install	$ 4,000
	Piping & Tank system Changes	$ 1,000
	Total	**$ 5,000**
More than 6 years since last upgrade		
	2 E15 Upgrade kits+install	$ 4,000
	Piping & Tank system Changes	$ 7,000
	Total	**$ 11,000**
Would have upgraded in 2017		
	Piping & Tank system Changes	$ 7,000
	Total	**$ 7,000**

Table 5.4 – Rate of Return on Investment

INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 11,000	7	7,560,000		0.15
$ 11,000	7	7,560,000	10%	0.36
$ 11,000	7	7,560,000	15%	0.42

Table 5.5 - Station Costs to Upgrade to E15 – Three or More Gasoline Tank Station

Three or more Gasoline tank station		
E15 Upgrade Costs		
6 years or less since last upgrade		
	4 E15 Upgrade kits+install	$ 8,000
	Piping & Tank system Changes	$ 1,500
	Total	**$ 9,500**
More than 6 years since last upgrade		
	4 E15 Upgrade kits+install	$ 8,000
	Piping & Tank system Changes	$ 8,000
	Total	**$ 16,000**
Would have upgraded in 2017		
	Piping & Tank system Changes	$ 8,000
	Total	**$ 8,000**

Table 5.5 shows three options for upgrading four E10 dispensers to E15 dispensers. Even using the most expensive of these options at $16,000 results in the rather modest margin increases

shown in Table 5.6. Even to achieve a 15% rate of return only requires a modest increase of 0.31 cents per gallon.

Table 5.6 – Rate of Return on Investment

INVESTMENT	LIFE	THROUGHPUT	RATE OF RETURN	BREAKEVEN
	YR	GALLONS		CENTS PER GALLON
$ 16,000	7	15,120,000		0.11
$ 16,000	7	15,120,000	10%	0.26
$ 16,000	7	15,120,000	15%	0.31

5.6 The Upgrade Cost Until E15 is Available at the Terminal

The above discussion assumes that E15 is available at the product terminal. For now, that may not be the case. Terminals blend BOB's (RBOB, CBOB or any other BOB) according to the certification instructions received with the batch as part of the Bill of Lading. When a terminal receives a batch of BOB that is certified for E10 blending, it is illegal for the terminal to blend 15% ethanol with the BOB without recertifying the final blend as meeting all the relevant federal, state and local fuel specifications. Terminals simply don't have the laboratory equipment to do this kind of recertification. As a result, until refineries begin testing and certifying batches of BOB for meeting all gasoline specifications with 15% ethanol, terminals will remain extremely resistant to blending 15% ethanol. The exception to this may be RFG. EPA deems all pertinent EPA RFG requirements to be met when 15% ethanol is blended into an RBOB certified for 10% ethanol. However, without lab testing at the terminal or refinery certification for 155, the terminal has no mechanism to assure that all relevant gasoline specifications are being met. The proposed ASTM ballot dealing with E15 specifications may make this less of a problem for the terminals, if and when it gets final approval.

Instead, most E15 today is blended from E85 at the station level and thus expansion of E15 is largely captured by the simpler process described above for E85. The only difference is that a blender pump rather than an E85 pump would need to be installed. The typical blender pump costs $5,000 more than an E85 pump, and therefore all the cost scenarios described above for E85 expansion would be increased by $10,000 for two tank stations and $20,000 for three tank stations to support the installation of E15 infrastructure.

2.4 E15 Misfueling

In connection with on the 2014, 2015, 2016 final RFS rulemaking, EPA raised concerns that E15 station owners might be concerned about their potential liability for E15 misfueling. This is particularly ironic since EPA previously issued E15 rules defining specific steps for the station owner to take to mitigate misfueling concerns. In the intervening four years, the vehicle fleet has aged and now only 9% of the fleet is older than model year 2001 and more and more non-road engines are E15 compatible. In addition, over the past four years there have been many efforts by various sides of the E15 process to educate all types and ages of engine owners on the advantages of E15. If EPA's E15 misfueling mitigation procedures provided adequate protection in 2012, they should provide considerably more protection now that there are many fewer engines that are incompatible with E15 and there is a more knowledgeable public. Also, with each additional year that passes the number of engines that are of concern is significantly reduced.

Appendix A

1 Ethanol and Gasoline Overview

Ethanol-gasoline blends are governed by a myriad of federal regulations, state regulations, local regulations, product quality restrictions, ethanol distribution systems, product transportation systems, product storage systems, product delivery systems, retail delivery equipment, the physical properties of ethanol, and materials compatibility with ethanol. All of these factors will be addressed in this paper. The supply of ethanol and vehicle compatibility of ethanol-gasoline blends are factors that will not be covered in this paper.

Across the nation, the gasoline that is sold to consumers varies with the regulations and climate governing the area of sale. These regulations may be environmental, commercial or product quality based. Generally, gasolines fall into two major classifications, reformulated and conventional. Reformulated gasolines have rather strict compositional restrictions set by regulations while conventional grades do not have such restrictions although product quality standards apply. In addition to these major classifications, gasoline has volatility classes that limit potential vapor lock tendencies and/or regulatory restrictions to limit the vapor emissions. The American Society for Testing and Materials (ASTM) standards govern general gasoline volatility and assign geographical areas a volatility class based on season and location. ASTM volatility standards are not adopted by all states.

Regarding ethanol, there are four types of gasolines sold in the U.S.:

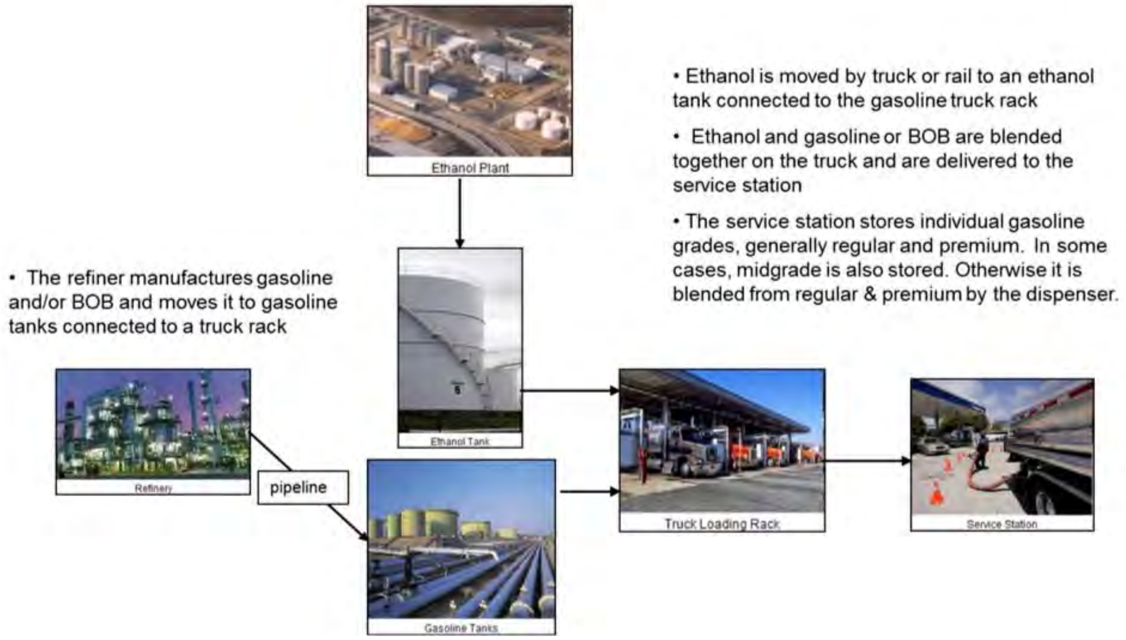
- Neat gasoline –Gasoline not containing ethanol. Neat gasoline sales volumes are small and limited to consumers that do not desire an ethanol blended gasoline. Alaska falls outside the RFS so gasoline in that state is neat.
- E10 – The predominant gasoline sold in the U.S. E10 contains approximately 10 volume percent of ethanol. It is produced by blending 10 percent ethanol with conventional gasoline where the Reid Vapor Pressure (RVP) waiver is effective, blending with a Blendstock for Oxygenate Blending (BOB) which is an unfinished gasoline that when blended with 10 percent ethanol will meet the applicable gasoline specifications, or blending with sub-octane gasoline which is a low octane unfinished gasoline that when blended with 10 percent ethanol will meet the required octane specifications.
- E15 – A gasoline containing 15 volume percent of ethanol. Starting in 2017 vehicles sold in the U.S. will as a practical matter be required to be compatible with this fuel, in light of EPA’s new Tier 3 vehicle rule.
- E85 – A fuel that is 51 to 83 volume percent ethanol. The balance of the fuel is hydrocarbon. This fuel can be used in Flexible Fuel Vehicles (FFVs). Sales of E85 have been limited by availability and price. Because ethanol contains two-thirds of the energy of hydrocarbon gasoline, the price of E15 and E85 must be lower than E10 gasoline for the consumer to achieve the equivalent cost per mile.

This paper will describe and examine the various factors governing the use of ethanol in gasoline, and describe the potential and the changes required to increase use of E15 and E85 by the vehicle fleet.

1.2 Overview of Gasoline Distribution System – from the Refinery to the Terminal

The gasoline distribution system, for the purpose of this study, begins at the refinery. The refinery produces finished gasoline or a BOB, depending on the destination requirements for the product. BOB is blended downstream to make E10.

Figure 1. Physical Flow of Gasoline, BOB and Ethanol



- Ethanol is moved by truck or rail to an ethanol tank connected to the gasoline truck rack
- Ethanol and gasoline or BOB are blended together on the truck and are delivered to the service station
- The service station stores individual gasoline grades, generally regular and premium. In some cases, midgrade is also stored. Otherwise it is blended from regular & premium by the dispenser.

- The refiner manufactures gasoline and/or BOB and moves it to gasoline tanks connected to a truck rack

Petroleum products leaving a refinery can be transported by tanker, barge, pipeline, railcar or truck. Fuel ethanol is somewhat different since it cannot be easily transported by pipeline. This restriction generally applies if it is shipped in neat form due to potential stress corrosion cracking, or, if it is shipped in a blend with petroleum products due to its tendency to phase-separate in the presence of water. As a result, fuel ethanol is usually shipped long distances by railcar, as part of either a manifest railcar or a unit train, from the ethanol production plant to the petroleum storage terminal or to an ethanol tanking facility where it is blended with unfinished gasoline to create E10 at a truck rack. From the truck rack, the E10 is trucked to the service station. The journey by railcar often terminates at a rail receipt hub where it is generally trucked to the petroleum storage terminal. Barges also move ethanol from the Midwest to the gulf coast. There are some exceptions involving marine vessels and dedicated short distance ethanol pipelines, but these exceptions are few in number.

1.2.1 The Marketing Storage Terminal

The terminal is the next link in the supply chain for refined product, detergent additives and fuel ethanol. Terminals in the U.S. receive gasoline product either by marine vessels or pipeline with shipping costs at approximately $0.07 to $0.12 per gallon. East Coast terminals are primarily either marine receipt terminals or pipeline terminals while the western U.S. terminals receive shipments by pipeline. The central region is composed of both marine along rivers and pipeline for the balance. Detergent additives are supplied by truck while fuel ethanol is delivered primarily by rail with exceptions in the Northeast and South where fuel ethanol is delivered by barge to some locations. Overall transportation cost for ethanol is approximately $0.25 per gallon because rail and truck movements are much more expensive than pipeline and barge movements.

Terminals can distribute gasoline via pipeline or through a truck loading rack. Terminals blend BOB or gasoline with ethanol as the delivery truck is loaded. The blending ratios are controlled by automated blending electronic meters that calculate the quantity of ethanol to be loaded. Existing systems are designed in most locations for a 10 percent injection rate. The truckloading rate of BOB and ethanol will vary but levels can be as high as 1,000 gallons per minute (gpm). The loading racks, in most markets, are open 24/7. Computer chip access cards control tank truck loading by identifying the account information and products authorized. The terminal operators are responsible for the accuracy and calibration of all systems including BOB, ethanol and detergent additives.

Terminals generally have multiple storage tanks and configure each tank service based on estimated market volumes and pipeline or marine delivery rates into the terminals. Loading rack plumbing and metering is designed for current volume and ratios. Once the product is loaded on the truck, the truck operator assumes responsibility for custody, quality and safety of the product. It is the duty of the truck operator to ensure that a tank truck is properly loaded with correct ratios of ethanol and detergent additives. Product custody is transferred to the retail or commercial site once the delivery to the designated storage tank is completed. The U.S. Department of Transportation (DOT) and EPA require bills of lading (BOL) to follow product to the final destination. Tank truck maximum volumes vary by state because some states like New York and Michigan grant overweight permits that allow trucks to deliver as much as 14,000 gallons, while other states like Massachusetts and Rhode Island grant waivers for lesser volumes. The Federal Highway Administration (FHWA) permits an 80,000 lbs. gross vehicle weight that equates to approximately 9,100 gallons depending on the design of the truck.

1.2.2 Retail Service Station

The service station retail site is the last link in the distribution system. There are approximately 153,000 service stations in the U.S.[16] Service stations vary in size but most will have at least two dispensers per island, specifically two cabinets with fueling nozzles on each side. Current data on underground storage tanks (USTs) is fragmented and inaccessible as a practical matter. It is captured by the states under multiple processes, using an assortment of data storage formats and reporting systems. In 1985 EPA did conduct a nationwide survey, The National Underground Storage Tank Survey, which specifically reported on tanks at service stations.[17] Although it is dated, because summary statistics from that report closely align with comparable summary measures from 2011 and 2012 U.S. and State Energy Act Reports, it was felt that the service station tank distributions reported in the older report would still have validity. The mean number of underground tanks at service stations was 3.5 to 3.6. EPA reported confidence intervals around those means that permitted a distribution to be estimated and portrayed as an integer distribution as shown in Figure 2.

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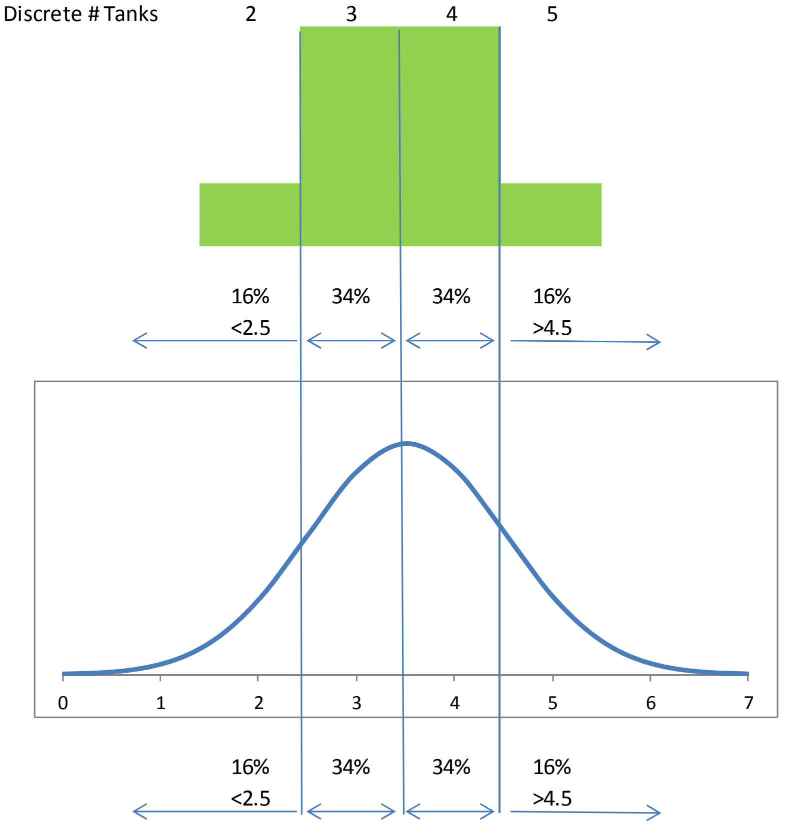
[16] API. *Oil and Natural Gas Overview – Service Station FAQs.* February 28, 2014. http://www.api.org/oil-and-natural-gas-overview/consumer-information/service-station-faqs

[17] EPA. *Underground Motor Fuel Storage Tanks: A National Survey*. May 1986. http://www.epa.gov/oust/pubs/USTsurvey.htm

Figure 2. Distribution of Service Station Underground Storage Tanks

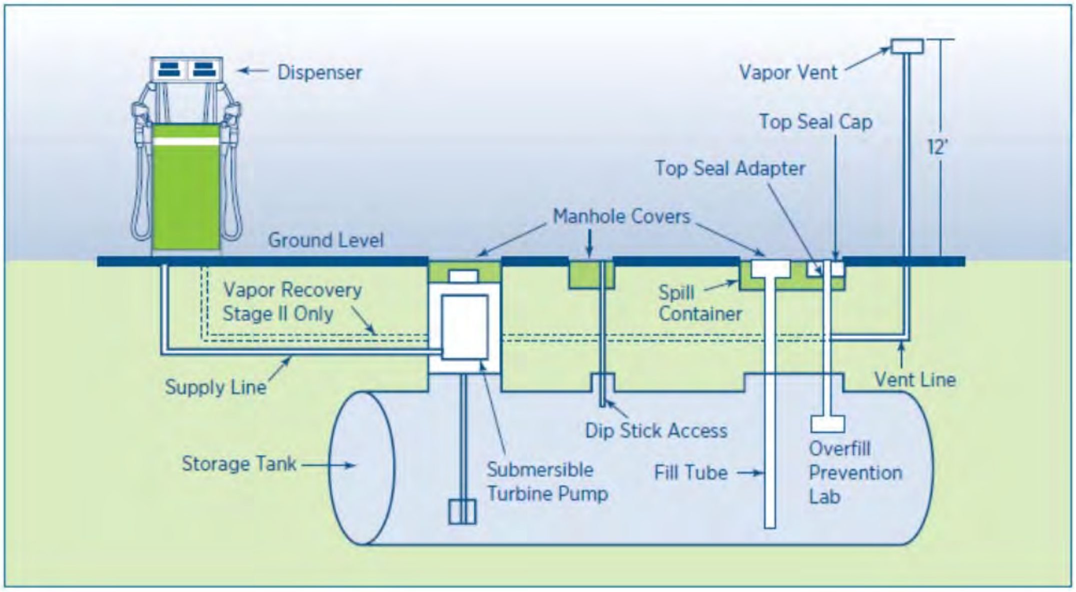


With respect to the incidence of three and four storage tanks per facility, the calculated distribution is roughly consistent with the results from a sample 203 stations separately surveyed by Stillwater in 2012.

Approximately 34 percent of existing service stations have three USTs and 34 percent have four USTs. At about half of U.S. stations diesel is stored in one tank. Locations with two gasoline tanks generally have one tank in the higher octane gasoline while the other tank contains lower octane gasoline which can be blended. Sites with three gasoline tanks usually have the higher volume selling grade assigned to two of the tanks or it has a tank in each Regular, Mid-Grade and Premium. Some stations may have diesel in the fourth tank.

There are around 3,100 stations that offer E85. A number of states in the Midwest have a small number of stations that have more ethanol grades available. The USTs at these E85 stations are typically double walled fiberglass, and come with an Underwriters Laboratories, Inc. (UL) rating and are monitored by State and Federal environmental protection agencies. The tanks contain submersible pumps that draw down as low as two inches from the bottom. Service station tanks range in size from 8,000 gallons to 12,000 gallons. In many cases, tanks are piped together. Tanks also have tank support systems, which provide leak detection, outage prevention and water level monitoring. Product is drawn from the tanks when the consumer activates the dispenser by selecting the desired grade. The dispenser, the cabinet that is mounted on the individual island, also contains blender equipment that signals to the pumps the volume necessary for the grade to be blended. The blender equipment, pumps, and associated equipment all have to meet UL standards to operate at posted blend levels (i.e. E10, E15, E85). This equipment is inspected and approved by local Weights and Measures agencies. Figure 3 shows a typical dispenser, underground storage tank and piping systems.

Figure 3. Typical Fuel Dispenser and Underground Storage Piping[18]



State and Local Government Regulations for Dispensing Equipment and USTs

State and local governments also play a role in regulating the safety of dispensing equipment and in implementing EPA's requirements for USTs.

For example:

- The Occupational Safety and Health Act (OSHA) allows states to develop and operate their own job safety and health programs. OSHA approves and monitors state programs and plans, which must adopt and enforce standards that are at least as effective as comparable federal standards. According to OSHA officials, there are currently 21 states with approved plans covering the private sector that enforce health and safety standards over the dispensing of gasoline within their respective states. Four additional states operate approved state plans that are limited in coverage to the public sector.
- Various state and local fire-safety codes—which aim to protect against fires—also govern the dispensing of fuel at retail fueling outlets. While state fire marshals or state legislatures are usually responsible for developing the fire code for their respective states, some states allow local Municipalities to develop their own fire codes. Fire codes normally reference or incorporate standards developed by recognized standards development organizations, such as the National Fire Protection Association and the International Code Council.[19] State, county, and local fire marshals are responsible for enforcing the applicable fire code within their respective jurisdictions. Local officials, such as fire marshals, typically inspect dispensing equipment for compliance with both state and local fire codes.
- States are largely responsible for implementing EPA's requirements under the UST program. EPA has approved 36 states, plus the District of Columbia and Puerto Rico, to operate programs in lieu of the federal program. The remaining states have agreements with EPA to be the primary implementing agency for their programs. Typically, states rely on Underwriters Laboratories (UL) certification as the primary method for determining the compatibility of UST systems with EPA requirements. Some states also allow compatibility to be demonstrated in

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[18] DOE Energy Efficiency & Renewable Energy. *Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends.* September 2013. http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf

[19] The mission of the international nonprofit National Fire Protection Association is to reduce the worldwide burden of fire and other hazards on the quality of life by providing and advocating consensus codes and standards, research, training, and education. The International Code Council is a membership association dedicated to building safety and fire prevention. The council develops the codes and standards used to construct residential and commercial buildings, including homes and schools.

other ways, including through the manufacturer's approval or a professional engineering certification[20].

On July 15, 2015 EPA issued a final rule revising underground storage regulations. These changes establish Federal requirements that are similar to key portions of the Energy Policy Act of 2005 (EPAct); they also update the 1988 UST and state program approval (SPA) regulations. Changes to the regulations include:

- Adding secondary containment requirements for new and replaced tanks and piping;
- Adding operator training requirements;
- Adding periodic operation and maintenance requirements for UST systems;
- Addressing UST systems deferred in the 1988 UST regulation;
- Adding new release prevention and detection technologies;
- Updating codes of practice; making editorial corrections and technical amendments; and
- Updating state program approval requirements to incorporate these new changes.

1.2.3 Converting stations to E15 and E85

Fueling Equipment - E85 stations require at least one storage tank and one dispenser devoted to selling the E85 fuel. Both have minimum requirements to handle E85.[21]

Tanks - The vast majority of USTs being used for petroleum-based fuels can also be used for E85 after proper conversion and documentation verification. Analysis has shown that converting a midgrade tank is the most cost effective; however, many types of tanks have been converted including premium, diesel, kerosene, and redundant regular gasoline tanks.

Dispensers - Gasoline dispensers need to be converted or replaced to serve E85. The local authority having jurisdiction (AHJ), typically a fire marshal, must approve the dispenser system. The AHJ dictates what components need to be replaced for proper conversion or whether a new dispenser is needed. The AHJs typically require UL-certified components, but the lack of listed equipment has resulted in AHJs approving E85 dispensers through other methods. However, OSHA regulations require that retailers use equipment listed by a "nationally recognized testing laboratory" (i.e., UL) and retailers are required to comply with all applicable laws and regulations to be in compliance with tank insurance policies, state fund requirements, bank loan covenants, and to be considered not-liable under negligence theory for any accidents that occur with the tank. Therefore, AHJs will likely require UL-certified dispensers once they are available. The two primary manufacturers of the dispenser technology and blending equipment are Gilbarco of Greensboro, North Carolina, and Dresser-Wayne located in Austin, Texas.

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[20] U.S. Government Accountability Office. Biofuels*: Challenges to the Transportation, Sale, and Use of Intermediate Ethanol Blends.* Jun 3, 2011. Publicly Released: Jul 8, 2011. http://www.gao.gov/products/GAO-11-513

[21] NREL. *Cost of Adding E85 Fueling Capability to Existing Gasoline Stations: NREL Survey and Literature Search.* March 2008. http://www.afdc.energy.gov/pdfs/42390.pdf

Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 7

OAK RIDGE
NATIONAL LABORATORY
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2012/182

Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel

July 2012

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ORNL/TM-2011/XXX

ANALYSIS OF UNDERGROUND STORAGE TANK SYSTEM MATERIALS TO INCREASED LEAK POTENTIAL ASSOCIATED WITH E15 FUEL

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ACRONYMS

ASTM	American Society for Testing and Materials
DOE	Department of Energy
E10	Gasoline containing 10% ethanol by volume
E15	Gasoline containing 15% ethanol by volume
E50	Gasoline containing 50% ethanol by volume
E85	Gasoline containing 85% ethanol by volume
EISA	Energy Independence and Security Act
EPA	U. S. Environmental Protection Agency
F-HDPE	Fluorinated high density polyethylene
Fuel C	A gasoline representative test fuel composed of 50%vol. toluene and 50%vol. isooctane
FRP	Fiber-reinforced plastic
FFV	Flex-Fuel Vehicle
HDPE	High density polyethylene
HSP	Hansen Solubility Parameter
ISO	International Organization for Standardization
LG	Leaded gasoline
MIC	Microbial-induced corrosion
MTBE	Methyl tertiary butyl ether
NBR	Acrylonitrile (or nitrile) butadiene rubber
NREL	National Renewable Energy LaboratoryOBP DOE Office of Biomass Program
ORNL	Oak Ridge National Laboratory
PBT	polybutylene terephthalate
PEI	Petroleum Equipment Institute
PET	polyethylene terephthalate
PP	polypropylene
PTFE	polytetrafluoroethylene
PCV	polyvinyl chloride
PVDF	polyvinylidene fluoride
RFS	Renewable Fuel Standard
S	Siemens (unit of electrical conductivity)
SAE	Society of Automotive Engineers
SBR	Styrene butadiene rubber
UL	Underwriters Laboratories
UST	Underground Storage Tank
VS	Volume swell
VTP	DOE Vehicle Technologies Program

FOREWARD

It is not the purpose of this report to define the acceptable limits of material performance or to rate individual materials. Rather, the purpose of this study was to assess critical property changes (volume, hardness, mass, etc.) for representative classes of materials used in underground storage tank systems with exposure to E15.

ACKNOWLEDGMENTS

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EXECUTIVE SUMMARY

E.1 Background

The Energy Independence and Security Act (EISA) of 2007 was an omnibus energy policy law designed to move the United States toward greater energy security and independence.[1] A key provision of EISA modified the Renewable Fuel Standard (RFS) which requires the nation to increase the volume of renewable fuel blended into transportation fuels from 7.5 billion gallons by 2012 to 36 billion gallons by 2022. Ethanol is the most widely used renewable fuel, and increasing the ethanol content in gasoline to 15% offers a means of getting significantly closer to the 36 billion gallon goal. In March 2009, Growth Energy (a coalition of ethanol producers and supporters) requested a waiver from the United States Environmental Protection Agency (EPA) to allow the use of 15% ethanol in gasoline.[2] In response the US EPA granted two partial waivers that allow (but do not require) E15 in 2001 and newer light-duty vehicles. Prior to the waiver being granted, uncertainties arose as to whether the additional fuel ethanol (from 10% to 15%), would cause an increase in leaking of underground storage tank (UST) systems, which include not only the tank but also the piping and connecting hardware.

The USEPA Office of Underground Storage Tanks was interested in determining how many (of the nearly 600 thousand) federally regulated underground storage tank (UST) systems across the U.S. could have releases or other failures if the ethanol content in gasoline increases from 10 volume percent to 15 volume percent. To better assess the leak potential, the EPA commissioned a study at Oak Ridge National Laboratory to develop a means to determine the potential of changes in releases and other failures if E15 fuel is stored in UST systems. Part of this effort was to develop an approach to estimate likelihood of failures and approaches for mitigating consequences associated with these failures. Currently, the lack of availability of data is the most significant barrier that prevents EPA from being able to perform the analysis.

The initial approach was to develop and apply a probabilistic failure analysis tool based on expert elicitation to estimate how many more releases would occur if E15 replaced E10 in regulated UST systems. The key resources needed to establish this tool were opinions provided by industry and regulatory experts to quantify (most likely values and uncertainties) the critical variables that impact failure likelihood estimates. Unfortunately, over the course of the investigation, it was discovered that there was no information on the performance of existing UST systems with E15 and the state/industry experts were unable to speculate on E15's impact to UST systems. As a result, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when switching from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study.[3] The ORNL study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, and E25. Later studies investigated material compatibility to E50 and E85.

The elastomeric and metallic materials were exposed to Fuel C, CE10a, and CE17a test fuels, which are based on standard fluids described by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE) for use in fuel-material compatibility studies. SAE Reference Fuel C (also known as Fuel C) is a 50:50 mix of isooctane and toluene, and was used as the base fuel in the ethanol-blended test fuels, where it is represented by the "C" nomenclature. The ethanol was made to an aggressive formulation per SAE J1681,[4] and is indicated by the letter "a". CE17a was chosen to represent E15 since fuel surveys have shown that the actual ethanol content in gasoline can vary by ±2%. Plastic materials were only evaluated in Fuel C and CE25a. Therefore it was necessary to assess E10 and E15 performance through an interpolation process using the known solubility parameters for these materials and their performance in Fuel C and CE25a.

E.2 Experimental Approach

The approach was to use the swell, mass change, and hardness data from the ORNL study to assess the risk of moving from E10 to E15. An extensive literature review was undertaken which was initially based on the EPA 22 state study[5] to accurately identify materials used in UST systems. The system components of interest included tanks, piping, sealants, and joined couplings. Piping was divided into three areas: metal, flexible plastic, and rigid fiberglass-reinforced plastic. Because most of the installed piping systems are plastic, these systems are discussed in greater detail. For the elastomeric and metallic materials, analysis was performed using results obtained from exposure to test fuels containing 10% and 17%. On the other hand, plastic materials were only exposed to Fuel C and CE25a. In order to estimate the level of swell (or solubility) for representative plastics in E10 and E15, an analysis was performed using the results obtained from the Fuel C and CE25a exposures and incorporating solubility theory. An estimate of the volume swell (at E10 and E15) was made by interpolating the results for Fuel C and CE25a.

E.3 Discussion and Analysis

Underground Storage Tanks and Piping Made of Steel

For metal-based tanks and piping, corrosion via oxidation of the metal can directly lead to the creation of a leak. Another potential concern with higher ethanol content is the initiation of a new phase of corrosion, such that previously passivated areas (rust plugs) are attacked and removed, thereby leading to potential leaks. All metal USTs are composed of mild-carbon steel and around 98% of metal piping is also mild-carbon steel.[5] The other metal of interest is aluminum since aluminum parts are used on submersible turbine pumps, connections and dispenser nozzle. The ORNL intermediate-blend study included both steel and aluminum; the study showed negligible corrosion of either steel or aluminum immersed in either CE10a or CE17a.[3] However, the test conditions may not accurately reflect actual field situations, whereby the metal structure may be under stress or exposed to fuel that has become separated into two phases, one of which is aqueous. Both of these conditions (stress and exposure to aqueous liquid) are considered to be more conducive to corrosion. The specimens evaluated in the ORNL intermediate-blends study were not placed under stress, so the stress corrosion cracking potential of steel to either E10 or E15 cannot be ascertained.

Phase separation (of water) is another scenario that needs to be addressed. The level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. Therefore, under identical conditions of phase separation (such as temperature excursions causing evaporation and condensation) E15 has the potential to generate twice the volume of aqueous phase than E10, which could translate to a higher corrosion (and therefore leak) potential. The presence of an aqueous phase is also a precondition for supporting microbial-induced corrosion (MIC), and if E15 has a higher potential for water formation, then MIC may also result in increased corrosion. If precautions are undertaken to keep water out of tanks, and stress corrosion cracking is not a factor, then the corrosion potential is minimized and E15 offers no added risk to metal corrosion than E10.

Underground Storage Tanks and Piping Made of Fiberglass-reinforced Plastic (FRP)

The other material used in the construction of USTs is fiberglass-reinforced plastic (FRP). FRP construction consists of initially placing an approximately 0.5mm thick layer of resin on a mandrel followed by adding an additional ~6mm layer of resin reinforced with fiberglass. The inner bare resin surface serves as the barrier layer to prevent fuel permeation and the fiberglass-reinforcement provides strength and elasticity. Some legacy designs also may incorporate a separate plastic film that was glued to the inside surface to provide a fuel-resistant barrier layer. The ORNL intermediate-blend materials compatibility study[3] had evaluated four resin types representative of those used in legacy and modern FRP UST construction. One resin was used extensively prior to 1990 and therefore may not have been designed for E10 compatibility. Two of the test resins were introduced during the 1990s (post-1990), during which time E10 was beginning to be used in the marketplace. The fourth resin type was a new advanced resin developed for improved resistance to ethanol fuels. These four resins were made into test coupons (with no added fiberglass) and exposed to test fuels of Fuel C and CE25a.

Because E15 and E10 test fuels were not used in this evaluation, it was necessary to estimate resin performance in E10 and E15 using the swelling data obtained from the Fuel C and CE25a exposures. This estimation was performed by interpolating the measured swelling data using the differences in the known total Hansen Solubility Parameters (HSPs) for the resins and test fuels. (This procedure is described in detail in Section 2.1.1.) The solubility parameter is based on the free energy of mixing and is useful in predicting the mutual solubility (and therefore swell) between liquids and solid hydrocarbon materials. The pre-1990 resin was severely damaged from exposure to CE25a, along with one of the post-1990 resins. The remaining post-1990 resin and the advanced resin type both remained intact after exposure to CE25a, but they did swell to over 20% from their original volume with addition of ethanol. However, interpolation of these results using the Hansen Solubility Parameters suggests that the additional swell achieved from E10 to E15 will be around 1.5% (which is low). It is also important to keep in mind that the addition of fiberglass reinforcement to any of these resins will prevent significant swelling and debonding of the composite structure, since the fibers themselves do not swell.

The ORNL intermediate-blend materials compatibility study later included three legacy FRP UST specimens for evaluation, but they were only exposed to Fuel C, CE50a, and CE85a. One sample had a green coloration and contained a separate plastic barrier liner glued to the inner resin layer. The other two samples were amber in appearance, and of typical construction which consisted of an inner resin-only layer which was surrounded by a 6mm thick layer of fiberglass-reinforced resin. The resin used in the green UST survived Fuel C exposure but was severely degraded following exposure to CE50a and CE85a. In each case, the glue holding the plastic liner to the resin surface had dissolved, but, the plastic liner was unaffected. Unfortunately, the plastic composition of the liner was unknown, making it impossible to assess compatibility to E10 and E15. This particular UST design may be uncommon since, of the over two dozen samples provided to ORNL, it was the only one which had a separate inner liner and green resin. The other two USTs did not experience noticeable degradation or swell associated with exposure to the CE50a and CE85a test fuels. Because the difference in HSPs for resin and ethanol-blended gasoline increases with decreasing ethanol content, these epoxy resins should be more soluble in E50 and E85 than for intermediate E10 and E15 levels. Therefore, it is expected that USTs composed of amber resins will be compatible with gasoline containing 10 and 15 percent ethanol.

As of 2009, rigid FRP piping makes up around 58% of all installed piping systems.[5] The technology and materials used in the manufacture of FRP tanks also applies to underground FRP piping systems as well. Therefore the compatibility of FRP piping systems should be the same or similar to FRP underground storage tanks.

Flexible Plastic Piping

As of 2009, flexible plastic piping is estimated to make up around 13% of all installed piping systems,[5] but many new systems employ flexible plastic piping since these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to other piping systems over the next 10 years. Typical compositional arrangement of most flexible piping includes an inner barrier liner with a layer of reinforcement (to provide strength) and an outer cover. Many of the outer layers are not compatible with ethanol and are only added to provide exterior protection and strength. The primary inner layer provides chemical resistance and a survey of flexible piping systems shows that the most common inner permeation barrier material is polyvinylidene difluoride (PVDF). Other plastics used as permeation barriers are nylons and polyethylene terephthalate (PET). PVDF, PET, and several grades of nylon were evaluated in the ORNL intermediate-blends study along with the other plastic materials that were exposed to Fuel C and CE25a. As with the UST resins, the performance (volume swell) with exposure to E10 and E15 was estimated using the measured volume swelling for exposure to Fuel C and CE25a and the known HSPs for these materials. The resulting analysis indicates that flexible piping permeation barrier materials will not have added significant swell (less than 1%) when moving from E10 to E15. Therefore, the increase in risk associated with leaking when switching from E10 to E15 will be low.

Elastomers, Sealants, Couplings and Fittings

Couplings and fittings used to connect piping, the submersible turbine pump, and valves represent one of the highest potential locations for leaking in UST systems. There are two potential locations/sources of leaks associated with fittings. One is where the coupling attaches to the piping and the other one is at the fitting-to-fitting seal interface. In many (but not all) cases fluorocarbons are used as interfacial seals between fittings. Fluorocarbons have been shown to be compatible with ethanol and it is unlikely that a properly installed fluorocarbon elastomer will leak when exposed to either E10 or E15. For metal and some rigid FRP piping systems, pipe thread sealants may be employed to seal fittings via threaded attachments. Some legacy pipe thread sealants were shown to be incompatible with gasoline containing 10% aggressive ethanol and would clearly not be acceptable for E15 use either. Newer engineered products (such as fluoroelastomers) have been developed for ethanol-blended gasoline and these sealants have been shown to be compatible with gasoline containing up to 25% aggressive ethanol.

For flexible piping systems a stainless steel coupling is normally compression fitted to the outer surface of the pipe so the leak potential is very low for properly installed couplings. In contrast fittings attached to rigid FRP systems typically utilize an adhesive to maintain a seal between the coupling and the outer pipe wall. Adhesives designed for fuel ethanol use are available. This material type was not included in the ORNL intermediate-blend study and its performance in either E10 or E15 was not ascertained. For rigid FRP pipe-to-pipe joining, fiberglass reinforced resin is also frequently applied to the joined ends in a butt-and-wrap arrangement. Since the wrapping is composed of fiberglass-reinforced resin similar to the piping itself, the leak potential with exposure to E15 for a properly installed joint should be low since the increase of swell associated with E15 (relative to E10) is estimated to be small (1.5%). It is important to note that the joined sections have lower structural integrity (mechanical strength) than the pipe as a whole, but should not leak as a primary result of the fuel exposure.

E.4 Conclusions

In general, the materials used in existing UST infrastructures would not be expected to exhibit compatibility concerns when moving from E10 to E15. The volume swell and hardness results of tested polymer materials were not significantly different when exposed to either CE10a or CE15a, although significant changes were observed when these fuels are compared to the E0 formulation. The indication is that UST systems were affected by switching from E0 to E10. However, since E10 and E15 produce similar results, compatibility is not expected to be altered noticeably when moving from E10 to E15. The metallic materials showed negligible corrosion as long as phase separation did not occur. If an aqueous phase is formed, then the possibility for aggressive corrosion exists. Therefore, the proper application of biocides and water monitoring is likely to be more critical at preventing corrosion for gasoline fuel containing ethanol.

1. INTRODUCTION

1.1 HISTORY AND BACKGROUND

In the United States oil dependence is driven primarily by the transportation sector. Transportation accounts for 69% of the total oil consumption in the United States, and the industry itself is around 90% oil dependent (and the remainder being natural gas, propane, electric and ethanol).[6] In 2008 the average daily oil consumption equivalent used the U.S. transportation sector was approximately 14 million barrels. This rate is projected to increase to around 16 million barrels per day by 2025.[7] Currently, the bulk of our oil usage is provided by other countries as foreign oil imports and makes up around 57% of the total oil usage.[8] This dependency impacts our nation's security, since our oil supply is determined partly by other countries, some of whom are not friendly to the United States. Foreign disruption has been shown to negatively impact the nation's economy and makes the U. S. more vulnerable during times of international crisis.

The Energy Independence and Security Act (EISA) of 2007 was enacted by Congress to move the nation toward increased energy independence by increasing the production of renewable fuels to meet its transportation energy needs. The law establishes a new renewable fuel standard (RFS) that requires the nation to use 36 billion gallons annually (2.3 million barrels per day) of renewable fuel in its vehicles by 2022. Ethanol is the most widely used renewable fuel in the United States, and its production has grown dramatically over the past decade. According to EISA and RFS, ethanol (produced from corn as well as cellulosic feedstocks) will make up the vast majority of the new renewable fuel requirements. However, ethanol use limited to E10 and E85 (in the case of flex fuel vehicles or FFVs) will not meet this target. Even if all of the E0 gasoline dispensers in the country were converted to E10, such sales would represent only about 15 billion gallons per year.[9] If 15% ethanol, rather than 10% were used, the potential would be up to 22 billion gallons. The vast majority of ethanol used in the United States is blended with gasoline to create E10, that is, gasoline with up to 10 % ethanol. The remaining ethanol is sold in the form of E85, a gasoline blend with as much as 85% ethanol that can only be used in FFVs. Although the U. S. Department of Energy (DOE) remains committed to expanding the E85 infrastructure, that market will not be able to absorb projected volumes of ethanol in the near term. Given this reality, DOE and others have begun assessing the viability of using intermediate ethanol blends as one way to transition to higher volumes of ethanol.

In October of 2010, the U. S. Environmental Protection Agency (EPA) granted a partial waiver to the Clean Air Act allowing the use of fuel that contains up to 15% ethanol for the model year 2007 and newer light-duty motor vehicles. This waiver represents the first of a number of actions that are needed to move toward the commercialization of E15 gasoline blends. On January 2011, this waiver was expanded to include model year 2001 light-duty vehicles, but specifically prohibited use in motorcycles and off-road vehicles and equipment.[2]

UST stakeholders generally consider fueling infrastructure materials designed for use with E0 to be adequate for use with E10, and there are no known instances of major leaks or failures directly attributable to ethanol use. It is conceivable that many compatibility issues, including accelerated corrosion, do arise and are corrected onsite and, therefore do not lead to a release. However, there is some concern that higher ethanol concentrations, such as E15 or E20, may be incompatible with current materials used in standard gasoline fueling hardware. In the summer of 2008, DOE recognized the need to assess the impact of intermediate blends of ethanol on the fueling infrastructure, specifically located at the fueling station. This includes the dispenser and hanging hardware, the underground storage tank, and associated piping.

The DOE program has been co-led and funded by the Office of the Biomass Program and Vehicle Technologies Program with technical expertise from the Oak Ridge National Laboratory (ORNL) and the National Renewable Energy Laboratory (NREL). The infrastructure material compatibility work has been supported through strong collaborations and testing at Underwriters Laboratories (UL). ORNL performed a compatibility study investigating the compatibility of fuel infrastructure materials to gasoline containing intermediate levels of ethanol. These results can be found in the ORNL report entitled *Intermediate Ethanol Blends Infrastructure Materials Compatibility Study: Elastomers, Metals and Sealants* (hereafter referred to as the ORNL intermediate blends material compatibility study).[3] These materials included elastomers, plastics, metals and sealants typically found in fuel dispenser infrastructure.

The test fuels evaluated in the ORNL study were SAE standard test fuel formulations used to assess material-fuel compatibility within a relatively short timeframe. Initially, these material studies included test fuels of Fuel C, CE10a, CE17a, and CE25a. The CE17a test fuel was selected to represent E15 since surveys have shown that the actual ethanol upper limit can be as high as 17%. Later, CE50a and CE85a test fuels were added to the investigation and these results are being compiled for a follow-on report to be published in 2012. Fuel C was used as the baseline reference and is a 50:50 blend of isooctane and toluene. This particular composition was used to represent premium-grade gasoline and was also used as the base fuel for the ethanol blends, where it is denoted by “C” in the fuel name. The level of ethanol is represented by the number following the letter E. Therefore a 10% blend of ethanol in Fuel C is written as CE10a, where “a” represents an aggressive formulation of the ethanol that contains water, NaCl, acetic and sulfuric acids per the SAE J1681 protocol.

1.2 ETHANOL COMPATIBILITY AND SOLUBILITY

Pure ethanol, by itself, is not generally considered corrosive toward most metallic materials; however, as a polar molecule, ethanol will be more susceptible to having compatibility issues with both metals and polymers due to (1) increased polarity relative to gasoline, (2) adsorption of water, and (3) a higher solubility potential relative to gasoline. The first two factors are relevant to metals and alloys, while the latter affects primarily polymers. The corrosion potential is directly related to the electrical conductivity of a solution. Kirk[10] measured the electrical conductivity for gasoline as a function of ethanol concentration and dissolved water level. A plot of the electrical conductivity as a function of ethanol concentration in gasoline is shown in Fig. 1. As shown in the figure, the electrical conductivity is low for ethanol-blended gasoline increases marginally with ethanol concentrations up to 20%. However, although the conductivity numbers are low, relatively speaking, E15 is 10 times more conductive than E10. As the ethanol concentration increases from 20% to 50%, the corresponding conductivity increases by almost two orders of magnitude. As a result, metal corrosion becomes a significant concern for gasoline blends containing 50% or more ethanol.

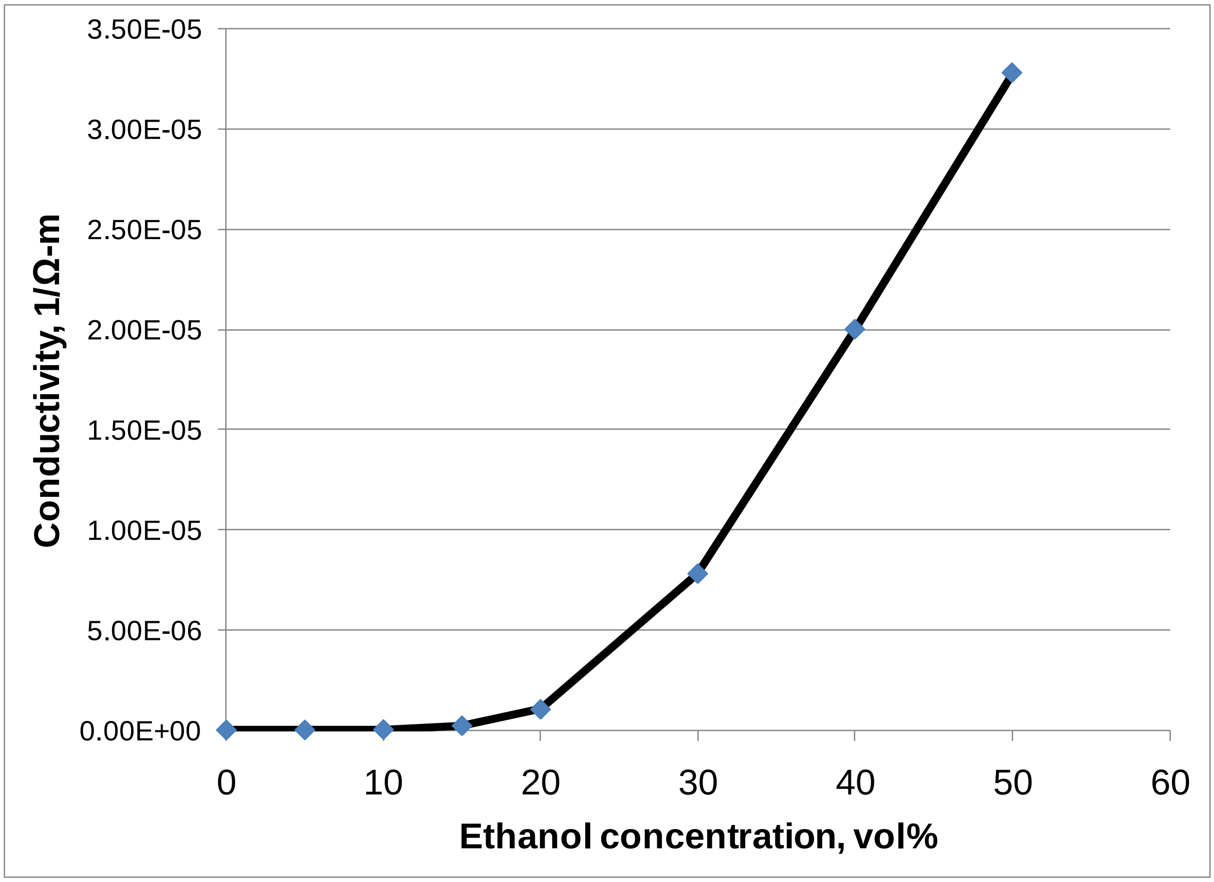

Fig. 1. Electrical conductivity of gasoline as a function of ethanol concentration. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

The level of dissolved water also has a pronounced effect. The results in Fig. 2 show the effect of water concentration in addition to ethanol level. In this figure, the electrical conductivity (listed as S in Fig. 2 and 1/Ω in Fig. 1) is plotted for blends containing 5, 10, 15, 20, 30 and 40% ethanol by volume. As the level of ethanol increases, the conductivity curves for each blend increase as well, and for each set of curves the conductivity also increases with the level of dissolved water. In fact, the water solubility limit increases the conductivity by an order of magnitude when going from E10 to E15. In addition, water itself is a solvent for NaCl and acids, which can lead to even higher rates of corrosion.

Ethanol also affects the material-fluid mutual solubility associated with the fuel blend, which is an important parameter for gauging the compatibility of fuels with polymers. The influence of the solubility parameter is complex; however, solvents and solutes having similar solubility parameters will have a greater affinity for permeation and dissolution.[11] The solubility parameter, or more specifically, the difference in parameters between the solute (polymer) and solvent (fuel), is important in predicting and understanding the solubility of a system. As the solubility parameter values for the solute and solvent converge, the propensity for the two components to mix (or allow the solvent to permeate into the solute) becomes thermodynamically possible. For an elastomer or plastic, this effect will be an increase in swelling of the polymer.

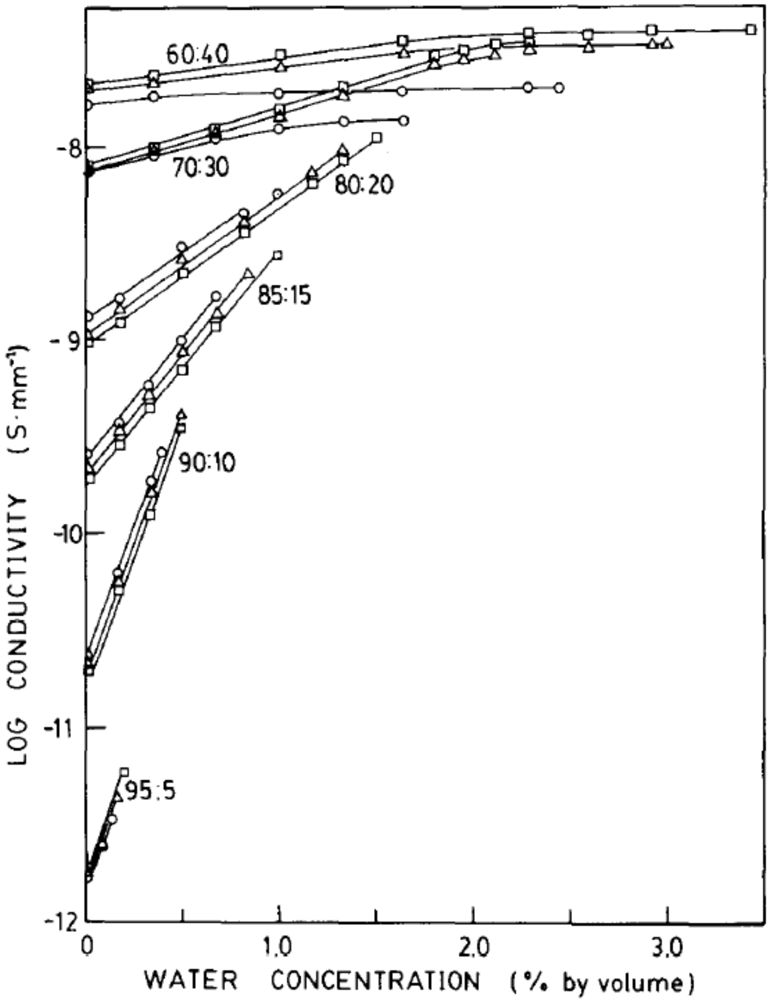

Fig. 2. Electrical conductivity of gasoline as a function of ethanol and water content. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

A simplified representation of solubility as a function of ethanol concentration in gasoline is shown in Fig. 3. The wide shaded horizontal band in the chart represents the range of solubility parameters, expressed as total Hansen Solubility Parameter (HSP) for many dispenser polymers, especially elastomers. Epoxies, such as those used as the matrix materials for underground storage tanks, have a total HSP value around $24(\mathrm{MPa})^{1/2}$, which is noticeably higher than the HSP for polymers. The implication for UST resins is that the solubility of the epoxy in the fuel will be highest for gasoline containing around 80% ethanol.

As the ethanol concentration increases from zero to 15%, it effectively raises the solubility parameter and approaches the solubility parameter of most dispenser polymers. Therefore, the propensity for the fuel to permeate into and dissolve polymeric components is enhanced. It is important to note that, in reality, solubility is determined from multiple thermodynamic factors, and that the highest level of mutual solubility for a given polymer does not necessarily match precisely with the theoretically-derived parameters which have been simplified in Fig. 3. Standard gasoline fuel delivery systems contain elastomeric materials having excellent compatibility and stability with hydrocarbon fuels. However, the ethanol molecule is relatively small and highly polar due to the –OH group. In addition the tendency to introduce hydrogen bonding is high. These features enable ethanol's permeation into and interaction with the elastomer structure, which can result in swelling and softening of elastomers. Another negative feature associated with permeation is that soluble components, especially plasticizers added to impart flexibility and durability in the elastomer, may be leached out, thereby affecting the mechanical properties of the compounded elastomer component and degrading the ability of the component to perform its intended function.

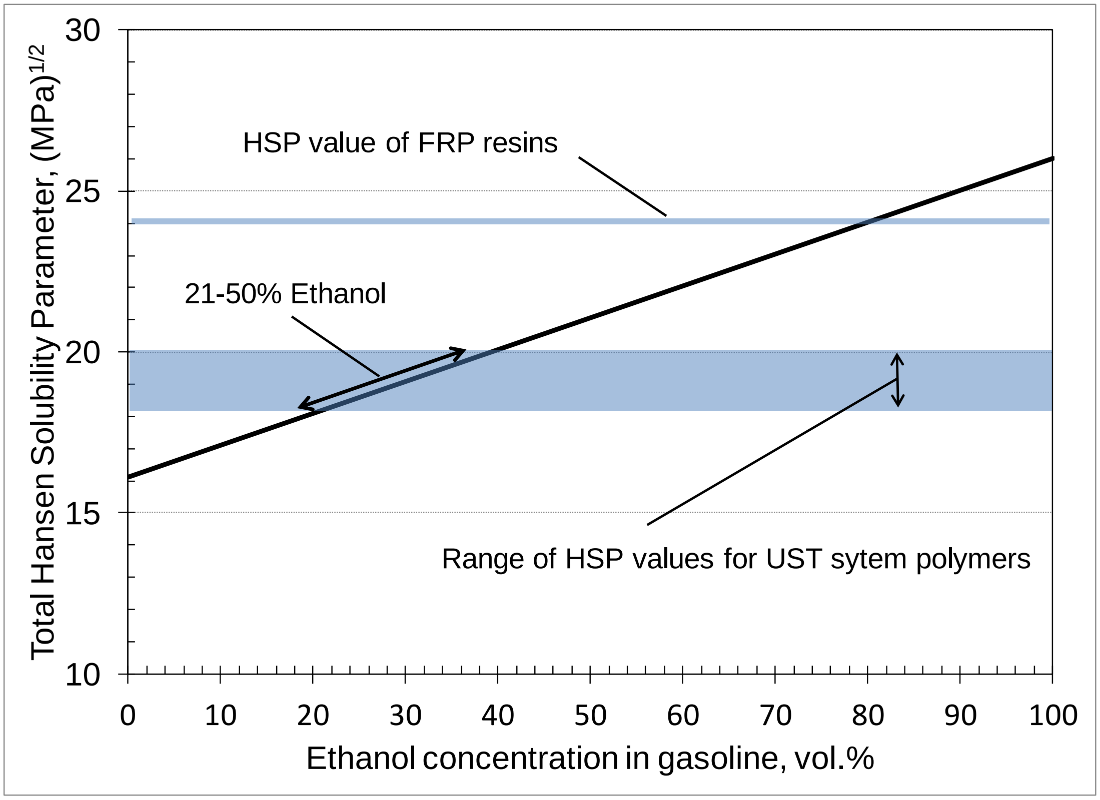

Fig. 3. Total Hansen Solubility Parameter as a function of ethanol concentration. The lower blue horizontal band represents the solubility range of many UST system elastomer and plastics. The upper blue band is representative of FRP resins.

Several studies have been undertaken to evaluate the compatibility of ethanol with engine materials, especially those used in fuel system components such as pumps, and much of this work has recently focused on the intermediate E15, E20, and E25 blends.[12–15] However, little work had been reported on the compatibility of these fuels to standard fuel dispenser materials, which subsequently became the focus of the ORNL-led materials compatibility study noted earlier.

1.3 FUELING DISPENSER MATERIALS AND ETHANOL COMPATIBILITY STUDY

As part of the ORNL intermediate-blend materials compatibility study, an extensive survey was performed to identify to the extent possible all materials used in the fueling dispenser infrastructure. A list of the materials identified and evaluated in the ORNL study is shown in Table 1, where those materials identified by the authors of this report for use in UST systems are highlighted. Most of the plastic materials are used as structural components in FRP tanks and in both FRP and flexible piping systems. The elastomeric materials most identified as seals and gaskets are Viton™ and Dyneon™ brand fluorocarbons, but NBR and rubberized cork may still be in use in legacy tank probes and overfill devices. Steel is used in tanks and piping and aluminum is also used in some applications, such as drop tubes.

It is important to note that while the researchers were able to discover and identify an extensive list of relevant materials over the course of this and other studies, it is possible, if not probable, that other materials used in legacy, and some new infrastructure systems, were not included in this investigation.

Table 1. List of materials evaluated in intermediate ethanol blends compatibility study. (Materials identified as being used in UST systems are highlighted.)

Metals/Alloys	Elastomers	Plastics	Sealants
304 stainless steel	**Viton™ fluorocarbon**	**High density polyethylene (HDPE)**	**PTFE-based sealants (two-types) with and without Teflon™ tape**
1020 carbon steel	**Dyneon™ fluorocarbon**	Fluorinated HDPE	
1100 aluminum	**Acrylonitrile butadiene rubber (NBR)**	Polypropylene (PP)	
Cartridge brass	Silicone rubber	Polyoxymethylene	
Phosphor bronze	Fluorosilicone rubber	**Nylon**	
Nickel 201	Neoprene rubber	**Polyvinylidene fluoride (PVDF)**	
Terne-plated steel	Styrene butadiene rubber (SBR)	**Polytetrafluoroethylene (PTFE)**	
Galvanized steel	Polyurethane	Polyphenylene sulfide (PPS)	
Cr-plated brass	**Rubberized cork**	**Polyethylene terephthalate (PET)**	
Cr-plated steel		Polybutylene terephthalate (PBT)	
Ni-plated		Polythiourea	
Ni-plated steel		**Isophthalic ester resin**	
		Terephthalic ester resin	
		Vinyl ester resin	
		Epoxy resin	

Of the all the test fuels investigated (Fuel C, CE10a, CE17a, CE25a, CE50a and CE85a), only the metal and elastomeric materials were subjected to each fuel type. The plastics were originally exposed to Fuel C and CE25a (and later to CE50a and CE85a) and the sealants were evaluated only in Fuel C, CE10a and CE25a. At a later point in this study, ORNL received sections of fiberglass USTs removed from use. Three UST sections were cut into test specimens and added to the final exposure runs of Fuel C, CE50a, and CE85a.

The test protocol consisted of immersing the specimen coupons in the test fuels and vapors for extended periods, 4 weeks for metals and elastomers and 16 weeks for plastics. During the exposure period the fuel temperature was maintained at 60^{o}C in order to maintain consistency with the UL Subject 87A-E25 test standard used in by Underwriter Laboratories when assessing fuel compatibility.[16]

2. UNDERGROUND TANKS & PIPING SYSTEMS

Underground fuel storage tanks are composed either of steel or fiberglass reinforced plastic. Both of these materials, as well as flexible plastic, are also used in piping systems. A breakdown of the piping types using an analysis based on 22 state databases[5] is shown in Table 2. The overwhelming majority of installed piping (~71%) is either flexible or rigid fiberglass reinforced plastic. Of the remaining metal systems, approximately 18% of metal piping systems are steel. Copper makes around 2% of underground piping and approximately 8% is of unknown material construction.[19] The most common installed piping systems are rigid FRP and flexible plastic systems. Older piping systems were typically single-walled, but most newly installed systems are double-walled. FRP makes up approximately 58% of installed piping, while flexible plastic piping accounts for around 13% of all installed piping systems.[5]

Table 2. Breakdown of piping materials.[5,19]

Material Class	Approximate Percentage Used as of 2009
Steel	18
Rigid Fiberglass Reinforced Plastic (RFP)	58
Flexible Plastic Piping	13
Other (copper, PVC, etc.)	2
Unknown	8

A large percentage of leaks occur in the piping system between the tank and the dispenser.[17] These leaks typically occur at joints and connections where the stresses are highest. Contributors to stress include movement and forces exerted on piping from environmental factors which can be caused by changes in ground-water level and settling changes in the soil. Even a small change in the position of a UST will result in stress on the piping, especially at joints.[18] The level of stress will be higher for rigidly designed systems as opposed to flexible systems which can reduce stress through bending and relaxation. Outside of environmental contributions to stress, there are inherent changes caused by the piping materials' response to the fuel chemistry. As stated earlier, ethanol will raise the solubility parameter of the fuel so that the resulting potential for degradation of plastics is increased. Increased solubility will likely cause an increase in the volume of the plastic. This volume increase will place the component pipe under additional elongation and stress. Expansion of piping caused by solubility (even at low levels of approximately 2%) may be high enough to lead to failure based on life cycle studies of polymeric piping materials.[18]

2.1 METALLIC MATERIALS FOR TANKS, COMPONENTS, AND PIPING SYSTEMS

Steel is commonly used as a tank material for both legacy and newer systems, and steel piping is estimated to be used in approximately 18% of piping systems. The other metallic material that is exposed directly to E10 (and potentially E15) is aluminum which is used in submersible pumps. Both steel (carbon and stainless) and aluminum were included in the ORNL intermediate-blend materials compatibility study.

As shown in Fig. 1, the electrical conductivity for E10 and E15 is low in relationship to higher ethanol concentrations; however, when compared to each other, E15 is actually 10 times more conductive than E10. When water is added to levels approaching the solubility limit (as shown in Fig. 2), the conductivity is further increased. The test fuels used in the ORNL-intermediate blends study included relatively high levels of dissolved water (0.09% of the total ethanol volume) to account for this factor. In this study, steel and aluminum, along with the other metal coupons (tested either as single components or galvanic couples) showed negligible corrosion from exposure to the test fuels.[20] As a result, corrosion that does occur on metal tanks or piping systems is likely due to one of more of the following factors (none of which were included in the ORNL study):

1. Phase separation of water from the ethanol fuel blend
2. External water intrusion from rain, humidity, etc.
3. Contamination by other means such as road salt, dirt, etc.
4. Stress corrosion cracking

The potential for aqueous phase separation can be discussed relative to Fig. 2. As shown in Fig. 2, the level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. The higher water content translates to a higher potential for corrosion.

2.2 POLYMER PIPING AND TANK SYSTEMS

As shown in Table 2, the majority of underground piping is constructed from plastic materials, which are categorized as two types, flexible piping and FRP piping. Although FRP systems are more established in the field, the majority of new piping systems installed today are flexible plastic systems because these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to the other piping systems over the next 10 years. The piping arrangement can consist of either single- or double-walled systems. The majority of installed single-walled piping systems are legacy units, but new requirements are resulting in increased use of double-walled piping systems. Double-walled systems have an interstitial space between the walls that can be monitored for leaks.

2.2.1 Flexible Plastic Piping

Typical compositional arrangement of flexible piping includes an inner barrier liner within a layer of fiber reinforcement (to provide strength) and a cover to protect the inner layers from damage from handling and to prevent water intrusion. We surveyed the materials used in the construction of the outer wall for double wall plastic-based systems. In virtually every case, the outer wall is composed of inexpensive materials, known to be less chemically resistant to ethanol.

Multiple piping manufacturers and the materials used in their systems are listed in Table 3.[21-25] Some of the manufacturer and material information included in the table was taken from surveys dating to 1997, and therefore, may not reflect current construction.

Table 3. Flexible piping materials according to manufacturer.

Manufacturer	Permeation Barrier Material	Reinforcement	Primary Pipe Cover Material (Single-walled)	Secondary Containment Materials (double-walled)
Advanced Polymer Technology	Nylon 12	Nylon fiber wrap	Polyethylene	HDPE
Ameron	PVDF	Polyester braid polyethylene	Nylon	HDPE
Containment Technologies	Selar nylon (amorphous)	None	Polyethylene	HDPE
Environ	PVDF	Polyester braid	Nylon-coated polyethylene	Nylon coated polyethylene
Furon	PVDF	Polyester braid	Nylon II	
OPW	PVDF	Polyester braid	Nylon II	
PetroTechnik	Nylon	None	Polyethylene	Polyethylene
Total Containment	Carilon polyketone (product discontinued)	Polyester or Kevlar braid	Polyethylene	Polyethylene
Western Fiberglass	PVDF	Polyester braid	Nylon II	HDPE
XP-Piping	Nylon 12 and mylar (PET)	Nylon fiber	Mylar (PET) coated nylon 12	Nylon 12
Pisces	Kynar (PVDF)	Nylon fiber	Nylon	Nylon
Geoflex	Kynar (PVDF)		Nylon coated polyethylene	Nylon coated polyethylene

Of the flexible pipes reported in Table 3, the majority had inner barrier layers composed of PVDF. The three remaining designs incorporated nylon, either as nylon 12, Selar™ amorphous nylon, or a combination of nylon 12 and Mylar™ PET. For most systems the permeation barrier layer was externally reinforced with wound fibers composed of either nylon or polyester. This reinforcement, in turn, is usually coated with nylon or polyethylene. Likewise, the most common materials used for the outer wall are polyethylene and nylon.

One manufacturer used PET as the inner barrier layer. However, most materials are either nylon or PVDF. In reality the actual arrangement and location material arrangement for flexible piping is somewhat complex. A cutaway diagram showing the material arrangement for one commercially-available flexible pipe is shown in Fig. 4. In all flexible piping systems, there is an inner permeation barrier layer composed of a plastic material that has low solubility (i.e., high resistance) to petroleum fuels and alcohols.

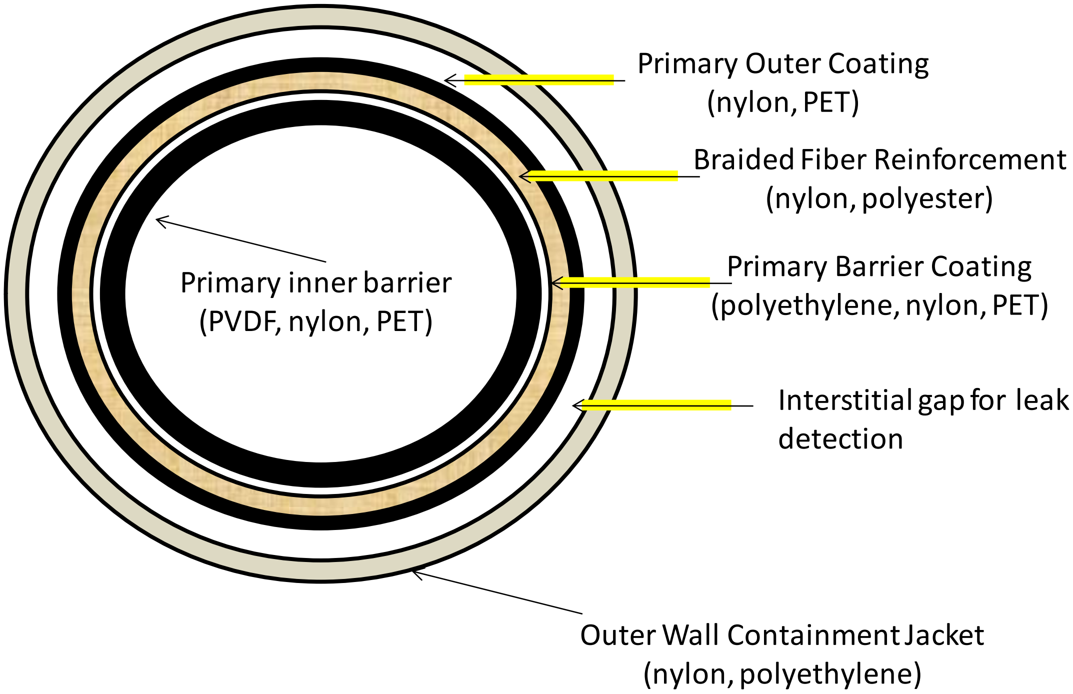

Fig. 4. Cross-section diagram of flexible piping showing an example of the layering position and arrangement of materials used in double-walled designs. A typical single-wall design is similar but would not include the outer wall containment jacket shown on the outside.

As stated earlier the two primary polymer types used in flexible fuel piping are nylon and polyvinylidene difluoride (PVDF). Other often used materials are polyketone and polyethylene terephthalate (PET). However, polyketone (Carilon™, Dupont) was discontinued and (to the best of our knowledge) the installed piping was removed and replaced. PET is more expensive than either nylon or PVDF, and as such, is not extensively used in piping applications. PVDF goes by the tradename, Kynar™ and is manufactured by Arkema, Inc. The other established material is the DuPont Selar™ nylon barrier material (which is amorphous grade of nylon).

Flex piping is easier to install and the flexible nature of the material allows the component to relax during swell. In contrast to fixed rigid piping systems, a flexible piping system can undergo small dimensional changes in volume and movement (relaxation), thereby reducing the stress load.

The ORNL intermediate blends compatibility study included samples of representative flexible pipe materials. These materials include PET, HDPE, nylon 6, nylon 6/6, nylon 11, and nylon 12. (Selar, which is an amorphous grade of nylon, was not evaluated.) These nylon grades are differentiated by the degree of molecular alignment (crystallinity), additives, and processing. In contrast to the other types, Nylon 11 is a unique specialty grade made from vegetable oil. Although Selar™ nylon was not specifically included among the test coupons, according to DuPont, its chemical resistance is comparable to other grades of synthetic nylon (nylon 6, 6/6, and 12).[26]

The ORNL materials compatibility study evaluated the response of selected plastic materials to Fuel C and CE25a only. Test fuels representing 10 and 15 percent aggressive ethanol were not exposed to plastics. Volume swell and hardness results are shown in Figs. 5 through 7 for common nylon grades, PET, PVDF, and HDPE exposed to Fuel C and CE25a.

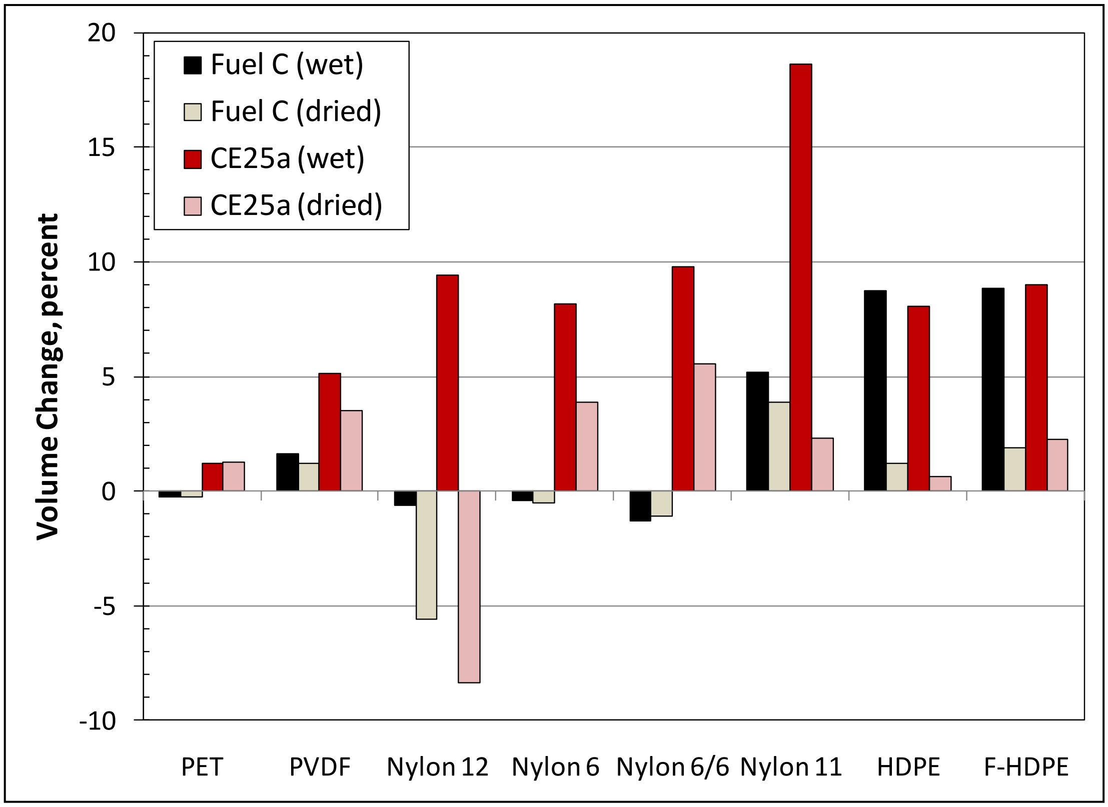

Fig. 5. Volume swell results for representative barrier materials used in underground piping.

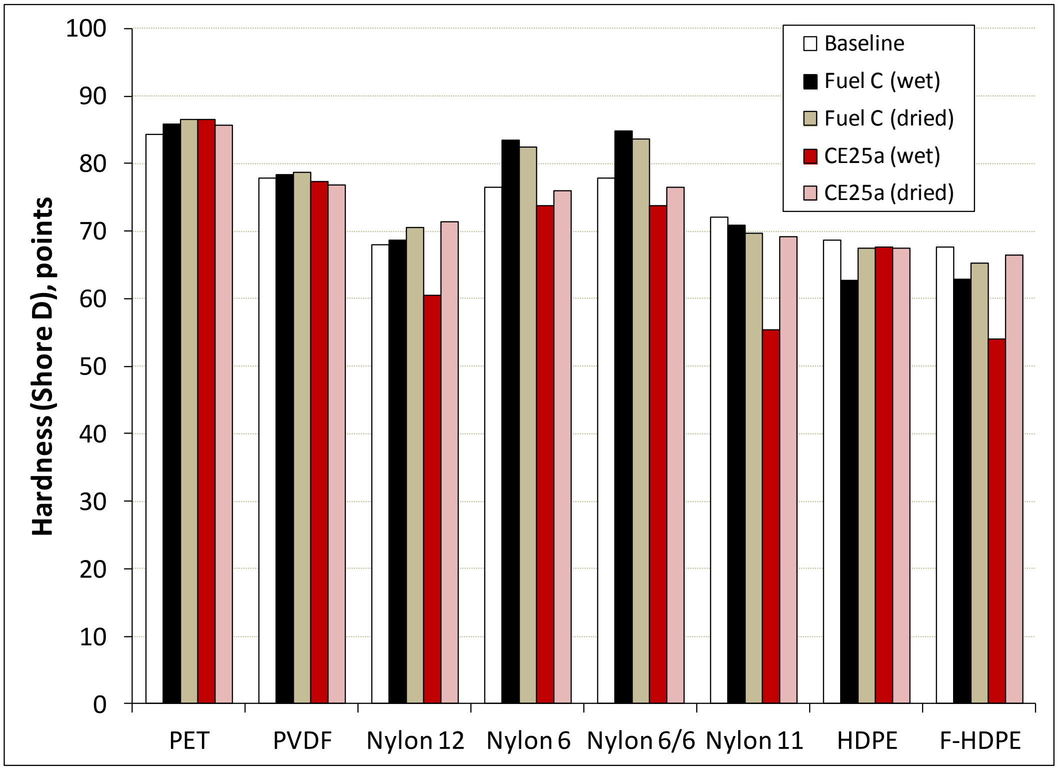

Fig. 6. Absolute hardness results for representative barrier materials used in flexible piping.

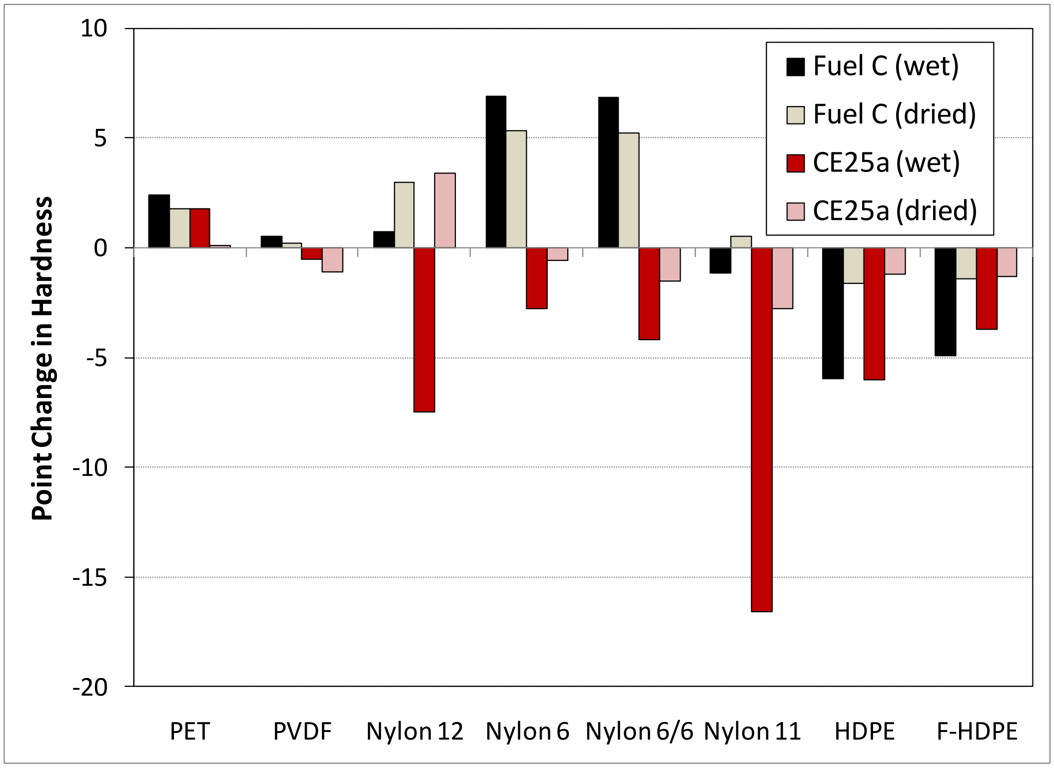

Fig. 7. Point change in hardness (from baseline) for representative barrier materials used in flexible piping.

As shown in Fig. 5, PET and PVDF experienced the lowest low volume swell (1.23% and 5.12%, respectively) following exposure to CE25a. In contrast, the nylon 6, nylon 6/6, and nylon 12, along with the HDPE samples swelled between 8 and 10 %. The highest level of volume swell occurred for nylon 11, and was around 18 %. Following dry out, these materials retained some fluid, as evidenced by the residual swell present in the dried samples. The one exception is nylon 12, which shrank from its original volume to over 5% from exposure to Fuel C and around 8% with CE25a. Such shrinkage is evidence that Fuel C and CE25a were able to dissolve and remove a significant portion of the solid material. The hardness results presented in Figs. 6 and 7 show that nylon 12 and nylon 11 both became softer with exposure to CE25. The decrease in hardness of nylon 12 was around 7 points, which is only marginally higher than the softening of the nylon 6, nylon 6/6 and the HDPE samples. However, nylon 11 dropped 17 points and this drop coupled with the high volume swell suggests that nylon 11 may not be acceptable for use in plastic piping, even for E0 formulations.

Although E10 and E15 test fuels were not evaluated, an estimation of the volume swell can be made using solubility parameters (obtained from the literature) and volume swell results in CE25a. Volume swell is a measurement of solubility. According to solubility theory, the difference between the solubility parameters is inversely related to the solubility between the solute (plastic) and solvent (test fuel). In other words, the closer match between the total Hansen Solubility Parameters of the solute and solvent, the more mutually soluble they are to each other. Using the known total HSP values for the plastic materials and E25, E15 and E10, and the measured volume swell in CE25a (as shown in Table 4), a calculated volume swell for each material in E15 and E10 can be made using the ratio of the differences in the total Hansen solubility parameters between the plastic and CE25a to the HSP difference between the plastic and CE15 and CE10. These calculated values are shown in Table 5.

The method for calculation of volume swell is as follows:

$$VS_{(EX)} = VS_{(E25)}\ (1-(\Delta HSP_{(EX)} - \Delta HSP_{(E25)}))/\ (\Delta HSP_{(EX)})$$

Where:

$VS_{(EX)}$ is the volume swell of the plastic sample after exposure to a fuel containing X percent of ethanol by volume.

$VS_{(E25)}$ is the volume swell of the plastic in CE25a

$\Delta HSP_{(EX)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing X volume percent ethanol

$\Delta HSP_{(25)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing 25 volume percent ethanol

Table 4. Volume swell results for representative barrier materials used in flexible underground piping

Plastic	Hansen Solubility Parameter (MPa$^{1/2}$)	Volume Swell in CE25a (%)
PVDF	23.17	5.12
Nylon 6	20.3	8.15
Nylon 12	22.2	9.40
PET	20.8	1.23
Fuel Type	**Hansen Solubility Parameter (MPa$^{1/2}$)**	
E25	18.58	
E15	17.59	
E10	17.09	

Table 5. Measured and calculated results for PVDF and Nylon 6

Barrier material	HSP (MPa$^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10	Estimated vol. increase associated with increasing ethanol from E10 to E15
PVDF	23.17	5.12	4.1	3.6	0.5
Nylon 6	20.3	8.15	5.2	4.4	0.8
Nylon 12	22.2	9.4	7.4	6.7	0.7
PET	20.8	1.23	0.8	0.7	0.1

The results in Table 5 show that the expected increase in volume swell when going from E10 to E15 is less than 1 percent for the primary barrier liner materials used in flexible piping. The low additional volume swell is not likely to create much stress in the piping since these materials are able to relax due to the flexible nature of the piping. Based on these results, we do not anticipate any noticeable potential for release associated with going from E10 to E15. However, if the piping is rigidly constrained somehow, then stress buildup may occur to cause bucking (or cracking) of the piping. Most of the changes in swell (and hardness) will occur from moving from E0 to E10.

2.2.2 Fiber-reinforced Plastic Tanks & Piping

Fiber-reinforced plastic piping materials, design and construction are similar to those used in fiberglass tanks. The construction consists of first placing resin on a mandrel and later adding fiber reinforced resin to serve as the outer layer. A diagram showing layering and arrangement is depicted in Fig. 8.

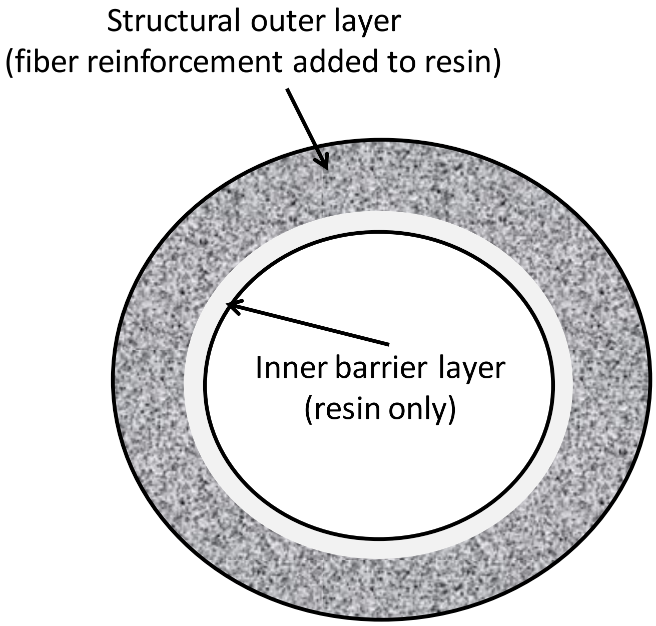

Fig. 8. Diagram of fiber-reinforced plastic piping.

As shown in Fig. 8, the inner barrier liner is approximately 0.5mm-thick resin layer surrounded by a much thicker (~6mm) layer of fiber-reinforced resin. For FRP systems used to contain petroleum fluids, the fiber reinforcing material is fiberglass.

ORNL tested several FRP resins to assess compatibility with CE25a. The resins that were evaluated included:

1. Isophthalic polyester resin (1 part isophthalic acid to 1 part polyester resin) known as Vipel F701-This resin type was used extensively in USTs prior to the 1990s.

2. Isophthalic polyester resin (2 parts isophthalic acid to 1 part polyester resin) known as Vipel F764-This resin type was used in USTs starting in the 1990s.

3. Terephthalic polyester resin (2 parts terephthalic acid to 1 part polyester resin) known as Vipel F774-This resin type was used extensively in 1990s.

4. Epoxy novolac vinyl ester resin known as Vipel F105-This is the most recently advanced corrosion resistant UST resin.

A survey of manufacturers shows that these resins are the most commonly used types for FRP UST construction.[27-30] It is important to note that for FRP tanks the construction does not consist of a multilayer structure similar to the arrangement used in flexible plastic piping. The inner barrier layer consists solely of the resin material, with fiberglass added to the thicker resin outer layer to provide strength and elasticity. The volume swell results are shown in Fig. 9 for these resins. (These specimens consisted of pure resin and did not contain fiber reinforcement.) Vipel F701 swelled to over 15 volume percent upon exposure to Fuel C. However, these samples fractured during dry-out making it impossible to ascertain accurate volume swell. For Vipels F764 and F774, the volume swell in Fuel C was around 9 percent and 7 percent, respectively. The most compatible grade was Vipel F085, which exhibited low volume swell (2%). When dried at 60°C for 20 hours, the volume swell was lower than the wetted condition, but still significantly higher than the starting condition. The increase in dry-out volume compared to the initial condition indicates that significant levels of Fuel C are contained within the resin. This fact is further illustrated in Fig. 10 which shows the corresponding mass change of the specimens before and after dry-out.

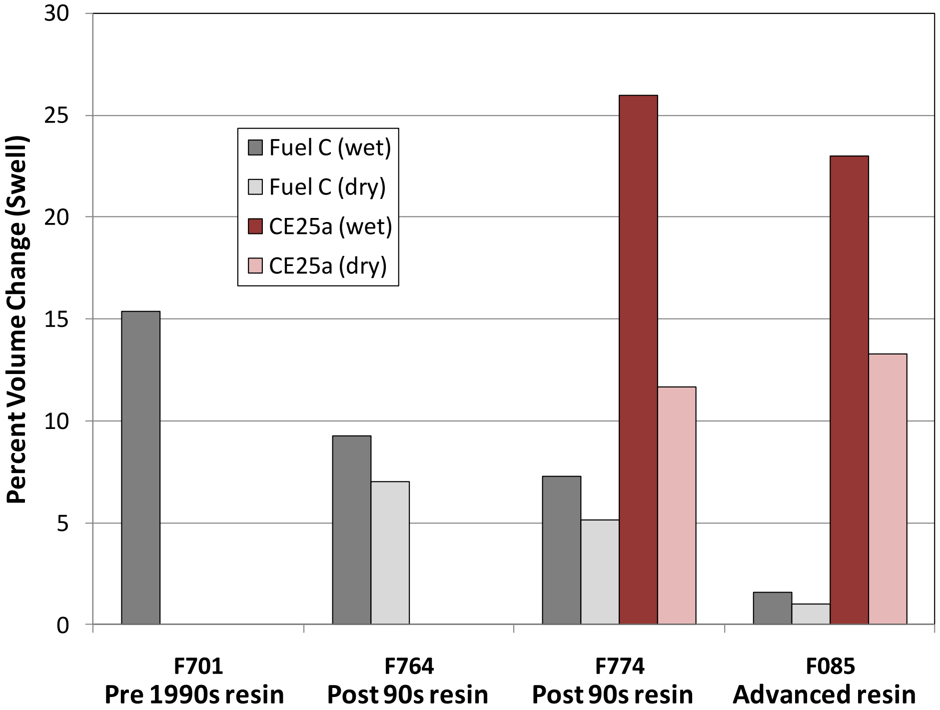

Fig. 9. Volume swell results for UST resins following exposure to Fuel C and CE25a.

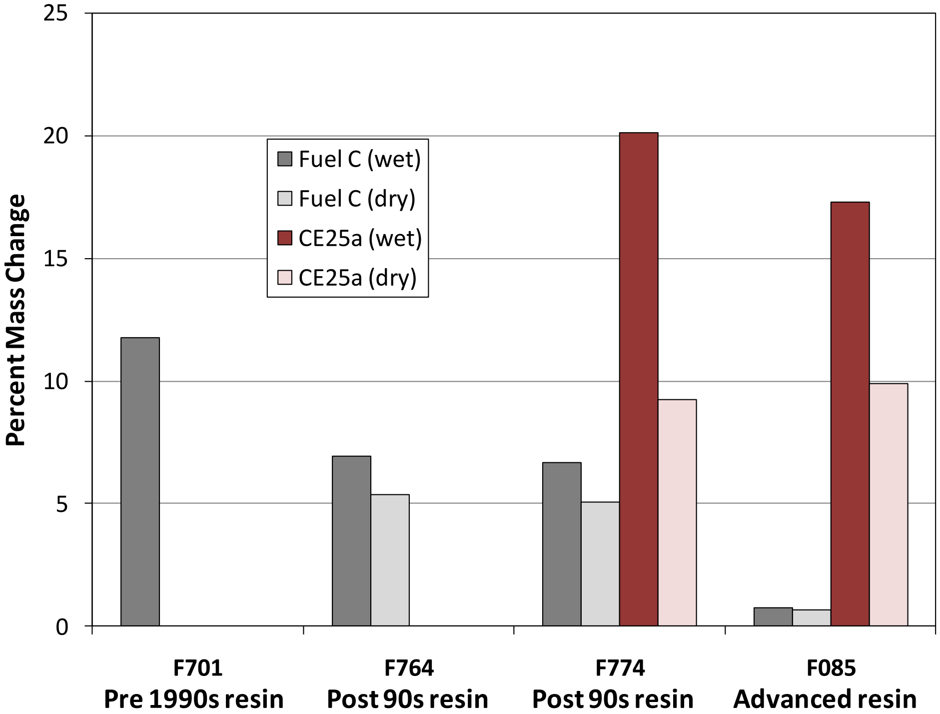

Fig. 10. Mass change for UST resins following exposure to Fuel C and CE25a.

Upon exposure to CE25a, Vipels F774 and F085 exhibited high degrees of swelling. F774 swelled to 26% while F085 swelled to around 23%. However, because the resins are reinforced with glass fibers, the actual swelling of the composite structure will be considerably lower. The inner barrier liner will be more susceptible to expansion, but the fiberglass reinforcement will prevent outward expansion of the resin barrier layer. However, inward expansion may occur and this effect may result in softening or cracking, or other forms of damage. It is important to note that the specimens which cracked in the test fuels (Vipel F701 and F764) were composed of pure resin, and these resins are not designed for use without fiberglass reinforcement. Fiberglass, by itself, is insoluble and is used in composite structures to provide modulus and strength. Fiberglass reinforcement would resist fuel permeation and elongation in the composite structure. As a result the level of swell in FRP systems would be expected to be much lower than for the pure resin. However, the inner barrier layer of an FRP tank (or FRP piping) is not reinforced and may experience degradation in the form of softening, spalling, or cracking.

The estimated volume swell for Vipel F774 and Vipel F085 in E10 and E15 was calculated using the Hansen Solubility Parameter-based method employed for estimating the volume swell for the flexible plastic materials. These results are shown in Table 6, and show that for the Vipel F774 and F085 resins, the difference in calculated volume swell associated with E10 and E15 is low (around 1.5% for both resin types). This means that in all likelihood there will be minimal effect when moving from E10 to E15. However, there is potential for a big difference when moving from E0 to E10.

Table 6. Measured and calculated results for UST resins Vipel F774 and Vipel F085

Resin material	HSP ($MPa^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10a	Estimated vol. increase associated with increasing ethanol from E10 to E15
Vipel F774	24.1	25.99	22.0	20.5	1.5
Vipel F085	24.1	22.99	19.5	18.1	1.4

The change in hardness results for the UST resins are shown in Fig. 11. For each resin type, the hardness dropped slightly with exposure to Fuel C, but CE25a was shown to significantly lower hardness in the wetted condition. Vipel F701 and Vipel F764 exhibited greatest drop hardness (31 and 20 points, respectively) from the original condition. These values are considered high and since hardness is a measure of strength and elastic modulus, it is not surprising that these two specimens exhibited fracture following exposure to CE25a. Interestingly, Vipel F774 also experienced a relatively large decrease in hardness of around 15 points. The combination of reduced volume swell and lower change in hardness (relative to the F701 and F764 resins) were enough to prevent fracture of the F774 resin. The most advanced resin grade, Vipel F085 exhibited the least change in hardness of the resins tested.

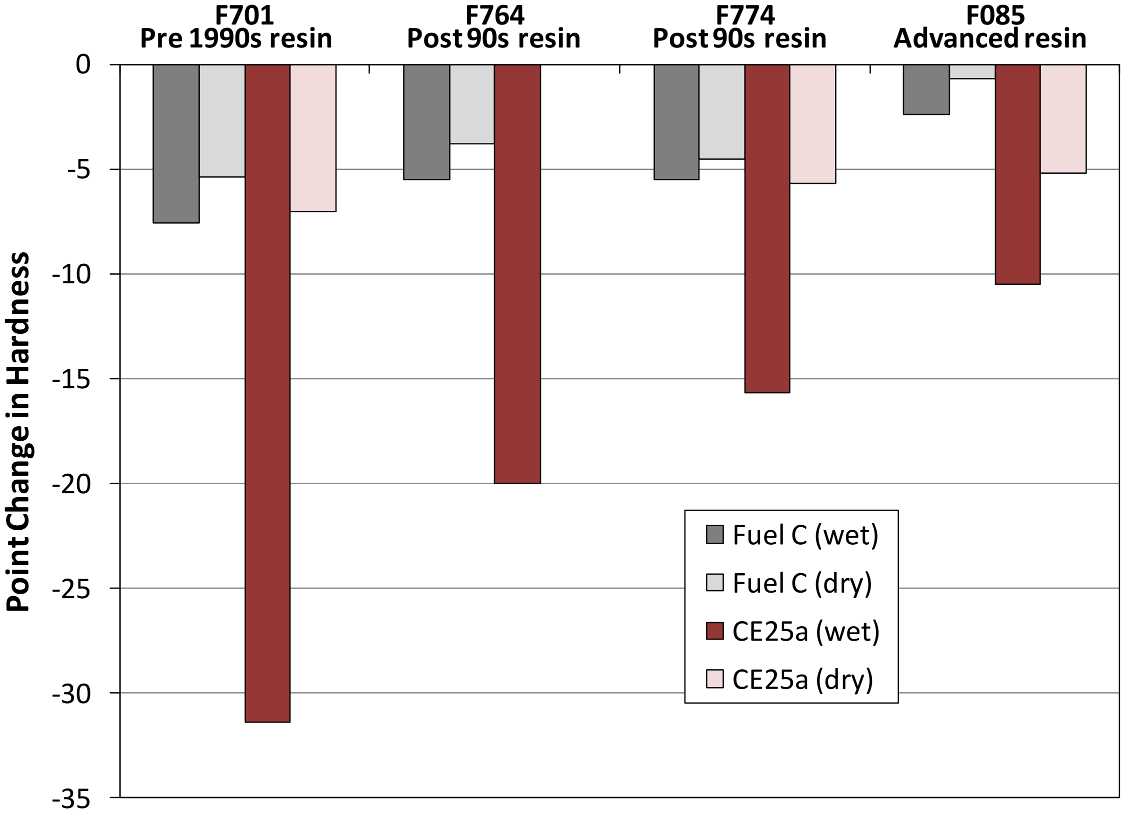

Fig. 11. Point change in hardness for the UST resin samples following exposure to Fuel C and CE25a.

Vipel F701 was used extensively in fiberglass reinforced USTs prior to 1990.[25] As such, it was designed primarily for gasoline use only and was not optimized for compatibility with ethanol-blended fuel. The volume swell and hardness decrease upon exposure to Fuel C would be considered acceptable for this resin type. F701 was replaced with more ethanol-resistant grades during the 1990s. Any legacy tanks composed of F701, or similar resin type, may be subject to ethanol degradation. Although the 30-year warrantee on tanks composed of F701 would have expired by now, many of these tanks are still in use. During the 1990s, many of the isophthalic resins were replaced by terephthalic-based and epoxy vinyl resins for improved performance.[28] The data provided by the materials compatibility testing shows that the terephthalic and vinyl resins are better suited for ethanol compatibility.

The ORNL intermediate-blend study also evaluated coupons taken from FRP underground storage tanks that had been removed from service. These tanks were cut into sections and sent to ORNL for evaluation. Photographs showing these specimens before and after exposure to the test fuels are shown in Figs. 12, 13, and 14. In each figure the baseline represents the unexposed sample.

Unfortunately the resin formulation of the UST sections was unknown, but the tanks were most likely pre-1990s vintage. Therefore, the resin formulations used in these tanks may not have been designed for use with ethanol-blended fuel. Over one dozen tanks were sectioned and sent to ORNL. All, except one, of these USTs were of amber coloration, similar to the pure resin coupons that were discussed previously, and nearly identical in appearance. There was one set of tank sections that was unique in that it was the only UST to have a corrugated plastic film adhered to the inner surface and was dark green in coloration. Test coupons were cut from three UST sections, which were labeled Batch 1, Batch 2, and Batch 3. Both

Batch 1 and Batch 2 were identical in appearance and of amber coloration, while Batch 3 was taken from the green section, which also contained the plastic film. Batch 3 was chosen since it represented an arrangement and coloration different from the rest.

Three coupons from each UST were evaluated in Fuel C, CE50a and CE85a test fuels. (The UST sections were not included in the earlier CE10a, CE17a, or CE25a test fluids, since this activity was started after these studies were completed.) These coupons were exposed in the test fluids for 16 weeks at 60°C along with other plastic specimens.

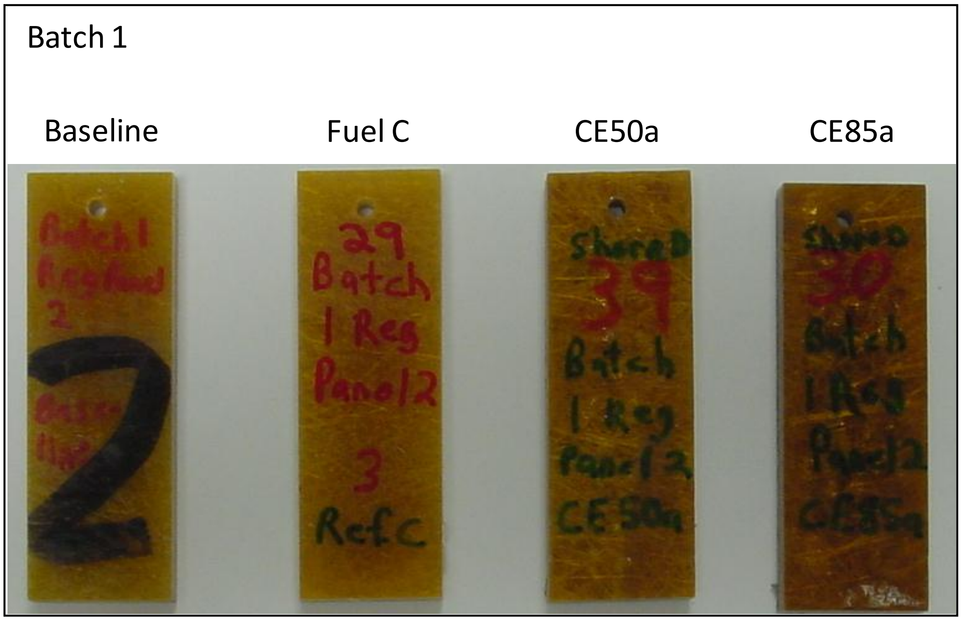

Fig. 12. Photograph showing the Batch 1 specimens before and after exposure to Fuel C, CE50a, and CE85a.

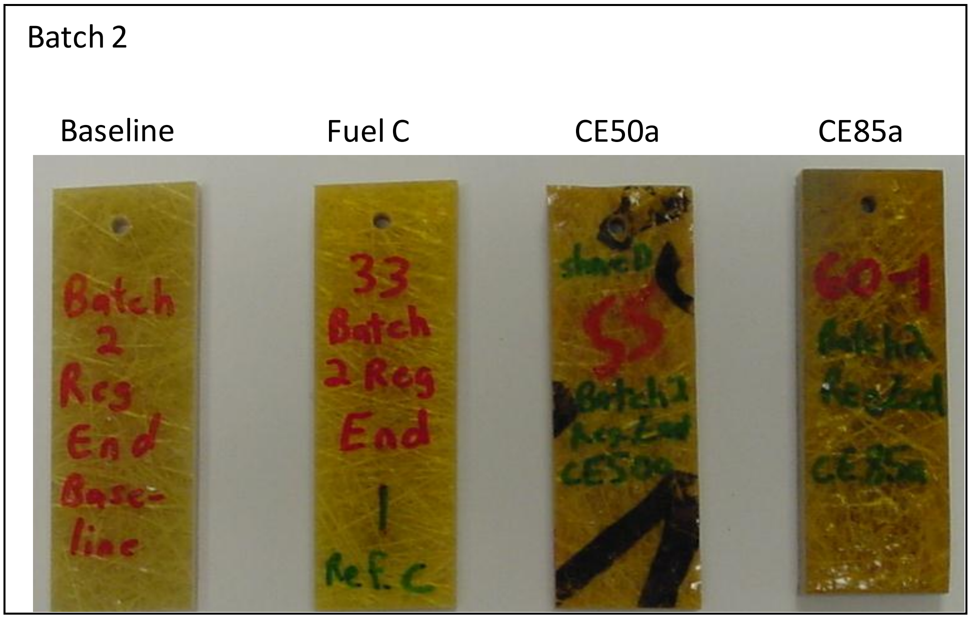

Fig. 13. Photograph showing the Batch 2 specimens before and after exposure to Fuel C, CE50a, and CE85a.

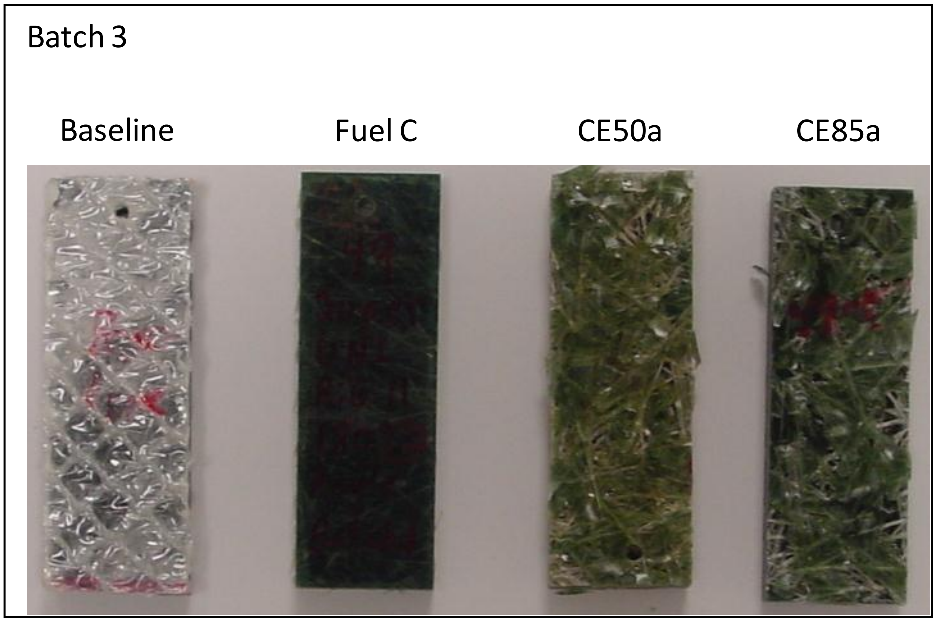

Fig. 14. Photograph showing the Batch 3 specimens before and after exposure to Fuel C, CE50a, and CE85a.

The photographs shown in Figs. 12 and 13 reveal that the amber resin specimens (Batch 1 and Batch 2) did not experience any observable degradation (outside of a slight change in color) from exposure to ethanol. However, the Batch 3 specimens (shown in Fig. 14) experienced massive degradation from the CE50a and CE85a test fuels. For this design, the corrugated liner was debonded by the Fuel C and the aggressive ethanol fuels. Interestingly, this liner survived exposure to the test fuels. However, the inner resin layer was removed and the resin surrounding the fiberglass reinforcement had dissolved to the extent that the fibers were completely exposed. It is important to note that, as depicted in Fig. 3, epoxy-based resins are likely to be more soluble in CE50a and CE85a fuels than for intermediate E10 and E15 levels. Therefore it is expected that the Batch 1 and Batch 2 USTs will be compatible to gasoline containing intermediate levels of ethanol. However, if the corrugated liner of the Batch 3 UST was damaged or breached, then it is likely that this UST has a high risk of leaking.

3. ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

3.1 ELASTOMERS

Although elastomers are ubiquitous in fuel dispenser components, especially as hoses and seals, they are not used extensively as primary piping materials in either FRP or flexible piping systems. However, these elastomers could be used as gaskets and seals in the submersible tank pump head. A survey of piping and coupling manufacturers listed Viton fluorocarbon as the only o-ring material sold today for use in couplings and fittings for gasoline delivery systems.[31] Other elastomer types were not mentioned as coupling materials for current and new UST piping systems, although they may be prevalent in legacy systems. Of the elastomers evaluated in the ORNL intermediate-blend materials compatibility study, fluorocarbons were found to be the most compatible to ethanol. The other elastomers, in particular nitrile rubbers (NBRs), showed moderate but significant increases (10-12%) in swell and increased softening with exposure to aggressive ethanol as shown in Fig. 15. However, the additional increase associated with CE17a exposure (compared to CE10a) was small (5 to 8%).

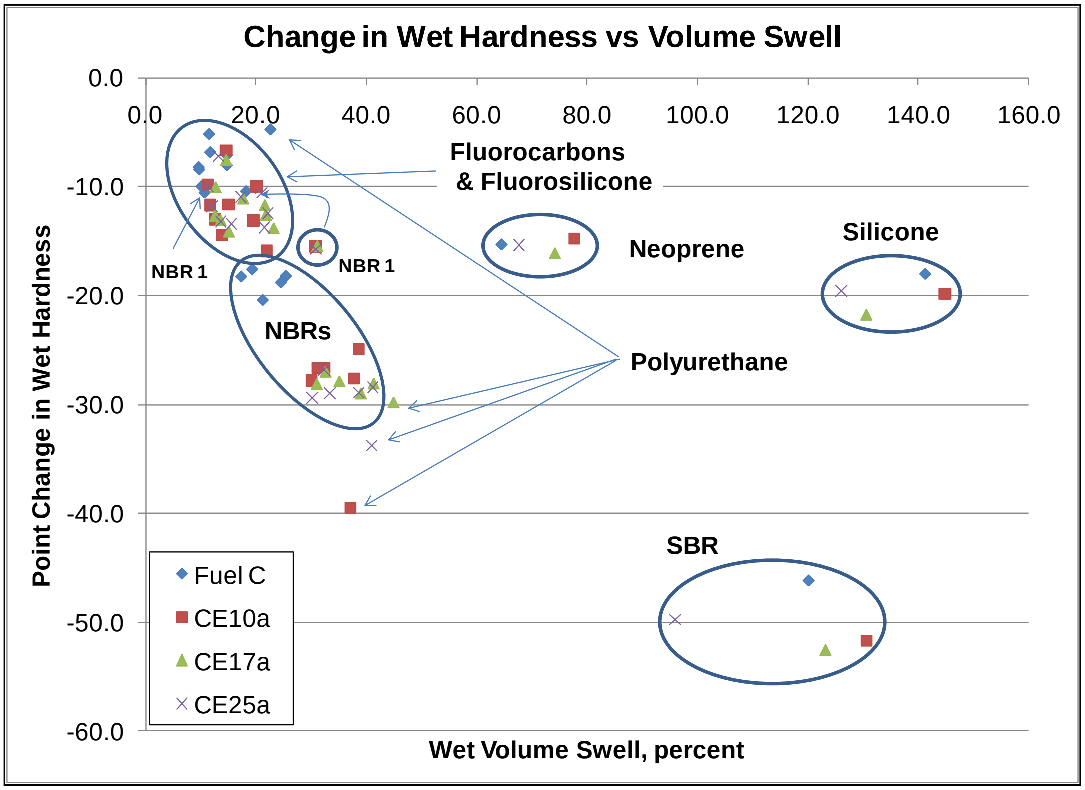

Fig. 15. Volume swell and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a.

During dry-out, elastomers such as NBR and neoprene exhibit moderate shrinkage and embrittlement (see Fig. 16) which is attributed to extraction of the plasticizer components. However the level of shrinkage or mass reduction associated is constant and independent of ethanol content. As a result, the increase in leak potential among the elastomers when moving from E10 to E15 is expected to be low. However, these materials (especially NBR, neoprene, and SBR) will exhibit a high increase in swell when moving from E0 to E10 (or E15). Therefore, care must be taken when placing ethanol-blended gasoline into a system that had only contained gasoline.

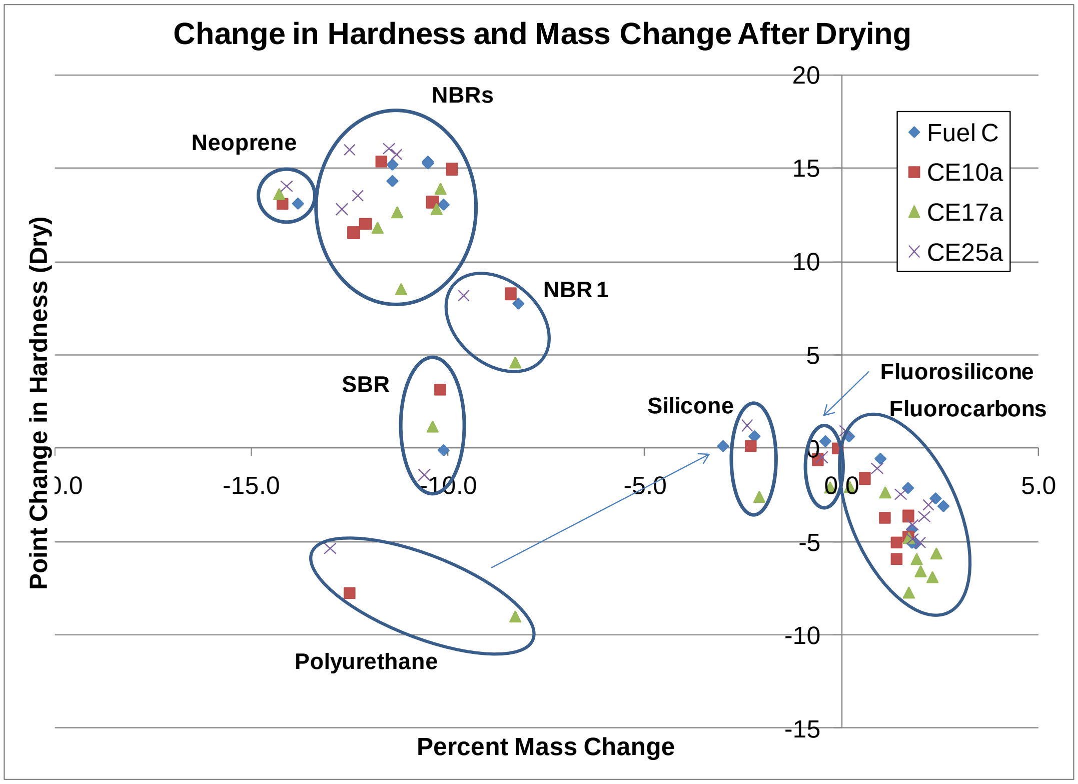

Fig. 16. Percent mass change and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a following dry-out.

It is important to note that these elastomers are used solely as seals (i.e., o-rings, gaskets, etc.) and are not utilized as structural materials for UST systems. Additional swell for o-rings and gaskets in some cases does not degrade seals or diminish sealing potential, and may, to a small degree, improve the performance of the seal. These materials are not recommended for use as structural components of piping and UST systems, since even moderate levels of swell will create internal stresses which, even at low levels, can significantly reduce the lifecycle and durability of a component.

3.2 PIPE THREAD SEALANTS

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™) were originally developed for E0 use and were used extensively in legacy piping systems. These sealants have been shown to be incompatible for use with alcohols. In the ORNL intermediate-blend materials compatibility study, RectorSeal™ was shown to be incompatible with CE10a. This result strongly indicates that the pipe thread sealants used in the E0 legacy systems experienced leaking when exposed to E10. Ethanol compatible sealants such as GasOila ESeal™ were subsequently developed for ethanol-blended gasoline use and are now the industry standard. The ORNL study showed that the GasOila ESeal™ product is compatible with fuel containing up to 25 percent aggressive ethanol. It is very likely that the standard PTFE sealants used in the legacy systems were replaced with the ethanol-compatible products during the implementation of E10. There is no hard data to support this assessment, but based on the development and widespread use of the GasOila product, it appears to be the case. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, we do not foresee any added potential for releases when switching from E10 to E15.

3.3 COUPLINGS AND FITTINGS

One of the most susceptible locations of the underground storage tank systems are the couplings used to connect piping, fittings, and valves. There are two potential sources of leaks. One is where the coupling attaches to the piping and the other one is at the seal interface mating two couplings together. The interfacial seal issue was discussed under the elastomer section and is not considered to be a significant point of release if seals and gaskets are made of fluorocarbon materials and are properly installed.

Flexible plastic piping typically utilizes swage-type fittings to join piping and connect valves and flanges. A typical coupling assembly consists of a stainless steel insert with one or two o-rings, a stainless steel ferrule with one o-ring, and a swivel nut (or other means) to compress the ferrule against the outer pipe surface.[31] A simplified schematic is shown in Fig. 17. The compression of the plastic between the stainless steel insert and ferrule maintains a leak tight seal. In this configuration, the fuel is only exposed to the plastic piping, stainless steel coupling and the o-ring used to seal the coupling adjacent faces. Newer units were found to utilize fluorocarbon as the o-ring material, although legacy couplings may use other elastomers (such as NBR). These couplings usually require a special tool (from the piping supplier) to install properly. It is important to note that couples for FRP piping cannot be installed in this manner because the hard resin would fracture under high compression.

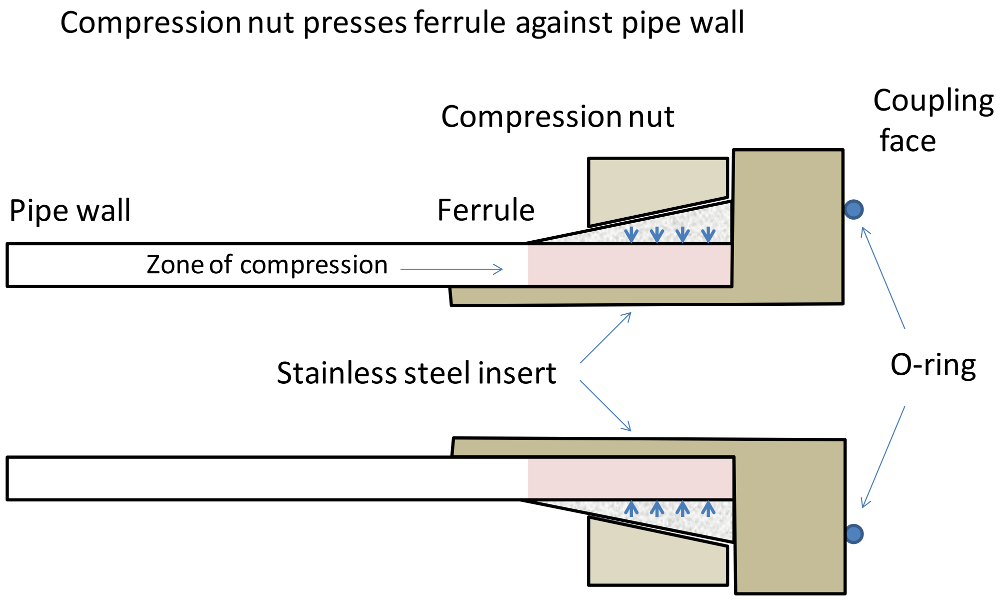

Fig. 17. Simplified schematic showing attachment of a coupling to flexible plastic piping.

The two most common methods for joining FRP piping and attaching couplings are adhesive bonding and butt and strap joints.[32] The butt and strap method is considered the most reliable means for joining FRP piping. Two pieces of pipe are butted together and layers of chopped fiberglass are wrapped around the pipe in a resin matrix similar to the pipe composition. A diagram depicting a butt and strap joint is shown in Fig. 18. If the butt and strap materials are similar or identical to the pipe materials, then compatibility performance is expected to be essentially the same and thus potential for further degradation due to E15 is minimal.

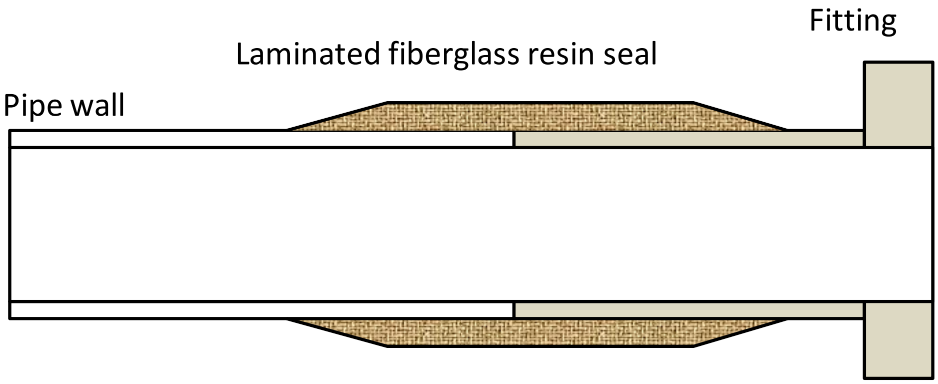

Fig. 18. Schematic diagram of the butt and strap joint.

The adhesive method involves adding an adhesive to glue a fitting or coupling to FRP. Because of its inherent weakness, this method is not used to join pipe sections, but is restricted to attaching fittings (such as flanges). Typically the outer surface of the pipe is sanded to allow better distribution of the sealant and to enable the adhesive to better grip the pipe surface and thereby form a strong mechanical bond. One application of this method is shown in Fig. 19. The adhesive maintains a seal between the fitting and the pipe end. At the fitting face, the adhesive will be exposed to fuel in the crevice region between the adjacent pipe ends. For some applications, the outer pipe walls are tapered at the ends to enable better fit between the pipe wall and fitting.

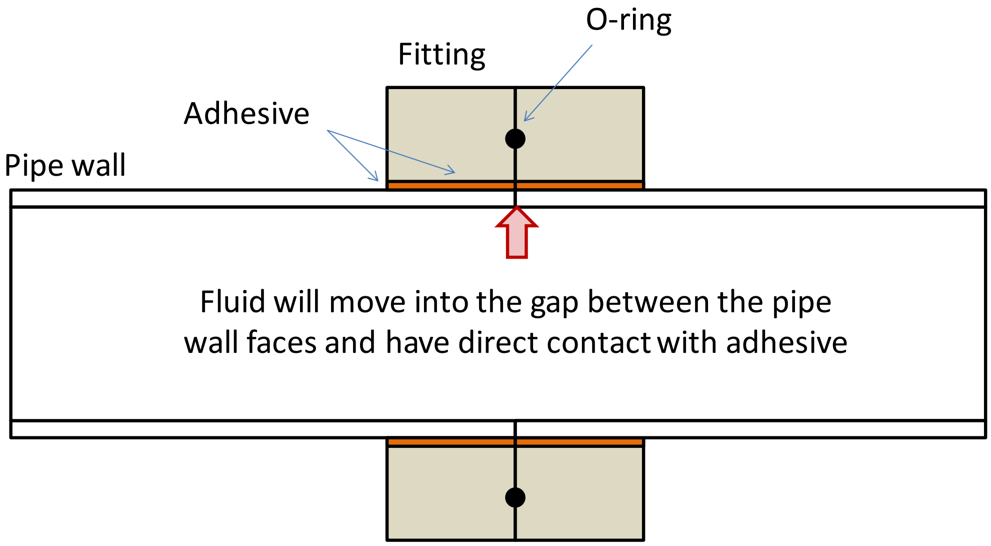

Fig. 19. Schematic showing a common arrangement of using adhesive on FRP piping.

The adhesives used for FRP systems contain a mix of inorganics (over 50%), such as clay, limestone, and silica and a mix of hydrocarbons.[33] The inorganic fraction imparts strength, rigidity and is resistant to attack from aggressive fuel components (including alcohols). The remaining hydrocarbons consist primarily of acrylic polymers, resins and distillate products. Information pertaining to adhesive resistance to ethanol was lacking and we were not able to ascertain ethanol compatibility.

4. CONCLUSIONS

The USEPA Office of Underground Storage Tanks commissioned a study at ORNL to evaluate whether an increased potential for leaking of USTs will occur when moving from E10 to E15 fuel. The original intention was to construct a probabilistic failure analysis tool to estimate the increase in releases, if any, if E15 replaced E10 in regulated UST systems. A key part of this process was to solicit opinions from a panel of industry and regulatory experts to identify critical variables that impact failure likelihood estimates. However, the lack of information on the performance of existing UST systems with E15 precluded the possibility that state/industry experts could speculate on E15's impact to UST systems. Therefore, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when moving from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study. This study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, E25, E50 and E85. Potential leak locations, such as pipe couplings were identified, and the elastomers and sealants used in couplings and joining were also studied.

4.1 CONCLUSION ON TANKS AND PIPING MATERIALS

Metallic materials included carbon and stainless steel and aluminum. A large number of USTs are composed of carbon steel, which is also used in approximately 18% of piping. Stainless steel is used in pipe couplings which are used to join piping sections and fittings. Aluminum, while not used as extensively as either carbon or stainless steels, is used in the construction of submersible pumps. However, failure of a submersible pump should not lead to leaking. The results from the ORNL intermediate-blends compatibility study showed that carbon and stainless steels, and aluminum will not undergo significant corrosion in either E10 or E15. However, it is important to note that the test conditions for these materials did not include stress or water-phase separation, both of which can contribute to increased corrosivity. In fact, if aqueous phase separation occurs, then the risk for corrosion will be higher for E15 since the maximum level of dissolved water is roughly twice that of E10.

Plastics are used extensively in underground piping systems. The two types of plastic piping, flexible and FRP, employ different types and grades of plastic materials. Flexible piping is primarily composed of various grades of nylon, PVDF, PET, polyester, and polyethylene. These materials were only tested in Fuel C and CE25a. As a result, the volume change, associated with CE10a and CE15a exposure, was estimated using the known swelling behavior at CE25a and Hansen Solubility Parameters for the plastics and test fuels. Nylon 11 exhibited the highest level of swelling (~18%) and would likely not be considered acceptable for use in USTs or flexible piping systems. Likewise, nylon 12 also may not be acceptable due to the significant loss of mass after drying. Other plastics, such as HDPE, F-HDPE, nylon 6 and nylon 6/6 exhibited relatively high swell (8-10%) and may not be suitable when switching from E0 to either E10 or E15. However, the calculated swell for nylon 6, nylon 6/6, PVDF, PET, and polyethylene indicated that the added increase in swell when moving from E10 to E15 was very low. This result suggests that the leak potential in E15 for flexible piping containing these materials will be low as well.

The performance of resins used in the construction of FRP tanks and piping is highly dependent on the type of resin. A pre-1990 legacy isophthalic polyester resin was visibly damaged with exposure to a test fuel containing 25% aggressive ethanol. Analysis of post-1990s resins (exposed to CE25a) were mixed; the resin composed of isophthalic polyester was damaged, while the resins composed of terephthalic polyester or vinyl ester were not. Interestingly, the two resins that were damaged from exposure to ethanol were both isophthalic polyesters. Based on these results, isophthalic polyester resins should be avoided in the construction of UST systems storing ethanol-blended fuels. The predicted level of volume swell associated with E10 and E15 was calculated for the terephthalic polyester and vinyl ester resins. The results suggest that the added volume swell associated with E15 (compared to E10) is extremely low and would not likely increase the potential for leaking with E15 fuel. ORNL was able to include three legacy UST samples in a later compatibility effort using CE50a and CE85a as test fuels. In one unique case, a legacy FRP UST that contained a separate plastic liner exhibited significant degradation of the resin material when exposed to high levels of ethanol. Although the liner was not visibly damaged, its performance with lower intermediate levels of ethanol-blended gasoline could not be ascertained. The other two UST sections were not damaged and would likely exhibit good compatibility with E10 or E15.

4.2 CONCLUSION ON ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

A high leak potential also exists where piping sections are joined and fittings are attached. The structural material typically used in these applications is stainless steel and the sealing materials are either elastomers and/or pipe thread sealants. Modern joining units employ primarily fluorocarbons in o-ring and sealing applications; however some legacy systems may use NBRs and other elastomer types. The ORNL intermediate-blend ethanol compatibility study investigated the performance of fluorocarbons, fluorosilicone, NBRs, silicone rubber, styrene butadiene rubber, neoprene and polyurethane. These elastomers all showed significant swelling with exposure to ethanol. However, because elastomers are used solely as seals (i.e., o-rings, gaskets, etc.), swelling is not necessarily an indication of leak potential. Additional swell for o-rings and gaskets may improve the performance of the seal. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, for field applications and materials examined in this study, there should not be any corresponding potential for releases associated with increase the ethanol concentration in fuel gasoline from E10 to E15. The flanges used in coupling systems are composed of stainless steel and this material has been shown to have excellent compatibility with ethanol-blended fuels.

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™), used in E0 applications, were shown to be incompatible for use with E10. However, ethanol-compatible sealants (such as GasOila ESeal™) were compatible with fuel containing up to 25 percent aggressive ethanol. Although it is very likely that standard PTFE sealants used in legacy systems were replaced with the ethanol-compatible products during the implementation of E10, there may be systems still in use with the incompatible sealant material.

FRP piping joined using either a butt and strap configuration or an adhesive is used to secure a fitting on one end. The butt and strap consists of a FRP wrap that contains resin similar or identical to the FRP pipe resin, and therefore, should be compatible with ethanol-blended fuel. Adhesives consist of a mix of various organic and inorganic materials, and we could not assess their compatibility to ethanol since they were not included in the ORNL intermediate-ethanol blends compatibility study.

In general, several materials evaluated in this study were found to not perform well in fuel blends containing ethanol. These materials demonstrated incompatibility with E10 and should not be used for E15 (unless it can be demonstrated that a particular polymer grade is, in fact, compatible). Systems most susceptible to increased leakage will be those legacy USTs which are currently using E0 and will be switching directly to E15.

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Exhibit List

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1	Environmental Health & Engineering, Inc., *Response to 2020, 2021, and 2022 Renewable Fuel Standard (RFS) Proposed Volume Standards* (Feb. 3, 2022)
2	Life Cycle Associates, LLC, *Review of GHG Emissions of Corn Ethanol under the EPA RFS2* (Feb. 4, 2022)
3	Net Gain, *Analysis of EPA's Proposed Rulemaking for 2020, 2021, and 2022 RVOs, Regarding Land Use Change, Wetlands, Ecosystems, Wildlife Habitat, Water Resource Availability, and Water Quality* (Feb. 3, 2022)
4	*Comments of Drs. Fatemeh Kazemiparkouhi, David MacIntosh, Helen Suh*, EPA-HQ-OAR-2021-0324 (Feb. 3, 2022)
5	Stillwater Associates, LLC, *Comments to EPA on 2020-2022 RFS Rule, Prepared for Growth Energy* (Feb. 4, 2022)
6	Stillwater Associates LLC, *Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017* (July 11, 2016)
7	Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012)
8	Growth Energy, *Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations*, Docket # EPA–HQ–OAR–2020–0448 (Apr. 19, 2021)
9	Petroleum Equipment Institute, *UST Component Compatibility Library*
10	Association of State and Territorial Solid Waste Management Officials, *Compatibility Tool*
11	Air Improvement Resource, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2022* (Nov. 16, 2021)
12	Renewable Fuels Association, *Contribution of the Ethanol Industry to the Economy of the United States in 2020* (Feb. 2, 2021)
13	ABF Economics, *Economic Impact of Nationwide E15 Use* (June 2021)
14	Jarrett Renshaw & Chris Prentice, *Exclusive: Chevron, Exxon seek 'small refinery' waivers from U.S. biofuels law*, Reuters (Apr. 12, 2018)
15	Stillwater Associates LLC, *Potential Increased Ethanol Sales through E85 for the 2019 RFS* (Aug. 17, 2018)

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

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Exhibit 8

growth energy™
America's Ethanol Supporters

Growth Energy Comments on EPA's Proposed E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks Regulations

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Docket # EPA–HQ–OAR–2020–0448

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April 19, 2021

INTRODUCTION

Growth Energy respectfully submits these comments on the Environmental Protection Agency's (EPA's) proposed rulemaking entitled "E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks" ("E15 Proposal").[1] Growth Energy is the leading association of ethanol producers in the country, with 85 producer members, producing more than 6 billion gallons of ethanol, and 91 associate members who serve the nation's need for renewable fuel. Growth Energy strongly supports EPA's proposal to remove labeling and infrastructure barriers to E15. E15 is the lowest carbon-intensity gasoline product on the market; if the United States transitioned from E10 to E15 in the nation for 2001 and later model year vehicles, GHG emissions would be lower by 17.62 million tons per year, which is the equivalent of removing approximately 3.85 million vehicles from the road.[2] Moreover, more than 98% of registered vehicles on the road can use E15.[3]

Growth Energy supports modification of the E15 label requirement to increase clarity and ensure it adequately advises consumers of appropriate uses of the fuel, while not unnecessarily dissuading the vast majority of consumers whose vehicles can refuel with E15. Growth Energy also responds below to EPA's request for public comment on preemption considerations related to potential removal or revision of the label. In short, either modification of EPA's E15 label or removal of the E15 label requirement entirely would expressly preempt and conflict-preempt any state or local government E15 label requirement.

In addition, Growth Energy strongly supports EPA's proposal to modify the underground storage tank (UST) compatibility requirements applicable to E15 and other fuel blends. There is ample support that a wide variety of fuel storage equipment, including USTs and related piping, may store E15 if it is suitable for use with E10. Removing unnecessary impediments to retailers' use of such existing equipment is imperative to providing E15 equal footing in the fuels marketplace. We address these issues in detail below.

I. E15 LABELING REQUIREMENTS

a. MODIFICATION OF THE EPA E15 LABEL IS NECESSARY AND APPROPRIATE.

E15 has been legal for sale for over a decade, during which time consumers have engaged in millions of transactions to purchase the fuel and have driven more than twenty billion miles on it.[4] Today, sixteen of the largest retail chains in the nation offer E15 across 30 states.[5] The current EPA fuel label, however, persists as a barrier to consumers' purchase of E15 as it is

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[1] Proposed Rule, *E15 Fuel Dispenser Labeling and Compatibility with Underground Storage Tanks*, 86 Fed. Reg. 5,094 (Jan. 19, 2021) ("E15 Proposal").

[2] Air Improvement Resources, Inc., *GHG Benefits of [E15] Use in the United States* (Nov. 30, 2020).

[3] Air Improvement Resources, Inc., *Analysis of Ethanol-Compatible Fleet for Calendar Year 2021* (Nov. 9, 2020).

[4] Growth Energy, "American Drivers Reach 20 Billion Miles on E15," https://growthenergy.org/2021/03/09/growth-energy-american-drivers-reach-20-billion-miles-on-e15/.

[5] Growth Energy, "Progress Report: E15 Rapidly Moving Into the Marketplace" (updated Mar. 16, 2021) https://growthenergy.org/wp-content/uploads/2021/03/e15-stationcount-2361-2021-03-16.pdf.

confusing and undermines consumer confidence in the fuel. Specifically, in a recent survey conducted by Quadrant Strategies, consumers responded that the current EPA label acts as a deterrent to purchasing E15, with almost half of respondents indicating the label makes them uncomfortable and unlikely to use the fuel.[6] Moreover, the label raises concerns about engine performance, with almost 40% of respondents indicating it leads them to believe E15 is bad for their vehicles' engine.[7] The wordiness of the current label is difficult for consumers to digest and leads to confusion about the fuel and whether it is allowed for use in the vast majority of vehicles on the road, for which it is legal.[8] In addition, with respect to the coloring of the label, almost half of respondents indicated that the orange/black coloring dissuades them from use of the fuel; whereas, a blue/white color scheme does not elicit such strong adverse reactions.[9] These unintended consequences of the current label's format, coloring, and content necessitate revision in order to correct perceptions and remove unnecessary barriers to consumer acceptance of the fuel.

Growth Energy requests that EPA consider replacing the current EPA label with this simplified, more clear label that succinctly informs consumers of the vehicles that may use the fuel:

Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel Vehicles

Survey data strongly supports that this proposed label accurately informs consumers of acceptable uses of the fuel, while leading to substantially fewer misperceptions regarding engine performance.[10] The coloring and content of the label are informational, rather than unnecessarily alarmist. In other words, it conveys the salient information about E15's characteristics and legal uses without unduly raising the specter of engine damage or causing consumers' skepticism of the fuel. In addition, this proposed label adheres to FTC's recommendation that the E15 label "be as concise as possible since consumers are much less apt to read detailed labels, particularly

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[6] Quadrant Strategies, Memorandum re: "E15 Labeling Study" at 2 (Apr. 16, 2021) (Attachment 1) (hereinafter "Quadrant Survey").

[7] *Id.*

[8] *See id.* at 5.

[9] *Id.* at 6.

[10] *Id.* at 2.

in the context of routine activities like buying gas."[11] Moreover, its color scheme and content correct potential confusion with the FTC labels required for higher-level ethanol blends that may *only* be used in flex-fuel vehicles (FFVs), rather than the vast majority of light duty vehicles on the road today that may refuel with E15. Specifically, the FTC labeling scheme for higher-level ethanol blends that may only be used in FFVs is orange and black.[12] It is confusing for the E15 label, for a fuel that can be used in the vast majority of registered vehicles, to have the same color scheme.

This proposed label is similar to the alternative EPA proposes, but it removes superfluous language to clearly and succinctly inform consumers of acceptable uses consistent with FTC guidance on brevity. However, to the extent EPA does not adopt the proposed label, Growth Energy supports revision of the label as outlined in the E15 Proposal to: (1) modify the color scheme to blue and white, which survey evidence shows will prevent dissuading consumers from using the fuel; and (2) simplify and clarify the language.[13]

The recommended label changes outlined above are appropriate measures under EPA's Clean Air Act Section 211(c)(1) authority. Specifically, the proposed label would accomplish the same ends as set forth in EPA's original Misfueling Mitigation Rule (MMR), namely, that retailers selling E15 inform consumers of the legal and prohibited uses of E15 and prevent misfueling as is appropriate under Section 211(c)(1).[14] A decade ago, EPA acknowledged the MMR commenters' concerns that the label may "discourag[e] or chill[] appropriate use of E15 in MY2001 and new light-duty motor vehicles."[15] Survey evidence is clear that this is an unintended consequence of the current EPA label that requires correction.[16] In light of this new information, EPA is justified in revising the label to better inform consumers while requiring a label that prevents misfueling consistent with the original MMR and the agencies' authority under the Clean Air Act.[17]

b. STATE AND LOCAL LABELING OF E15 IS PREEMPTED.

Below we address EPA's request for comment on E15 labeling preemption considerations. As an initial matter, as EPA acknowledged in the E15 Proposal, both EPA and

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[11] 76 Fed. Reg. 44,406, 44,414 (Jul. 25, 2011).

[12] *See* 16 C.F.R. §§ 306.10, 306.12. Unfortunately, the FTC requires that an E15 label state the fuel is for "use only in Flex-Fuel Vehicles," when E15's use is not restricted to such vehicles pursuant to the partial waiver decisions and EPA regulations.

[13] Specifically, Growth Energy would support, in the alternative, the label in Figure 2 in the docket memorandum, "Potential Label Changes," (Oct. 27, 2020), Doc. ID EPA-HQ-OAR-2020-0448-0002.

[14] 76 Fed. Reg. at 44,418; 42 U.S.C. § 7545(c)(1) (providing EPA authority to regulate fuel or fuel additives which contribute to air or water pollution that may reasonably be anticipated to endanger public health or welfare, as well as fuel or fuel additives that will impair to a significant degree the performance of any emission control device or system which is in general use).

[15] 76 Fed. Reg. at 44,413.

[16] *See generally* Quadrant Survey.

[17] *Nat'l Cable & Telecomms. Ass'n v. Brand X Internet Servs.*, 545 U.S. 967, 981 (2005) (internal citation omitted) (noting that it is entirely appropriate for an agency to continually evaluate the wisdom of its policies, especially "in response to changed factual circumstances").

FTC regulate labeling requirements for E15. Specifically, the FTC regulations found at 16 C.F.R. § 306.10 (Automotive Fuel Rating Posting) require fuel dispenser labels for gasoline-ethanol fuel blends containing greater than 10 percent ethanol. EPA has also adopted an E15 label under Clean Air Act (CAA) section 211(c)(1) that can be used in lieu of the FTC's label.[18] Thus, as EPA noted in its proposal, if it removes its own E15 label, the FTC label requirement would still apply.[19] Regardless of which label requirement is applicable, both the CAA and FTC regulations contain express preemption provisions that prohibit states or local governments from adopting or enforcing their own E15 label requirements. Specifically:

<u>CAA Preemption</u>. CAA section 211(c)(4)(A) provides that states and local governments cannot "prescribe or attempt to enforce, for purposes of motor vehicle emission control, any control or prohibition respecting any characteristic or component to a fuel or fuel additive in a motor vehicle engine," unless identical to the federal control or prohibition. As EPA noted in its proposal, section 211(c)(4)(A) preemption would apply to state controls and prohibitions respecting labeling of E15 fuel dispensers.[20]

<u>FTC Preemption</u>. 16 C.F.R. § 306.4 similarly provides that "[t]o the extent that any provision of this title applies to any act or omission, no State or any political subdivision thereof may adopt or continue in effect, [except as provided by limited exceptions], any provision of law or regulation with respect to such act or omission, unless such provision of such law or regulation is the same as the applicable provision of this title." Because the FTC has acted to regulate E15 with respect to labeling, preemption would apply to any state adoption or enforcement of an E15 label that differs from FTC's, even in the absence of an EPA label.

A. State E15 Label Requirements Would Be Expressly Preempted by Either Modification of the EPA Label or Removal of the E15 Label

If EPA modifies the E15 label (or retains the current label), any state that adopts a label requirement not *identical* to the EPA requirement for the purposes of motor vehicle emission control would be expressly preempted by Section 211(c)(4)(A). As EPA stated in the MMR and reiterated in the E15 Proposal, the E15 label is for purposes of vehicle emission control, and the label requirement is promulgated pursuant to Section 211(c)(1).[21] In addition, the FTC preemption provision prohibits states from adopting any regulation with respect to E15 labeling, regardless of purpose.[22] Thus, states and local governments are expressly preempted from prescribing and enforcing their own E15 label requirements under both the Clean Air Act and FTC regulations.[23]

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[18] *See* 76 Fed. Reg. 44,406; E15 Proposal at 5,096.

[19] 86 Fed. Reg. at 5,096 ("[I]f we were to remove our label requirement…absent additional action from FTC, retailers would be required to use FTC's label for ethanol blends containing between 10 and 15 percent ethanol.").

[20] *Id*. at 5,099.

[21] 76 Fed. Reg. at 44,411; 86 Fed. Reg. at 5,097.

[22] *See* 16 C.F.R. § 306.4.

[23] *See id*.; CAA § 211(c)(4)(A).

If EPA removes its label requirement (which Growth Energy does not support at this juncture), the FTC label would still apply.[24] Therefore, any state that sought to adopt a label requirement not identical to the FTC requirement would be expressly preempted by 16 C.F.R. § 306.4.

B. State E15 Label Requirements Would Be Conflict Preempted by Either Modification of the EPA Label Or Removal of the E15 Label

Even if express preemption did not apply (which it does), states would also be unable to adopt or enforce their own E15 labeling requirement pursuant to the doctrine of conflict preemption. Specifically, if EPA revises the label, a state control or prohibition on fuels or fuel additives that is not identical to EPA's modified E15 label would be impliedly preempted because it would "conflict" with the federal standard, preventing compliance with EPA's and FTC's E15 label requirements and/or serving as an obstacle to the accomplishment of EPA and FTC's objectives with respect to E15 regulation. Namely, a non-identical state label would serve as an obstacle to EPA's objectives of clearly conveying which vehicles and engines can lawfully use E15, reducing consumer confusion, and selecting a color and format most suited for the label's purpose. Any inconsistency with regard to the label requirement would jeopardize EPA's stated goal of "improving clarity regarding which vehicles can use E15 while protecting vehicles and engines for which E15 use in appropriate."[25]

Similarly, if EPA removes its label requirement, conflict preemption would apply to any state attempting to adopt an alternative E15 label because this would conflict with the federal standard, preventing compliance with the FTC label requirement. In addition to preventing compliance with the FTC label, a state label requirement would create an obstacle to the accomplishment of the FTC's goals in establishing a label requirement for E15. These goals include providing "information to consumers about ethanol concentrations and suitability for their cars and engines," "preventing consumer confusion," creating "greater flexibility for businesses to comply with the ethanol labeling requirements," and avoiding "unnecessary burden on industry."[26] Any state E15 label requirement not identical to the federal standard would create consumer confusion, burden industry which would have to comply with multiple different standards, and could dissuade consumers from using E15 altogether.

Consequently, whether EPA revises the label, retains, or removes it, states are preempted from requiring non-identical E15 labels, both expressly and impliedly. Therefore, EPA should confirm in its final rule that, regardless of the option it ultimately chooses, states and local government would continue to be unable to adopt or enforce their own E15 label requirements.

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[24] *Id*. at 5,096, 5,098.

[25] *Id*. at 5,098.

[26] 81 Fed. Reg. 2,054, 2,055 (Jan. 14, 2016).

II. EPA SHOULD REVISE THE 2015 UST REGULATION TO BE LESS BURDENSOME FOR UST OWNERS AND OPERATORS TO DEMONSTRATE COMPATIBILITY.

Growth Energy strongly agrees with EPA that it is important for USTs to be constructed, maintained, and operated in a manner so that petroleum and other regulated substances are stored safely. Growth Energy also agrees that, due to the continued growth in biofuels in the United States, the 2015 UST regulation[27]—requiring owners and operators to provide additional notification, demonstration and recordkeeping when storing fuel blends, such as those with more than 10% ethanol or more than 20% biodiesel—should be revised to grant certain allowances for compatibility demonstration and make it less burdensome for UST owners and operators to meet the current requirements. By revising the 2015 UST regulation, EPA can ensure that the future national UST infrastructure is compatible with a broad range of biofuels while encouraging growth in the nation's renewable fuel production.

As an initial matter, the scientific literature strongly supports that UST systems compatible with E10 are also compatible with E15.[28] As a National Renewable Energy Laboratory (NREL) infrastructure report ("NREL Report") found, there have been *no* known incidents of E10 causing releases from UST systems, or even any association between E10 and any specific UST release.[29] E10 now constitutes 98% of gasoline sold in the United States, which means the vast majority of retailers have underground equipment that is already E15-compatible.

The agency states in the proposal that the following equipment is E15-compatible and warrants no further compatibility demonstration requirements:

- all steel tanks (single- and double-walled);
- all fiberglass tanks manufactured after July 2005;
- all flexible reinforced plastic piping.[30]

The existing scientific literature clearly indicates the compatibility of this equipment. In addition, according to manufacturers, *all* double-walled fiberglass tanks have always been E10 compatible, and single-walled fiberglass tanks have been E10 compatible since February 1981.[31]

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[27] 80 Fed. Reg. 41,566 (July 15, 2015).

[28] National Renewable Energy Laboratory, *E15 and Infrastructure*, DOE (May 2015) (hereinafter "NREL Report") (Attachment 2); Oak Ridge National Laboratory, *Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel*, ORNL/TM-2012/182 (Jul. 2012) (hereinafter "ORNL Report") (Attachment 3).

[29] *Id*. at 11.

[30] The Fiberglass Tank & Pipe Institute stated that "[u]nderground fiberglass piping and fittings installed in service stations have been compatible with up to 100%-percent ethanol for over 40 years." *See* http://www.fiberglasstankandpipe.com/wp-content/uploads/2018/11/Ethanol-Compatibility-with-Fiberglass-11102016-retired.pdf.

[31] US DRIVE Fuels Working Group, *Potential Impacts of Increased Ethanol Blend-Level in Gasoline on Distribution and Retail Infrastructure*, Figure 2-6 (Feb. 2019), https://www.energy.gov/sites/prod/files/2019/02/f59/USDRIVE_FWG_PotentialImpactsIncreasedEthanolBlend-Level.pdf.

Because the literature strongly supports that E10-compatible tanks can be safely used with fuel with 5% higher ethanol content,[32] EPA is warranted in excluding from additional compatibility demonstrations all double-walled fiberglass tanks and all single-walled fiberglass tanks manufactured after 1981. Moreover, the NREL Report comprehensively identifies in appendices the USTs, piping, and related equipment that are E15-compatible. This report supports and supplements the equipment that EPA may exclude from the compatibility demonstration requirements under 40 C.F.R. § 280.32. For example, the report supports that most flexible plastic piping is E-15 compatible.

In addition, based on robust compatibility analyses conducted by Oak Ridge National Laboratory, from a materials perspective, all metal and flexiglass UST system piping and the vast majority of flexible plastic piping is E15-compatible.[33] Particularly with respect to flexible plastic piping, Oak Ridge's analysis indicates a small minority of flexible plastic pipes with a nylon permeation barrier may not be compatible with E10, but that equipment would have long-since been replaced in the transition to E10, especially as this equipment is only warrantied for approximately 10 years.[34] Notably, the remainder of flexible plastic piping with polyvinylidene fluoride (PVFD) and polyethylene terephthalate (PET) permeation barriers, the two most common types, is compatible with intermediate ethanol blends.[35] This data supports exclusion of these piping materials from further compatibility demonstration. For other auxiliary equipment in a UST system, including containment sumps, pumping equipment, release detection equipment, spill prevention equipment, overfill prevention equipment, seals, pipe couplings, and sealants, the ORNL analysis supports that equipment suitable for use with E10 poses no E15-compatibility issues.[36] For example, ORNL found that pipe couplings using flexible plastic piping are generally comprised of a band of stainless steel compression-fitted around the pipe (which show no corrosion issues up to E25 blends). With regards to sealants, ORNL found that fluorocarbons are often used and perform well with intermediate ethanol blends including E15. In addition, pipe dope that is E10-compatible (most commonly Gasoila E-Seal) is appropriate for use with immediate blends, up to E25.[37]

In sum, ORNL stated: "The indication is that UST systems were affected by switching from E0 to E10. However, since E10 and E15 produce similar results, compatibility is not expected to be altered noticeably when moving from E10 to E15."[38] These technical judgments regarding the suitability of E10-compatible UST equipment for E15 support that EPA need only identify the small subset of in-use equipment that is not E10 compatible, and require a demonstration of compatibility for that subset of equipment. As an additional measure, Growth Energy recommends that EPA modify the existing compatibility regulations to allow a retailer

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[32] Oak Ridge National Laboratory, "Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel." ORNL/TM-2012/182 (Jul. 2012).
[33] ORNL Report at 24.
[34] *Id.*
[35] *Id.*
[36] *See e.g., id.* at 20.
[37] *Id.* at 21.
[38] ORNL Report at xviii.

that wishes to transition E10 retail equipment to E15 to forgo demonstration requirements if the regulated party is subject to semi-annual third-party UST inspections paid for by the party, with reporting of inspection results to the regulating agency. This alternative will remove unnecessary barriers to retailers' transition to E15, while ensuring protectiveness to the environment and no increased burden on regulating entities, which are already resource constrained in UST inspections. To the greatest extent possible, EPA should work with other relevant federal and state agencies to further clarify that all retail infrastructure above and below ground, including dispensers in use for E10, should be deemed compatible for use with E15.

Three final points: First, Growth Energy supports EPA's proposal to allow the use of secondary containment with interstitial monitoring in lieu of being able to demonstrate compatibility of all UST system equipment and components required by the 2015 UST regulation. As noted above, all double-walled tanks (i.e., secondary containment) are E15-compatible, and as EPA indicates, secondary containment with monitoring is adequately protective of the environment in ensuring any leaks are promptly addressed before substances reach the environment.[39] Second, Growth Energy also supports the agency's proposal to require newly-installed UST systems to be compatible with up to 100% ethanol. All tanks and piping manufactured today meets this requirement, and these components are the most expensive components of the UST system.[40] For other ancillary components, the costs of ensuring E100 equipment are minimal, particularly given the overall cost of installing a new UST system or replacing an existing system. In short, this measure will ensure flexibility in the fuel distribution system at minimal additional cost to retail stations. Third, EPA should reconsider its requirement that a retailer selling E15 on a shared hose with E10 must have a dedicated E10 (or E0) position on the premises. For retailers with few dispensers, this unnecessarily limits the availability of E15 despite the prevalence of E15 compatible vehicles.

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[39] 86 Fed. Reg. at 5,099-5,100.

[40] NREL Report.

Attachment 1

QUADRANT
STRATEGIES

TO: Interested parties
FROM: Quadrant Strategies
DATE: April 13, 2021
RE: E15 Labeling Study

Methodology: Between April 4, 2021 and April 9, 2021, Quadrant Strategies conducted an online quantitative survey of a random sample of 1,000 US consumers, reflective of the overall 18+ population in gender, age, education, race, ethnicity, area, and region. Of those US consumers, we looked at the data for drivers with E15 Eligible Vehicles[1] (n=841). The margin of error for US consumers was +/- 3.1 percentage points and the margin of error for drivers with E15 Eligible Vehicles was +/- 3.39 percentage points.

Objective: Determine the impact of the current EPA E15 Label, as well as alternative labels, on the perception of, and likelihood to use, E15.

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[1] *Drivers with E15 Eligible Vehicles are defined as drivers who responded that their primary vehicle is a passenger vehicle produced in 2001 or later or is a flex fuel vehicle. Must have a current Driver's license and drive very frequently, somewhat frequently, or rarely. The vast majority of respondents had vehicles for which E15 is legal. Quadrant Strategies omits from these results the small, statistically insignificant number of responses from individuals with vehicles for which E15 is not allowed.*

Executive Summary:

The current EPA E15 label fosters misconceptions about E15 and likely deters its usage. Among drivers with E15 Eligible Vehicles, the current EPA E15 label raises concerns about the fuel’s impact on vehicle engine condition and performance. The proposed Growth Energy E15 label is less likely to raise concerns while still providing similar guidance about E15 as the current EPA label.

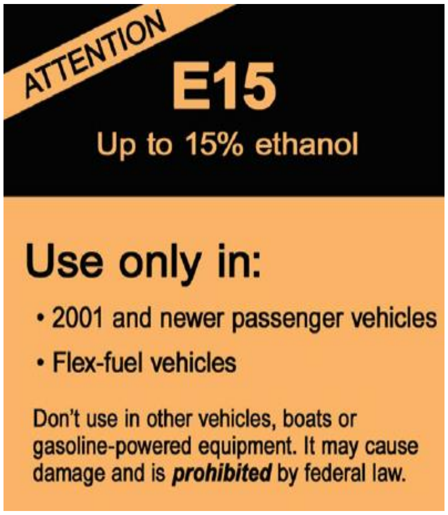
We found that the current EPA label:

- **Deters drivers with E15 Eligible Vehicles from using E15.** The label makes nearly half uncomfortable with E15 and unlikely to use it.
- **Raises concerns around engine performance**. After viewing the label, nearly 4 in 10 drivers with E15 Eligible Vehicles think that E15 is bad for engine performance and bad for the condition of their engine.

Meanwhile, the proposed Growth Energy label:

- **More effectively informs consumers about E15. The vast majority** of drivers with E15 Eligible Vehicles (84%) correctly interpret that they can use E15 - compared to 75% after seeing the current EPA label.
- **Generates far fewer misconceptions about E15.** Drivers of E15 Eligible Vehicles are much less likely to say the proposed label makes them uncomfortable with E15 (a 20-point difference compared to the current label). Similarly, they are much less likely to say E15 is bad for the condition of their engine based on the proposed label (an 18-point difference).

E15 Labels Tested:



ATTENTION

E15

Up to 15% ethanol

Use only in:

- 2001 and newer passenger vehicles
- Flex-fuel vehicles

Don't use in other vehicles, boats or gasoline-powered equipment. It may cause damage and is ***prohibited*** by federal law.

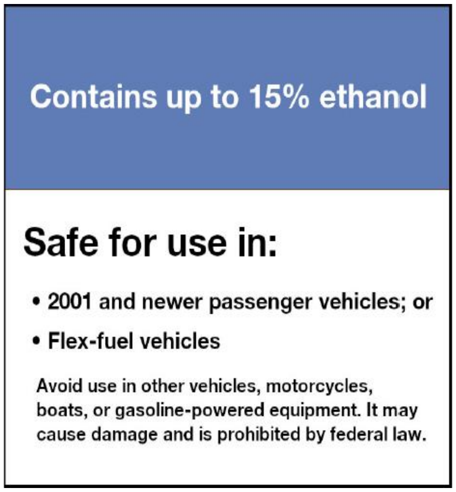
Current EPA Label

Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel Vehicles

Proposed Growth Energy Label



Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel vehicles

Avoid use in other vehicles, motorcycles, boats, or gasoline-powered equipment. It may cause damage and is prohibited by federal law.

Proposed EPA Label #1

Contains up to 15% ethanol

Safe for use in:

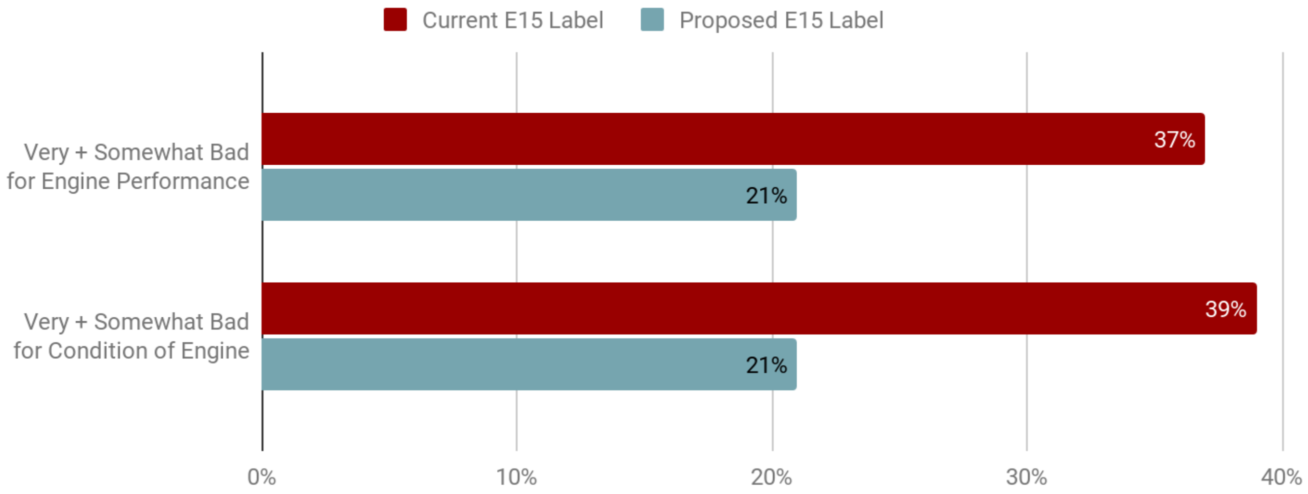
- 2001 and newer passenger vehicles; or
- Flex-fuel vehicles

Avoid use in other vehicles, motorcycles, boats, or gasoline-powered equipment. It may cause damage and is prohibited by federal law.

Proposed EPA Label #2

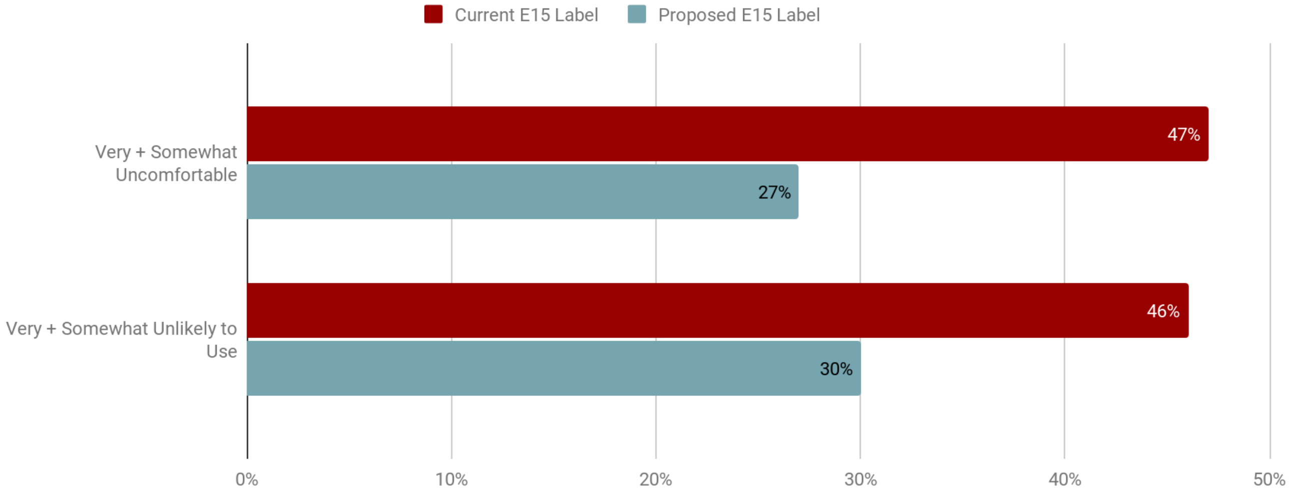
Key Data:

- **The current EPA label is much more likely to raise concerns about the fuel's impact on vehicle engines than the Growth Energy proposed label.**



Does this label make you feel like this fuel is good or bad for each of the following?
Showing drivers with E15 Eligible Vehicles (n=841)

- **And it makes drivers less comfortable with and less likely to use E15.**



***Top**: Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.*
***Bottom**: Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.*
Showing drivers with E15 Eligible Vehicles (n=841)

- **The proposed Growth Energy label provides more accurate E15 guidance than the current EPA label.**

Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel Vehicles

With E15 Eligible Vehicles:
84% correctly interpreted that they can use E15

ATTENTION

E15

Up to 15% ethanol

Use only in:

- 2001 and newer passenger vehicles
- Flex-fuel vehicles

Don't use in other vehicles, boats or gasoline-powered equipment. It may cause damage and is ***prohibited*** by federal law.

With E15 Eligible Vehicles:
75% correctly interpreted that they can use E15

Based on what you see, can you put this type of fuel in your car?
Showing drivers with E15 Eligible Vehicles (n=841)

- E15 Eligible drivers overwhelmingly perceive the **current label more as a warning**.
- In contrast, they overwhelmingly perceive the **proposed Growth Energy label more as providing information**.

Current Label

ATTENTION

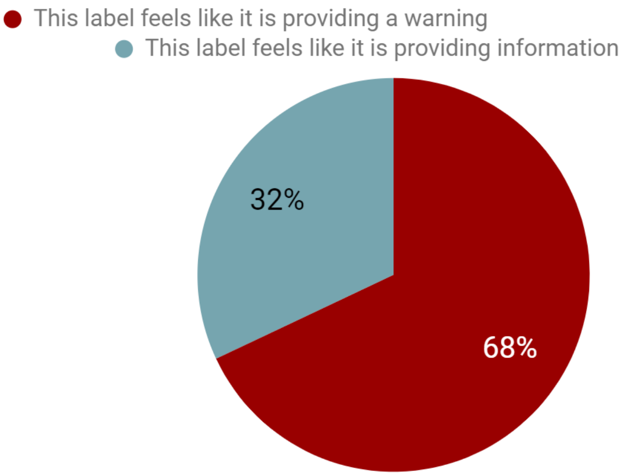
E15

Up to 15% ethanol

Use only in:

- 2001 and newer passenger vehicles
- Flex-fuel vehicles

Don't use in other vehicles, boats or gasoline-powered equipment. It may cause damage and is ***prohibited*** by federal law.

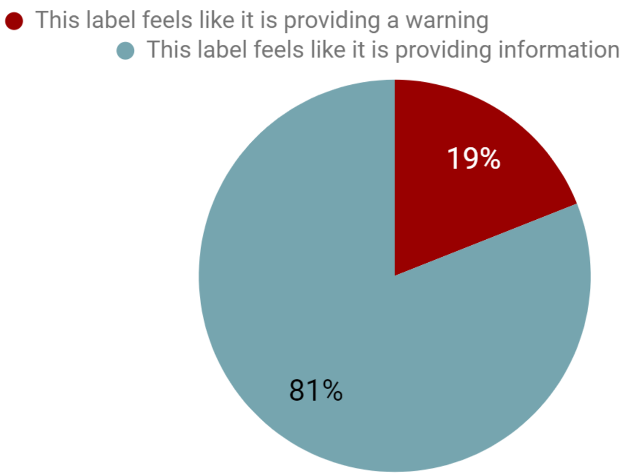


Proposed Growth Energy Label

Contains up to 15% ethanol

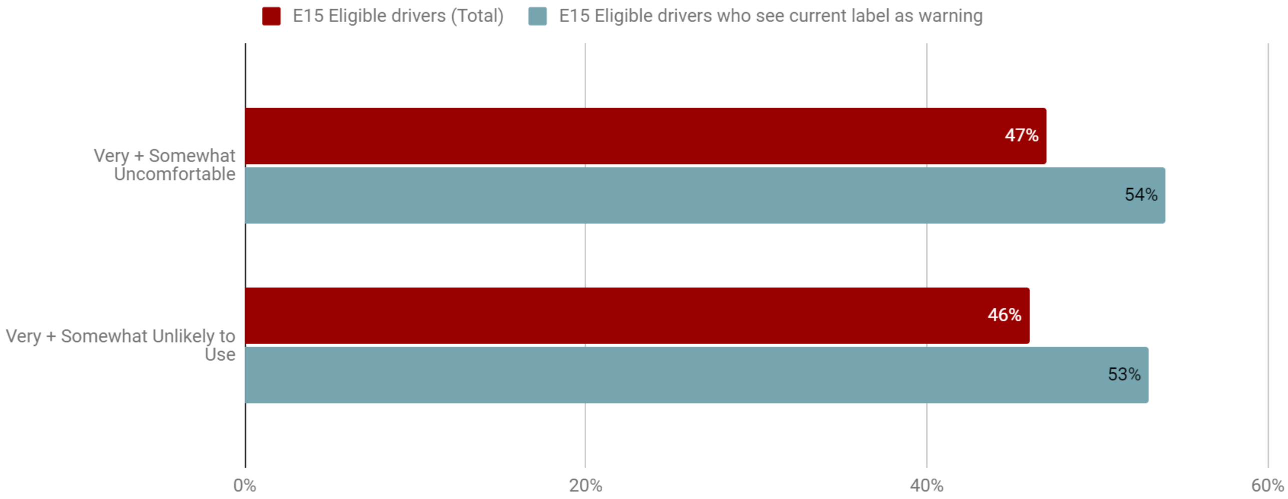
Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel Vehicles



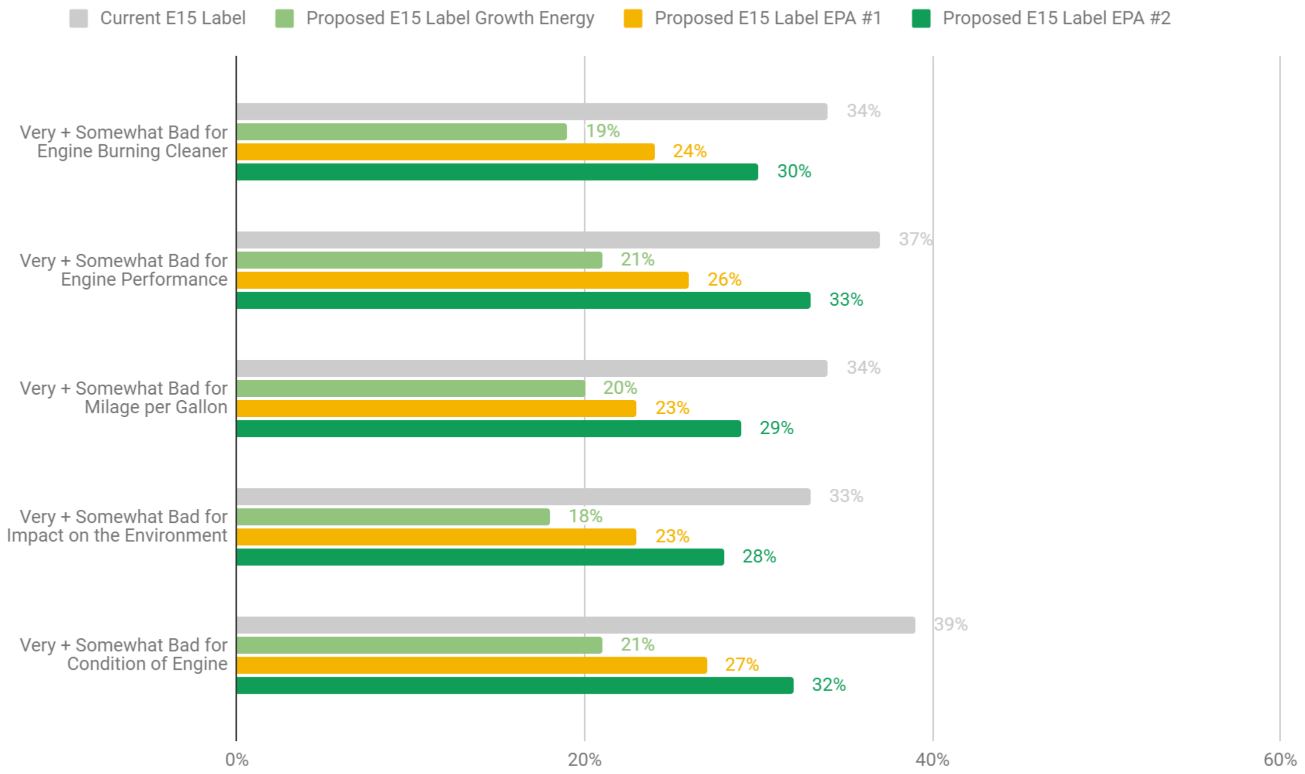
Which of the following most aligns with how you feel about the label?
Showing drivers with E15 Eligible Vehicles (n=841)

- **And E15 Eligible drivers who perceive the current label as a warning are both more uncomfortable and more unlikely to use E15.**

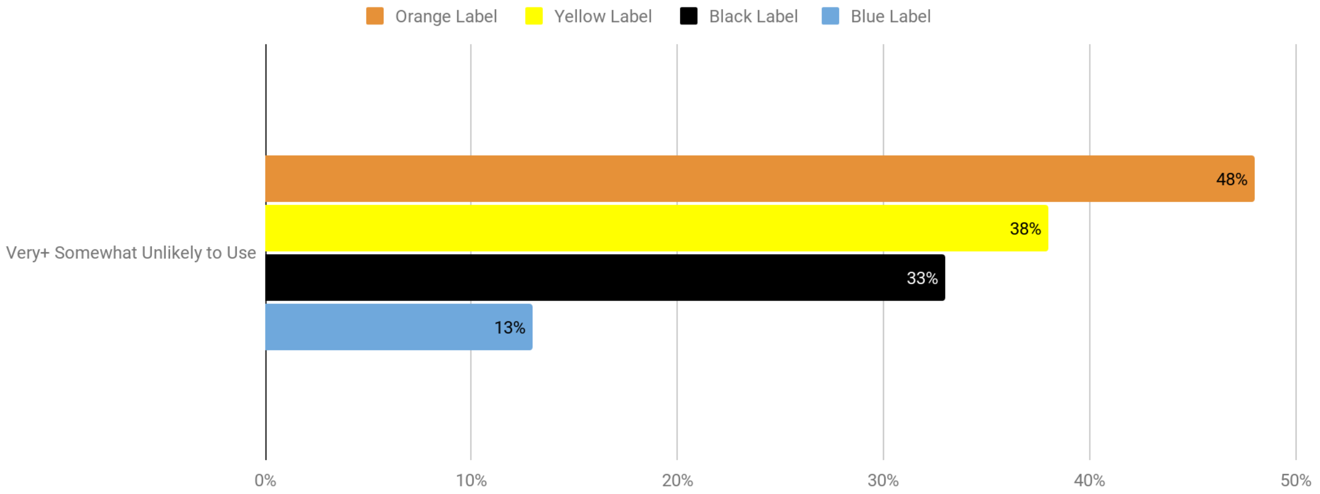


Top: Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.
Bottom: Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did
Showing drivers with E15 Eligible Vehicles (n=841)
Showing drivers with E15 Eligible Vehicles who see current label as a warning (n=575)

- **Among the four E15 labels tested, the proposed Growth Energy is the least likely to generate misconceptions about E15.**



- **Label color has an impact on likelihood to use. Orange and black make drivers much less likely to use a fuel than blue.**



Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.
Showing Drivers with E15 Eligible Vehicles (n=841)

APPENDIX I: LABELS TESTED

ATTENTION

E15

Up to 15% ethanol

Use only in:

- 2001 and newer passenger vehicles
- Flex-fuel vehicles

Don't use in other vehicles, boats or gasoline-powered equipment. It may cause damage and is ***prohibited*** by federal law.

Current EPA Label

Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel Vehicles

Proposed Growth Energy Label

Contains up to 15% ethanol

Safe for use in:

- 2001 and newer passenger vehicles; or
- Flex-fuel vehicles

Avoid use in other vehicles, motorcycles, boats, or gasoline-powered equipment. It may cause damage and is prohibited by federal law.

Proposed EPA Label #1

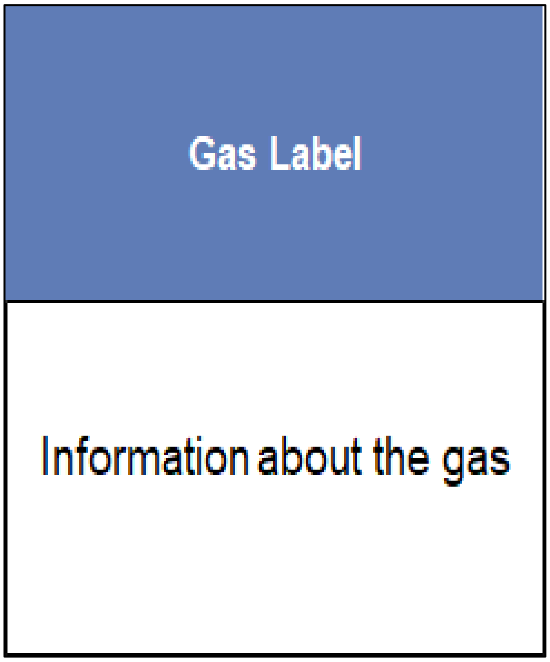
Contains up to 15% ethanol

Safe for use in:

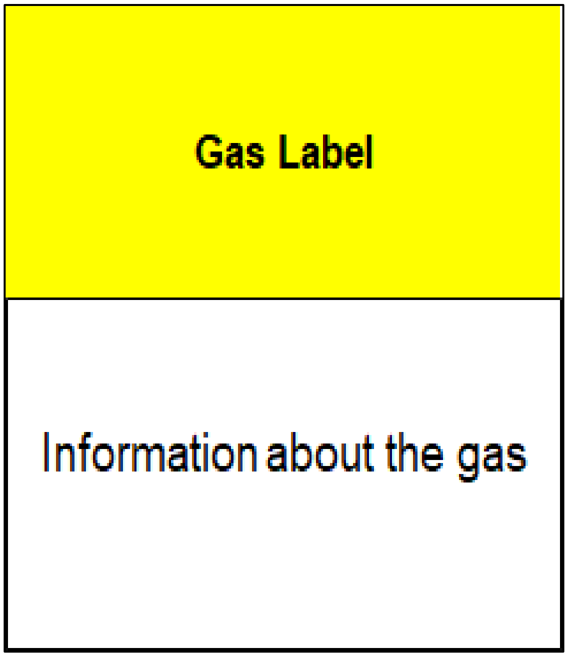
- 2001 and newer passenger vehicles; or
- Flex-fuel vehicles

Avoid use in other vehicles, motorcycles, boats, or gasoline-powered equipment. It may cause damage and is prohibited by federal law.

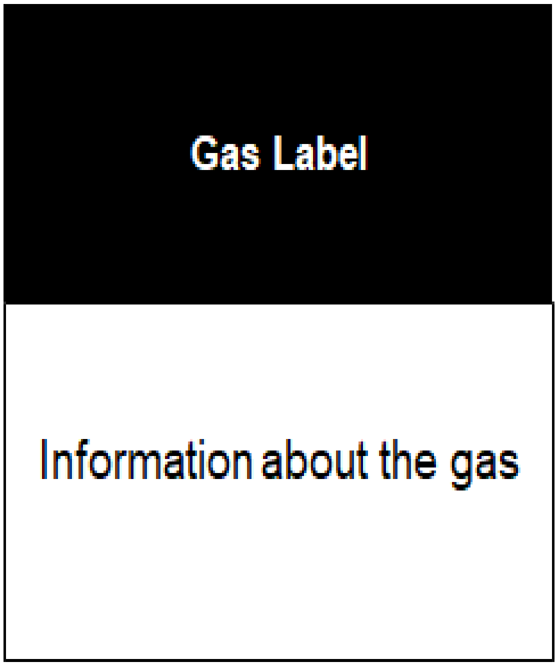
Proposed EPA Label #2



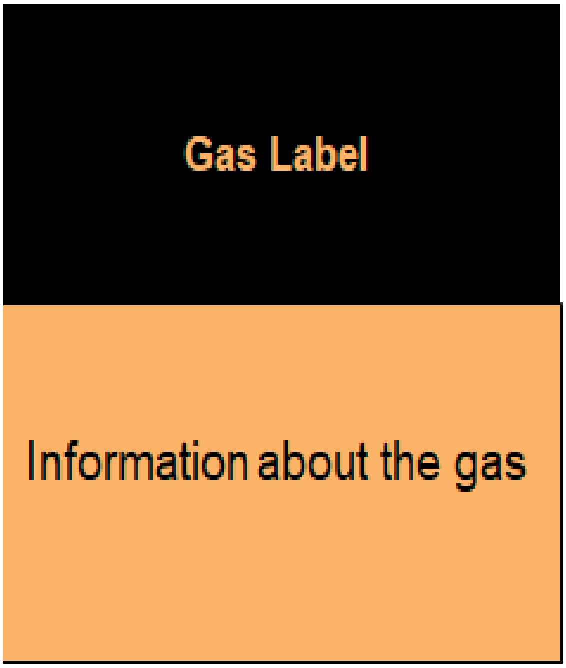
Blue Blank
Label



Yellow Blank
Label



Black and White
Blank Label



Orange Blank
Label

APPENDIX II: FULL DATASET

Between April 4, 2021 and April 9, 2021, Quadrant Strategies conducted an online quantitative survey of a random sample of 1,000 US consumers, reflective of the overall 18+ population in gender, age, education, race, ethnicity, area and region. Of those US consumers, we looked at the data for drivers with E15 Eligible Vehicles[2] (n=841). The margin of error for US consumers was +/- 3.1 percentage points and the margin of error for drivers with E15 Eligible Vehicles was +/- 3.39 percentage points. Full survey results are below.

Do you currently describe yourself as a man, a woman, or in some other way? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
A man	47%	48%
A woman	53%	52%
In some other way	0%	0%

Please enter your age: (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Under 18	0%	0%
18-24	15%	14%
25-34	16%	16%
35-49	31%	31%
50-64	28%	29%
65+	10%	11%

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[2] *Drivers with E15 Eligible Vehicles are defined as drivers who responded that their primary vehicle is a passenger vehicle produced in 2001 or later or is a flex fuel vehicle. Must have a current Driver's license and drive very frequently, somewhat frequently, or rarely.*

Which state do you live in? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Alabama	2%	2%
Alaska	0%	0%
Arizona	2%	2%
Arkansas	0%	0%
California	11%	11%
Colorado	1%	1%
Connecticut	2%	2%
Delaware	0%	0%
District of Columbia	0%	0%
Florida	6%	6%
Georgia	3%	4%
Hawaii	0%	0%
Idaho	0%	0%
Illinois	4%	5%
Indiana	2%	2%
Iowa	1%	1%
Kansas	1%	1%

Kentucky	1%	1%
Louisiana	1%	1%
Maine	1%	1%
Maryland	2%	2%
Massachusetts	3%	3%
Michigan	4%	4%
Minnesota	2%	2%
Mississippi	1%	1%
Missouri	1%	1%
Montana	0%	0%
Nebraska	0%	0%
Nevada	1%	1%
New Hampshire	1%	1%
New Jersey	4%	4%
New Mexico	1%	1%
New York	7%	6%
North Carolina	3%	3%
North Dakota	0%	0%

Ohio	3%	4%
Oklahoma	2%	2%
Oregon	0%	0%
Pennsylvania	4%	4%
Rhode Island	0%	0%
South Carolina	2%	2%
South Dakota	0%	0%
Tennessee	3%	3%
Texas	7%	7%
Utah	1%	1%
Vermont	0%	0%
Virginia	2%	3%
Washington	3%	2%
West Virginia	0%	0%
Wisconsin	1%	1%
Wyoming	0%	0%
Other	0%	0%

In the past 3 years, have you or anyone in your household worked for any of the following industries? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Advertising	0%	0%
Banking	3%	3%
Finance or accounting	4%	4%
Government	6%	7%
Transportation	3%	3%
Agriculture or farming	1%	1%
Healthcare or pharmaceutical	11%	12%
Journalism, media or the press	0%	0%
Computer manufacturer and design	1%	1%
Market research	0%	0%
Tourism or hospitality	2%	2%
Energy or electricity	2%	1%
Public relations	0%	0%
None of the above	73%	71%

What is the highest level of education that you have attained? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Grade school	0%	0%
Some high school	1%	1%
High school graduate	21%	19%
Some college	26%	25%
College graduate	29%	30%
Graduate school / Advanced degree	20%	21%
Technical school	3%	3%
Prefer not to answer	0%	0%

Which of the following best describes your current employment status? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Employed full-time	47%	51%
Employed part-time	12%	12%
Stay-at-home-parent / homemaker	7%	6%
Unemployed	12%	9%
Full time student	7%	5%

Retired	15%	16%
Prefer not to answer	0%	0%

For statistical purposes only, please select the following category below that represents your total personal annual income? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than $25,000	23%	18%
$25,000 to $49,999	23%	22%
$50,000 to $74,999	19%	20%
$75,000 to $99,999	11%	13%
$100,000 to $124,999	8%	9%
$125,000 to $149,999	6%	7%
$150,000 to $199,999	6%	7%
$200,000 to $249,999	2%	2%
$250,000 or more	2%	2%
Prefer not to answer	0%	0%

Are you of Hispanic, Latino, or Spanish origin, such as Mexican, Puerto Rican, or Cuban? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)

Yes	13%	13%
No	87%	87%

What is your race or origin? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
White	71%	75%
Black or African-American	15%	13%
Asian or Asian-American	9%	8%
American Indian or Alaska Native	3%	2%
Native Hawaiian or other Pacific Islander	1%	1%
Some other race or origin	6%	6%

Do you live in a city, just outside a city or suburb, or a less developed or rural area, not near a city? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
City	34%	33%
Just outside a city or suburb	47%	49%
More rural, less developed area	18%	18%
Prefer not to answer	0%	0%

How would you describe your political party affiliation? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Strong Republican	14%	14%
Lean Republican	15%	16%
Independent	28%	27%
Lean Democrat	18%	18%
Strong Democrat	25%	24%
Prefer not to answer	0%	0%

How many cars does your household own or lease? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
0	8%	0%
1	43%	47%
2	33%	36%
3	11%	12%
4 or more	5%	5%
Prefer not to answer	0%	0%

Do you have a driver's license? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)

Yes	92%	100%
No	8%	0%
Prefer not to answer	0%	0%

How often do you drive? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very frequently	52%	60%
Somewhat frequently	30%	33%
Rarely	10%	7%
Never	8%	0%
Prefer not to answer	0%	0%

My primary vehicle (select all that apply)... (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Uses unleaded gasoline	92%	93%
Uses diesel	7%	7%
Is electric	3%	3%
Other:	2%	1%

How familiar, if at all, are you with the following fuel sources?
(Showing % Selected)

Total (n=1000)	Regular or unleaded	Mid Grade	Premium	E15	E85
Very familiar	78%	36%	44%	7%	13%
Somewhat familiar	18%	38%	36%	15%	17%
Not very familiar	2%	15%	13%	21%	18%
Not at all familiar	2%	11%	7%	58%	52%

E15 Eligible (n=841)	Regular or unleaded	Mid Grade	Premium	E15	E85
Very familiar	79%	37%	44%	7%	13%
Somewhat familiar	17%	38%	37%	15%	18%
Not very familiar	2%	14%	12%	21%	18%
Not at all familiar	2%	11%	7%	57%	51%

How likely are you to use each of the following types of fuel for your car? If you aren't familiar enough with a particular source to have an opinion, please answer "don't know."
(Showing % Selected)

Total (n=1000)	Regular or unleaded	Mid Grade	Premium	E15	E85
Very likely	81%	20%	25%	5%	8%
Somewhat likely	10%	29%	20%	9%	8%
Somewhat unlikely	4%	17%	18%	7%	8%
Very unlikely	3%	24%	30%	35%	34%

Don’t know	2%	10%	7%	44%	42%

E15 Eligible (n=841)	**Regular or unleaded**	**Mid Grade**	**Premium**	**E15**	**E85**
Very likely	81%	20%	25%	5%	9%
Somewhat likely	10%	30%	19%	10%	9%
Somewhat unlikely	4%	17%	18%	7%	7%
Very unlikely	3%	24%	31%	35%	35%
Don’t know	2%	9%	7%	43%	41%

CURRENT EPA LABEL **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	68%	68%
This label feels like it is providing information	32%	32%

CURRENT EPA LABEL **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	72%	75%
No	28%	25%

CURRENT EPA LABEL **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	19%	21%
Somewhat comfortable	32%	32%
Somewhat uncomfortable	28%	28%
Very uncomfortable	20%	19%

CURRENT EPA LABEL **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	20%	22%
Somewhat likely	32%	32%
Somewhat unlikely	26%	26%
Very unlikely	23%	21%

CURRENT EPA LABEL
Does this label make you feel like this fuel is good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	17%	18%	17%	20%	17%
Somewhat good	47%	43%	48%	45%	43%
Somewhat bad	26%	29%	26%	25%	29%
Very bad	10%	10%	9%	10%	11%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	18%	19%	17%	22%	17%
Somewhat good	47%	44%	49%	45%	43%
Somewhat bad	25%	28%	26%	24%	29%
Very bad	9%	9%	8%	9%	10%

CURRENT EPA LABEL **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	78%	79%
2009 flex fuel SUV	81%	82%

2008 pick-up truck	66%	66%
1999 SUV	3%	4%
All of these	4%	3%
None of these	4%	3%

PROPOSED EPA LABEL #1 Which of the following most aligns with how you feel about the label? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	34%	33%
This label feels like it is providing information	66%	67%

PROPOSED EPA LABEL #1 Based on what you see, can you put this type of fuel in your car? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	77%	81%
No	23%	19%

PROPOSED EPA LABEL #1 **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	26%	27%
Somewhat comfortable	41%	41%
Somewhat uncomfortable	19%	19%
Very uncomfortable	14%	13%

PROPOSED EPA LABEL #1 **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	26%	27%
Somewhat likely	39%	39%
Somewhat unlikely	20%	20%
Very unlikely	15%	13%

PROPOSED EPA #1
Does this label make you feel like this fuel is good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	Engine burning cleaner	Engine performance	Mileage per gallon	Impact on environment	Condition of engine
Very good	21%	21%	19%	25%	19%
Somewhat good	54%	52%	56%	50%	52%
Somewhat bad	20%	21%	20%	18%	22%
Very bad	6%	6%	5%	7%	6%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	21%	21%	20%	27%	21%
Somewhat good	55%	53%	57%	50%	52%
Somewhat bad	19%	21%	19%	17%	22%
Very bad	5%	5%	5%	5%	5%

PROPOSED EPA LABEL #1 **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	Total (n=1000)	E15 Eligible (n=841)
2001 Sedan	78%	79%
2009 flex fuel SUV	83%	84%

2008 pick-up truck	67%	67%
1999 SUV	3%	3%
All of these	5%	5%
None of these	3%	3%

PROPOSED EPA LABEL #2 **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	52%	52%
This label feels like it is providing information	48%	48%

PROPOSED EPA LABEL #2 **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	74%	78%
No	26%	22%

PROPOSED EPA LABEL #2 **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)

Very comfortable	22%	24%
Somewhat comfortable	39%	40%
Somewhat uncomfortable	24%	24%
Very uncomfortable	15%	13%

PROPOSED EPA LABEL #2 **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don’t own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	22%	23%
Somewhat likely	36%	37%
Somewhat unlikely	25%	24%
Very unlikely	17%	16%

Proposed EPA Label #2 **Does this label make you feel like this fuel is good or bad for each of the following?** (Showing % Selected)					
Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	18%	18%	17%	21%	17%
Somewhat good	51%	48%	53%	49%	49%

Somewhat bad	25%	27%	23%	22%	26%
Very bad	7%	6%	6%	8%	8%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	19%	18%	18%	23%	17%
Somewhat good	52%	49%	53%	49%	50%
Somewhat bad	24%	28%	23%	21%	26%
Very bad	6%	6%	6%	7%	6%

PROPOSED EPA LABEL #2 **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	80%	81%
2009 flex fuel SUV	82%	83%
2008 pick-up truck	67%	67%
1999 SUV	3%	3%
All of these	4%	4%
None of these	3%	3%

PROPOSED GROWTH ENERGY LABEL **Which of the following most aligns with how you feel about the label?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
This label feels like it is providing a warning	20%	19%
This label feels like it is providing information	80%	81%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, can you put this type of fuel in your car?** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	81%	84%
No	19%	16%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	31%	33%
Somewhat comfortable	39%	40%
Somewhat uncomfortable	18%	17%
Very uncomfortable	12%	10%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	28%	30%
Somewhat likely	40%	40%
Somewhat unlikely	19%	19%
Very unlikely	13%	11%

PROPOSED GROWTH ENERGY LABEL
Does this label make you feel like this fuel is good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	22%	23%	22%	27%	21%
Somewhat good	57%	55%	58%	53%	57%
Somewhat bad	17%	18%	16%	15%	17%
Very bad	4%	4%	4%	4%	4%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**

Very good	22%	23%	22%	29%	22%
Somewhat good	58%	55%	58%	53%	57%
Somewhat bad	16%	18%	16%	15%	17%
Very bad	3%	4%	4%	4%	4%

PROPOSED GROWTH ENERGY LABEL **Based on what you see, please select all of the following vehicles this fuel may be used in.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2001 Sedan	80%	80%
2009 flex fuel SUV	84%	85%
2008 pick-up truck	70%	70%
1999 SUV	3%	3%
All of these	5%	5%
None of these	3%	2%

Out of all of the labels you've seen, which one makes you the most comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	18%	17%

Proposed EPA Label #1	35%	36%
Proposed EPA Label #2	9%	9%
Proposed Growth Energy Label	38%	38%

Out of all of the labels you've seen, which one makes you the least comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	58%	59%
Proposed EPA Label #1	12%	12%
Proposed EPA Label #2	10%	10%
Proposed Growth Energy Label	19%	19%

Between these two labels, which one makes you the most comfortable about putting the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did. (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Current EPA Label	27%	28%
Proposed Growth Energy Label	73%	72%

BLACK AND WHITE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	21%	22%
Somewhat comfortable	45%	45%
Somewhat uncomfortable	25%	24%
Very uncomfortable	9%	8%

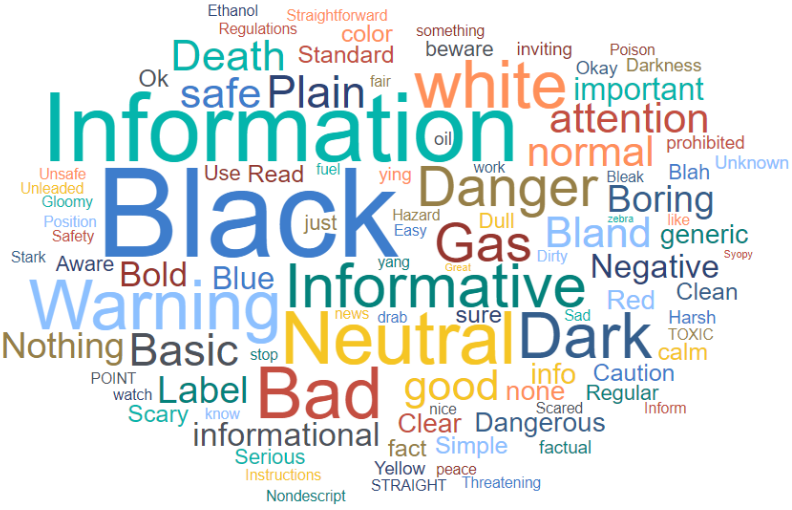
BLACK AND WHITE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	22%	23%
Somewhat comfortable	44%	45%
Somewhat uncomfortable	25%	24%
Very uncomfortable	9%	9%

BLACK AND WHITE BLANK LABEL **Based on the color alone, do you feel like this fuel would be good or bad for each of the following?** (Showing % Selected)		

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	15%	17%	17%	16%	17%
Somewhat good	49%	48%	48%	45%	47%
Somewhat bad	30%	29%	28%	30%	30%
Very bad	7%	6%	6%	8%	7%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	15%	17%	18%	16%	17%
Somewhat good	50%	49%	49%	46%	47%
Somewhat bad	29%	28%	28%	29%	29%
Very bad	6%	6%	6%	8%	6%

BLACK AND WHITE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)



ORANGE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	15%	16%
Somewhat comfortable	34%	35%
Somewhat uncomfortable	37%	38%
Very uncomfortable	13%	12%

ORANGE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	16%	16%
Somewhat likely	35%	36%
Somewhat unlikely	36%	35%
Very unlikely	13%	13%

ORANGE BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	13%	14%	14%	14%	13%
Somewhat good	40%	39%	39%	37%	39%
Somewhat bad	39%	39%	38%	39%	39%
Very bad	9%	9%	9%	11%	9%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	14%	14%	15%	15%	14%
Somewhat good	39%	39%	39%	37%	39%
Somewhat bad	39%	39%	38%	38%	39%
Very bad	8%	8%	8%	10%	8%

ORANGE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

BLUE BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	38%	39%
Somewhat comfortable	48%	49%
Somewhat uncomfortable	9%	8%
Very uncomfortable	4%	4%

BLUE BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	36%	38%
Somewhat likely	49%	49%
Somewhat unlikely	10%	9%
Very unlikely	5%	4%

BLUE BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	26%	26%	26%	29%	25%
Somewhat good	60%	60%	61%	55%	62%
Somewhat bad	11%	11%	10%	12%	11%
Very bad	2%	3%	3%	4%	2%

E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	26%	26%	26%	29%	24%
Somewhat good	61%	61%	63%	57%	63%
Somewhat bad	10%	10%	9%	10%	10%
Very bad	2%	2%	2%	4%	2%

BLUE BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

YELLOW BLANK LABEL **Based on the color alone, how comfortable would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very comfortable	19%	19%
Somewhat comfortable	42%	43%
Somewhat uncomfortable	32%	31%
Very uncomfortable	8%	7%

YELLOW BLANK LABEL **Based on the color alone, how likely would you be to put the fuel associated with this label in your car? If you don't own a car, imagine how you would respond if you did.** (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Very likely	19%	19%
Somewhat likely	41%	42%
Somewhat unlikely	32%	31%
Very unlikely	8%	7%

YELLOW BLANK LABEL
Based on the color alone, do you feel like this fuel would be good or bad for each of the following?
(Showing % Selected)

Total (n=1000)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**
Very good	16%	16%	17%	16%	15%
Somewhat good	46%	47%	48%	45%	47%
Somewhat bad	32%	32%	31%	32%	32%
Very bad	6%	5%	5%	7%	5%
E15 Eligible (n=841)	**Engine burning cleaner**	**Engine performance**	**Mileage per gallon**	**Impact on environment**	**Condition of engine**

Very good	16%	17%	18%	16%	16%
Somewhat good	47%	48%	48%	47%	48%
Somewhat bad	32%	31%	30%	31%	31%
Very bad	5%	4%	4%	6%	5%

YELLOW BLANK LABEL
What word do you associate with this color? (OPEN END)
(Showing Total)

What type of car do you drive most often? (Showing % Selected)	Total (n=1000)	E15 Eligible (n=841)
Compact Car (e.g. Ford Focus)	12%	12%
Regular Sedan (e.g. Honda Accord)	31%	31%
Truck (e.g. Chevrolet Tahoe)	8%	8%

Minivan (e.g. Toyota Sienna)	5%	5%
SUV (e.g. Ford Explorer)	30%	32%
Luxury Sedan (e.g. Mercedes Benz S-Series)	8%	9%
Sports Car (e.g. Chevrolet Corvette)	3%	3%
Prefer not to answer	2%	1%

Is the vehicle you drive most often a flex fuel vehicle? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	23%	24%
No	61%	60%
Unsure	16%	15%

Approximately, what year was your primary vehicle manufactured? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
2010-2022	66%	70%
2001-2009	29%	30%
1990-2000	4%	1%
Older than 1990	1%	0%

How often do you generally fill up your car(s) with gas? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than once per month	5%	4%
Once per month	14%	14%
Twice per month	27%	29%
Three times per month	13%	13%
Once per week	26%	27%
Twice per week	9%	8%
Three times per week	3%	3%
More than three times per week	1%	1%
Prefer not to answer	1%	0%

How far do you estimate you drive per day? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Less than 10 miles per day	30%	29%
Between 10 and 20 miles per day	32%	33%
Between 20 and 30 miles per day	18%	18%
Between 30 and 40 miles per day	8%	9%
Between 40 and 50 miles per day	5%	5%

More than 50 miles per day	6%	6%
Prefer not to answer	1%	1%

Do you own, lease, or rent your car(s)? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
I own my car(s)	89%	89%
I lease my car(s)	10%	10%
I rent my car(s)	2%	2%
Prefer not to answer	1%	1%

How much attention do you pay toward each of the following? (Showing % Selected)			
Total (n=1000)	**The gasoline you put in your car**	**How clean burning your car engine is**	**The performance of your car engine**
A lot	49%	28%	47%
Some	39%	39%	39%
Not a lot	10%	25%	10%
None	2%	8%	4%
E15 Eligible (n=841)	**The gasoline you put in your car**	**How clean burning your car engine is**	**The performance of your car engine**

A lot	48%	29%	48%
Some	40%	40%	39%
Not a lot	10%	24%	10%
None	2%	7%	4%

Which type of fuel do you most frequently put in your car? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Regular or unleaded	69%	68%
Mid Grade	6%	6%
Premium	16%	16%
E15	2%	3%
E85	2%	2%
Diesel	4%	4%
Other:	1%	1%

What is your current marital status? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Single/Never married	36%	31%
Married	48%	53%
Widowed	3%	3%

Divorced	11%	11%
Separated	2%	1%
Prefer not to answer	1%	1%

Do you have children? (Showing % Selected)	**Total** (n=1000)	**E15 Eligible** (n=841)
Yes	52%	56%
No	47%	43%
Prefer not to answer	0%	0%

Attachment 2

E15 and Infrastructure

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National Renewable Energy Laboratory

J. Yanowitz
Ecoengineering, Inc.

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NREL is a national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy
Operated by the Alliance for Sustainable Energy, LLC

Strategic Partnership Project Report
NREL/TP-5400-64156
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E15 and Infrastructure

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List of Acronyms

AHJ	authority having jurisdiction
CARB	California Air Resources Board
CFR	Code of Federal Regulations
E0	pure gasoline
E10	10% denatured ethanol; 90% gasoline blendstock
E100	pure ethanol fuel
E15	15% denatured ethanol, 85% gasoline blendstock
E25	25% denatured ethanol, 75% gasoline blendstock
E85	marketing term for high-blend ethanol 51%–83%
EPA	U.S. Environmental Protection Agency
FDEQ	Florida Department of Environmental Quality
NACS	National Association of Convenience Store Owners
NREL	National Renewable Energy Laboratory
OSHA	Occupational Safety and Health Administration
OUST	Office of Underground Storage Tanks
PEI	Petroleum Equipment Institute
psi	pounds per square inch
RFA	Renewable Fuels Association
STI	Steel Tank Institute
STP	submersible turbine pump
UL	Underwriters Laboratories
ULSD	ultra-low sulfur diesel
UST	underground storage tank
vol%	percent by volume

Executive Summary

This paper addresses the compatibility of E15 (15% denatured ethanol, 85% gasoline blendstock) with equipment at refueling stations. Over the last decade, a tremendous amount of work by refueling equipment manufacturers, industry groups, and federal agencies has resulted in a long list of equipment that can be used with E15. This report addresses compatibility through a literature review, a summary of applicable codes and standards, review of equipment manufacturer products, and verification with manufacturers regarding which ethanol blends work with their products. Over time, the refueling equipment manufacturers have improved their sealing materials for compatibility with a wide range of fuels. Upgrading materials in equipment improves consumer safety and reduces the risk of releases to the environment.

It is often stated that tanks cannot be used to store E15, but this assumption is incorrect as the majority of installed tanks can store blends above E10. For many decades, underground storage tank (UST) manufacturers approved their tanks for blends up to E100, for example, all steel tanks and double-walled fiberglass tanks since the year 1990. Manufacturers of pipe thread sealants (pipe dope) used in UST systems have stated that their products have been compatible with ethanol blends up to E20 for many years. For those tanks with low ethanol blend certifications, the U.S. Environmental Protection Agency's (EPA's) Office of Underground Storage Tanks (OUST) issued *Guidance – Compatibility of UST Systems with Biofuels Blends* in 2011 to enable alternative compliance with federal code as UST systems are in use for decades. This guidance allowed tank manufacturers to issue letters stating the compatibility of their tanks with specific ethanol blends. All existing tank manufacturers have issued such letters, and the majority of installed tanks are compatible with E15. Additionally, all existing pipe manufacturers have Underwriters Laboratories (UL) listing for E100.

All fuel and vapor handling equipment at a station was reviewed to determine if it was certified by a third-party (such as UL) and if it was listed for specific ethanol blends. The aggregated list confirms there are UL testing standards available now for all gasoline–ethanol blends from 0% to 85% ethanol. Stations comprise approximately 60 pieces of equipment designed to move and control fuel and vapors. The function of most equipment is to prevent, detect, and contain releases. The equipment includes tanks; pipes; dispensers and associated hanging hardware (breakaway, hose, nozzle, and swivel); fill equipment; leak detection; overfill prevention; and vapor equipment. Some of this equipment is specifically covered by codes and standards while other equipment relies on sound design and manufacturing. Certain equipment types are typically UL listed—these include tanks, pipes, dispenser, hanging hardware, submersible turbine pumps, and shear valves. UL listing is not a requirement; some manufacturers simply prefer to have UL listings for their products. Manufacturers will select, which, if any, models they will list for ethanol blends above E10. A review was conducted with each manufacturer to determine compatibility with ethanol blends. There is an extensive list of E15 and E15+ compatible equipment available in the appendices.

A literature review going back 15 years was conducted to determine if there were any negative impacts during the multi-year deployment of E10 nationwide. No incidents of E10 causing releases (also referred to as leaks) from UST systems were identified. None of the reviewed literature noted any association between E10 and any specific UST release. The EPA OUST's Performance Measures' data on UST releases were reviewed, and as E10 was deployed

nationwide, the trend was fewer UST releases. Anecdotal input solicited from infrastructure industry experts said that they knew of no published reports of releases caused by E10.

There are future opportunities for retailers to remove or replace their current equipment not necessarily related to continuous changes in motor fuel composition. Credit card companies are requiring retail fueling stations to update their dispensers to accept new chip and PIN secure credit cards by October 2017, at which time fraud liability would switch to station owners if they have not updated their equipment. This presents an opportunity to increase E25 UL-listed equipment through a retrofit kit if electronics are being upgraded to accommodate the new credit cards, or if a station owner must purchase a new dispenser, it could pay a minimal amount more for an E25 dispenser. If a new dispenser is purchased, this may also present an opportunity to upgrade to an E85 dispenser, but at significant additional cost.

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1 Background

1.1 E15 Background

In 2011, the U.S. Environmental Protection Agency (EPA) approved E15 for use in conventional light-duty cars and trucks model year 2001 and newer.[1] As of the end of 2014, 65% of the registered gasoline vehicles are 2001 and newer.[2] EPA approved the Clean Air Act waiver based on significant testing and research (McCormick et al. 2013). EPA defines E15 as ethanol blends greater than 10 volume percent (vol%) and up to 15 vol% ethanol. E15 is not widely available largely due to misinformation and retailer concerns. The primary concerns retailers have expressed include additional federal and state regulations to sell E15, misfueling liability, and the inability to meet the EPA's vapor pressure requirement for E15 in the summer.

Regulations to sell E15: There are several federal government requirements for selling E15 that do not apply to other fuel sold at stations. Federal regulations for a station to sell E15 include: an EPA E15 label on each dispenser selling E15, implementation of a misfueling mitigation plan,[3] participation in a fuel quality survey (ensures dispenser is labeled and measures ethanol content and vapor pressure), product transfer documents for all deliveries of fuel for E15 use, and an approved dispenser/hose configuration.[4] All requirements for E15 are available in the Renewable Fuels Association's (RFA's) *E15 Retailer Handbook*.[5]

Exposure to liability: Some stations owners have expressed concerns about misfueling of E15 into older vehicles. It is not uncommon for a consumer to be unaware of the model year of their vehicle. Under the Clean Air Act, any entity in the transportation fuel supply chain, including refueling stations, could be fined by the EPA up to $37,500 per day for violations. The EPA has never fined a station this amount, and it has the authority under code to reduce the fine based on business size.

Vapor pressure: Blending of ethanol in to gasoline in the 10 to 15 vol% range typically causes the vapor pressure to increase by 1 pound per square inch (psi).[6] The EPA regulates gasoline vapor pressure from June 1 to September 15 to reduce evaporative fuel emissions. In 1992, E10 received a 1-psi waiver, commonly known as the 1-pound waiver, from these requirements for non-reformulated gasoline areas. For purposes of the 1-pound waiver, E10 blends are defined as containing 9 to 10 vol% ethanol. The E10 1-pound waiver code is included in the Code of Federal Regulations which states that the waiver is for E10 only and not any other ethanol blend.

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[1] E15 Notices & Regulations. EPA. http://www.epa.gov/otaq/regs/fuels/additive/e15/e15-regs.htm

[2] Polk data 2014. Based on a total U.S. gasoline light-duty vehicle registration of 228 million of which 149 million are model year 2001 and newer.

[3] RFA developed *Renewable Fuels Association Model E15 Misfueling Mitigation Plan*, which was approved by EPA in March 2012 and is available free of cost to stations selling E15. http://www.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-model-e15-misfueling-mitigation-plan.pdf

[4] For hose configurations, please review the EPA-approved *Addendum: E15 Retail Advisory (updated 1/2013)*. Last accessed March 10, 2015: http://www.epa.gov/otaq/regs/fuels/additive/e15/documents/rfa-e15-retail-advisory-addendum.pdf

[5] *E15 Retailer Handbook*. RFA. Accessed March 10, 2015: http://ethanolrfa.3cdn.net/643f311e9180a7b1a8_wwm6iuulj.pdf

[6] Vapor pressure is a method to measure the volatility of gasoline. Formerly known as Reid vapor pressure or RVP, today it is technically dry vapor pressure equivalent (DVPE) and is measured using ASTM Method D5191.

E15 is not afforded the same 1-pound waiver and therefore cannot be sold in non-reformulated gasoline areas in summer months unless a lower vapor pressure hydrocarbon blendstock is used.[7]

1.2 Station Data

Overall, the total number of retail stations has declined over time, but approximately 1,600 new stations open annually (AFDC 2015, NACS 2014a). The following statistics from the National Association of Convenience Store Owners (NACS) *2015 Retail Fuels Report* show some of the challenges in reaching various types of station owner and their ability to afford equipment upgrades and installations (NACS 2015):

- There are approximately 153,000 fueling stations.
- Fifty-eight percent are single-store owners/operators.
- Major oil companies own 0.4% of stations.
- Approximately 50% of stations sell branded fuel.
- Convenience stores sell 80% of transportation fuels. Hypermarkets (large grocery chains or merchandise stores) sell 14%. The remainder of fuel is sold at low-volume locations like marinas.
- Sales per convenience store average 128,000 gallons per month (4,000 gallons/day).
- Transportation fuels are 71% of sales at a convenience store, but only 36% of profits.
- The average profit per convenience stores in 2013 was $55,000 with most profit coming from selling products in the store.

One of the challenges in introducing E15 is reaching all the single-station owners. As evidenced in Figure 1, after single-store owners, the next highest percentage of ownership—17%—is ownership groups with more than 500 stations.

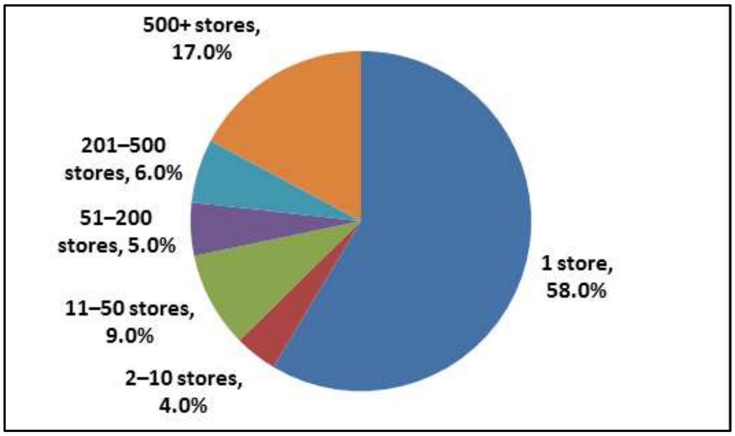

Figure 1. Breakout of station ownership

Source: *2015 Retail Fuels Report.* NACS, 2015

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[7] CFR 42 Chapter 85 Subchapter II Part A 7545 Regulation of Fuels (h) (4)

Approximately 50% of convenience stores are branded by either an oil company (31%) or refinery/distributor (19%) (NACS 2014b). This ensures a market for oil and refinery company products and provides station owners with brand recognition. A contract typically lasts 10 years, and the terms will include sales volume requirements for fuels supplied, including regular and premium, and diesel if the station sells it. Due to sales volume requirements, there will be more challenges for branded stations to sell E15 than independent stations or convenience store chains.

2 Regulations, Codes, and Certifications

In addition to the EPA requirements summarized in Section 1.1, E15 is subject to other regulations and codes that apply to other transportation fuels. There is no one entity that regulates all equipment at a station. Often times, the local authority having jurisdiction (AHJ) approves a station to sell a new fuel. "AHJ" refers to regulating organizations, offices, or individuals responsible for overseeing codes and standards and ensuring safety. Examples of AHJs include local fire marshals, state energy and environment offices, air and water boards, and similar organizations or offices. The most significant federal agencies overseeing some equipment at stations include EPA's Office of Underground Storage Tanks (OUST) and the Occupational Safety and Health Administration (OSHA). The Underwriters Laboratories (UL) role is significant in developing testing protocols and certifying refueling equipment for specific fuels.

Two organizations, the National Fire Protection Association (in particular, Code 30A, which includes language on alternative compliance to address new fuels) and the International Code Council, provide standard codes for retail stations that are accepted or modified to meet local requirements. Other organizations developing best practices and codes include American Petroleum Institute, Fiberglass Tank and Pipe Institute, NACE International, National Conference on Weights and Measure, National Leak Prevention Association, Petroleum Equipment Institute (PEI), and Steel Tank Institute (STI).

2.1 EPA Office of Underground Storage Tanks

EPA's OUST regulates tanks that store transportation fuels under Subtitle I of the Solid Waste Disposal Act states that a tank system must be compatible with the fuel stored. This code is currently under revision with a final rule expected in 2015. States administer the underground storage tank (UST) program, and compatibility is the responsibility of the tank owner.

The following critical components must be demonstrated as in compliance with federal code: tank (including tank lining); piping; line leak detector; flexible connectors; drop tube; spill/overflow equipment; submersible turbine pumps (STPs); sealants (pipe dope, thread sealant, fittings, gaskets, O-rings, bushings, couplings, boots); containment sumps; release detection floats/ sensors/probes; fill and riser caps; and shear valves.

Title 40 of the Code of Federal Regulations (CFR) Part 280–Technical Standards and Corrective Action for Owners and Operators of Underground Storage Tanks (UST), covers design, construction, and installation; operating requirements; release detection; release reporting; corrective action for releases; UST out-of-service and closures; financial responsibility (ability to cover the costs to clean up a release); and lender liability. It requires that tanks and piping be constructed, installed, and any portion that is underground and routinely contains product be protected from corrosion in accordance with a code of practice developed by a nationally recognized association or independent testing laboratory. It also requires that the UST be made of or lined with materials compatible with the regulated substance stored. There are requirements to have equipment installed to prevent releases, including the use of spill containment and overfill prevention equipment. There are also requirements to have equipment capable of detecting releases of regulated substances from the portions of the UST that routinely contain product. Since 1986, UST owners must submit documentation that a new tank has been installed along with certification of installation and keep maintenance records. UST owners must report all suspected and confirmed releases, generally within seven days.

40 CFR Part 281–Approval of State Underground Storage Tank Programs, and Part 282–Approved Underground Storage Tank Programs, explain the requirements to authorize states to administer UST federal code under Subtitle I of the Resource Conservation and Recovery Act. 40 CFR Part 302 Designation, Reportable Quantities, and Notification, defines hazardous subjects stored in USTs (includes gasoline, ethanol, and many other chemicals), releases, and penalties.

In 2011, OUST released the *Guidance – Compatibility of UST Systems with Biofuels Blends* document, which provides an alternative path for demonstrating compliance with the compatibility requirements in federal code when storing biofuels above E10 or B20 (20% biodiesel; 80% petroleum diesel) (EPA 2011). OUST believes that while most biofuel blends are compatible with tanks and pipes, there could be issues with associated UST equipment.[8] Tanks and associated equipment are in use for decades, and the guidance allows manufacturers to state compatibility with specific biofuel blends. This guidance is expected to be published in the CFR in 2015 after the Office of Management and Budget approves it. Incorporating this guidance into the CFR gives refueling station owners an added layer of security as it ensures their tank insurance is uncompromised, which is also an important factor in their ability to maintain a line of credit with their financial institution.

2.2 Underwriters Laboratories

UL is the primary third-party certification laboratory servicing the refueling equipment industry globally. UL develops testing standards by consensus and allows manufacturers time to comply.[9] These standards have been available for many decades in the marketplace. There are many standards covering individual products in the fueling system and many different approaches to evaluating safety. The more recent standards address higher levels of ethanol and the introduction of biodiesel. Some standards comprehensively evaluate structural integrity, material compatibility, operating performance, and electrical safety while others may limit evaluations to specific items. In the past, some standards that provided listings for specific fuels were limited to petroleum products, but were then revised to handle low levels of ethanol blends. Over time, many UL standards provided the option for equipment manufacturers to list their products for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85). While some UL standards allow manufacturers to select which fuel ratings to list for, there is trend towards revising standards to require equipment to be listed for all fuel types and blends that are commercially available. Testing is not conducted with commercial fuels. The trend is towards aggressive test fluids where gasoline is represented by Reference Fuel C (equal parts iso-octane and toluene) and it is mixed with ethanol, acid, and water. Table 1 summarizes the relevant refueling equipment UL standards. Information on applicable UL standards for each piece of refueling equipment at a station is described in Section 4. Table 1 confirms that there are UL testing standards available now for all gasoline–ethanol blends from 0% to 85% ethanol content.

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[8] Communicated by EPA OUST staff during a December 2013 call with National Renewable Energy Laboratory and Oak Ridge National Laboratory staff.

[9] The terms "UL listed" and "UL certified" can be used interchangeably.

Table 1. Key UL Testing Standards for Refueling Equipment

UL Testing Standard	Equipment Covered	Listing for Ethanol Blends
UL 58	Underground steel tanks	Does not list for specific fuels
UL 1316	Underground fiberglass tanks	E100 (non-aggressive test fluids)
UL 971	Pipes and pipe fittings	E100 (non-aggressive test fluids)
UL 2447	*Sumps:* tank, dispenser, transition, fill/vent (spill buckets) *Sump fittings*: penetration, termination, internal, test and monitoring *Sump accessories*: cover, frame, brackets, chase pipe	E85 (non-aggressive test fluids for current listings). The new Standard 2447 requires testing with aggressive E25 and E85. Manufacturers must recertify by June 2016.
UL 2583	*Part I Vapor Control Products:* emergency vents, pressure vacuum vents, fill and vapor adaptors, and monitor well caps *Part II Liquid Control Products:* overfill protection (or prevention) valves, ball float vent valve (or flow restriction device), drop tubes, extractor tee, jack screw kit, face seal adaptor (or threaded riser adaptor), fill cap and adaptors	Part I and Part II require testing with aggressive E25, E85, B25, and Reference Fuel F.
UL 87	Power-operated dispensing devices for petroleum products	E10 (non-aggressive test fluid)
UL 87A	Power-operated dispensing devices for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 25	Meters for flammable and combustible liquids and LP-gas	E10 (non-aggressive test fluid)
UL 25A	Meters for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 79	Power-operated pumps for petroleum dispensing products	E10 (non-aggressive test fluid)
UL 79A	Power-operated pumps for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 330	Hose and hose assemblies for dispensing flammable liquids	E10 (non-aggressive test fluid)
UL 330A	Outline for hose and hose assemblies for use with dispensing devices dispensing gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 331	Strainers for flammable fluids and anhydrous ammonia	E10 (non-aggressive test fluid)

UL Testing Standard	Equipment Covered	Listing for Ethanol Blends
UL 331A	Strainers for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 428	Electrically operated valves	E10 (non-aggressive test fluid)
UL 428A	Outline for electrically operated valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 567	Emergency breakaway fittings, swivel connectors and pipe-connection fittings for petroleum products and LP-gas	E10 (non-aggressive test fluid)
UL 567A	Emergency breakaway fittings, swivel connectors and pipe-connection fittings for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 842	Valves for flammable fluids	E10 (non-aggressive test fluid)
UL 842A	Valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 - E85)	E25 and/or E85 (tests with aggressive test fluids)
UL 2586	Hose nozzle valves	E10 (non-aggressive test fluid)
UL 2586A	Hose nozzle valves for gasoline and gasoline–ethanol blends with nominal ethanol concentrations up to 85% (E0 – E85)	E25 and/or E85 (tests with aggressive test fluids)

Source: UL

2.2.1 UL Standards Summary

UL 1316, Glass-Fiber-Reinforced Plastic Underground Storage Tanks for Petroleum Products, Alcohols, and Alcohol-Gasoline Mixtures

This standard covers underground fiberglass tanks and allows manufacturers to select in which of three fuel ratings to have their product listed. Essentially it is an “a la carte” menu. Both existing fiberglass tank manufacturers have UL listing for E100.

The test fluids used to evaluate compatibility for the three fuel ratings are:

1. Petroleum products: includes but is not limited to: regular and premium gasoline, diesel fuel, fuel oil, Reference Fuel C, kerosene, and fuel oil #6 (option at elevated temperature)
2. Alcohol and petroleum blends: includes fuel #1 plus E10 and E30. (This allows listing for E10 but not E30 despite testing with it.)
3. Alcohol and petroleum blends: includes #1 and #2 test fluids plus E15, E50, E100, and methanol blends at the same volumes.

UL 58, Standard for Steel Underground Tanks for Flammable and Combustible Liquids

This standard covers underground steel tanks. It does not test or certify equipment for specific fuels but instead for flammable and combustible liquids. All existing U.S. steel tank manufacturers have UL listing under this standard.

UL 1746, External Corrosion Protection Systems for Steel Underground Storage Tanks

This standard provides certification for external corrosion protection systems applied to UL 58 steel tanks. There are four parts, and parts i (galvanic-type cathodic protection systems), ii (fiber-reinforced plastic composite systems), and iv (polyurethane-coated systems) do not test with specific fuels; listing is for flammable and combustible liquids. Part iii (polyurethane, polyurea, high density polyethylene, or fiber-reinforced plastic jacketed systems) provides ethanol listing only for jacket tanks with secondary containment because there is an interstitial space formed by the jacket. The test requires 30 days of exposure to test fluid and includes the same testing fluids as UL 1316.

UL 1856, Underground Fuel Tank Internal Retrofit Systems

This standard allows a station owner to retrofit the existing tank onsite in three ways, all of which require the tank's internal surface to be refurbished prior to applying nonmetallic coatings with new fuel ratings. In the past, this standard allowed manufacturers to select which class of fuels to list for, the same as UL 1316. However, UL 1856 has recently been revised to require compliance with all automotive fluids, including E25 and E85, by June 14, 2017.

UL 142, Aboveground Flammable Liquid Tanks

This standard covers aboveground tanks, which are not very common at commercial fueling stations. It does not test or certify equipment for specific fuels but instead for flammable and combustible liquids. UL Standards 2080 and 2085 also apply to aboveground tanks for fire protection, as they require use of a UL 142 core tank.

UL 971, Standard for Nonmetallic Underground Piping For Flammable Liquids, and UL 971A, Outline of Investigation for Metallic Underground Piping for Flammable Liquids

This standard covers flexible and rigid piping and pipe fittings for both fuel and vapor. This standard has similar fuel ratings and uses similar test fluids as UL 1316. All existing pipe manufacturers have UL listing for E100.

UL 2039, Outline of Investigation for Flexible Connector Piping for Fuels

This standard covers flexible connectors that typically connect underground piping to other equipment in sumps. In the past, this standard offered the same selection of test fluids as UL 1316. The standard was updated in December 2010 to require all automotive fluids, including E25 and E85.

UL 2447, Containment Sumps, Fittings and Accessories for Fuels

This standard covers containment sumps (dispenser, tank, transition, spill buckets) and all the fittings (termination, penetration, test/monitor, internal) and accessories (frames, brackets, chase, etc.). This standard previously and currently allows manufacturers to select test fluids from the same three classes as UL 1316. However, the standard has been updated, and manufacturers will need to demonstrate compliance with the standard and listing for all automotive fuels, including E25 and E85, by June 30 2016 (originally the date was June 30, 2015, but manufacturers asked for an extension). Some manufacturers list under this standard and others do not.

UL 2583, Outline for Investigation for Fuel Tank Accessories

This new standard covers equipment that may have been listed under other, older standards and also covers equipment that has never previously been listed by UL. Few manufacturers listed products under the old standards. This new standard requires manufacturers to list all automotive fuels, including E25 and E85. Part I was issued in June 2011 to cover all vapor control products—any functional device on tank top or directly fitting on or indirectly connected to a pipe to control vapors. Equipment covered includes emergency vents, pressure vacuum vents, fill and vapor adaptors, and monitor well caps. Part II was issued in June 2014 and covers liquid control products; specifically functional equipment designed to connect to tank top and to contain spills and prevent overfills. This covers overfill protection (or prevention) valves, ball float vent valves (or flow restriction devices), drop tubes (never previously listed by UL), extractor tees, jack screw kits, face seal adaptors (or threaded riser adaptors), fill caps, and adaptors.

UL 87, Power-Operated Dispensing Devices for Petroleum Products, and UL 87A, Standard for Power-Operated Dispensing Devices for Gasoline and Gasoline/Ethanol Blends with Nominal Ethanol Concentrations up to 85 Percent (E0 – E85)

UL 87 allows listing for up to E10 with minimal exposure to test fluids. In 2007, UL introduced UL 87A, Outline of Investigation for Power-Operated Dispensing Devices for Gasoline/Ethanol Blends with Ethanol Content Greater than 15 Percent to address E85. At the time, UL 87A covered additional testing for multiple pieces of related equipment. These standards work somewhat differently than those for tanks, pipes, and associated tank equipment. A manufacturer can select UL 87 for listing a product up to E10 or UL 87A to list a product for up to just E25 or opt to test and list it for E85 also. Since development of UL 87A in November 2012, equipment has been split out into different standards specific to each equipment type. (The designation "A" after a listing denotes the option to list a product for up to just E25 and/or E85).

- Breakaways, swivels, pipe connection fittings: 567/567A
- Dispensers: 87/87A
- Filters: 331/331A
- Hoses: 330/300A
- Meters: 25/25A
- Nozzles: 2586/2586A

- Shear valve (emergency shut-off valve): 842/842A
- Submersible turbine pump: 428/428A

2.3 Occupational Safety and Health Administration

OSHA regulates some fuel-dispensing equipment. Its regulations applicable to service stations have not been updated in decades and therefore do not specifically address biofuels. OSHA is planning to update these standards to address new fuels in the marketplace.

OSHA 1910.106 (g)(3)(iv) and (g)(3)(vi)(a) require dispensers and nozzles to be listed by a third party for specific fuels.

OSHA 1910.106(b)(1)(i)(b) and (c)(2)(ii) require tanks, piping, valves, and fittings other than steel to use sound engineering design for materials used; however, there is no listing requirement. OSHA 1910.106(b)(1)(iii) covers steel tanks and requires sound engineering and compliance with UL 58 and American Petroleum Institute Standards 650 and 12B as applicable.

2.4 State Regulations

2.4.1 California Air Resources Board

The California Air Resources Board (CARB) is the division of the California Environmental Protection Agency tasked with reducing air pollutants. CARB developed test procedures for vapor recovery equipment and requires specialized enhanced vapor recovery equipment. The following equipment must be approved under this program: adaptors, drop tubes, hoses, nozzles, overfill protection devices, pressure vacuum vents, spill containers, and vapor return piping (CARB 2015). The requirements are not for equipment use with specific fuels.

2.4.2 Florida Department of Environmental Quality

The Florida Department of Environmental Quality (FDEQ) approves station storage tank equipment through state regulations (FDEQ 2015). The regulations require State of Florida approval of tank system equipment prior to installation or use, except for the following equipment: dispensers, islands, nozzles, hoses; monitoring well equipment; manhole and fillbox covers; valves; cathodic protection stations; metallic bulk product piping; small-diameter piping not in contact with soil unless the piping extends over or into surface waters; and vent lines. All other equipment must be approved through a third-party laboratory demonstration that provides a technical evalution of the equipment, test results verifying equipment functions as designed, and a professional certification that the equipment meets Florida performance standards (FDEQ 2015). The performance standards are straightforward and are not fuel specific. The State of Florida has a long list of approved equipment (FDEQ 2015).

3 Literature Review

A literature review was performed to identify specific components or materials that have been associated with releases from USTs storing E10. The information is intended to be used to minimize the potential for future releases, particularly during the rollout of E15. The literature review was limited to releases identified during the years 2000 to the present. During the years covered by this literature review, the penetration of E10 into the U.S. gasoline pool went from minimal in many regions of the country to full saturation.

Scope of Review

The following sources were used:

- LUSTLine 2000 – present.
- *PEI Journal* 2009 – present (PEI Journal not available online before 2009).
- *TulsaLetter* (The *TulsaLetter* is the official e-newletter of PEI.) 2000 – present.
- Experts in refueling infrastructure were contacted, including EPA, Fiberglass Tank and Pipe Institute, PEI, STI, and oil industry representatives.
- EPA OUST release data website.
- Web search for literature and data on UST E10 releases.

Major Findings

- The number of reported UST releases has been steadily declining since 2000 from occurring in about 2% of all USTs in the United States to about 1% in 2014 (EPA 2015a).
- There is no evidence of different trends in the number of UST releases between states that were early adopters of E10 and states that only recently reached full saturation of E10.
- EPA has collected data on the source and cause of UST releases. Because of the high number of releases that were attributed to "unknown" or "other causes," the data cannot be considered conclusive, but roughly 10% of all releases were attributed to corrosion in a 2004 review and 7% in 2009 (EPA 2004, Eigmey 2011).
- Anecdotal input solicited from infrastructure industry experts said that they knew of no published reports of releases caused by E10.
- None of the reviewed literature listed any association between E10 and any specific UST release.

Figure 2 shows the number of USTs declining over time which is a result of the declining number of retail stations. There were approximately 571,000 registered USTs in the United States as of September 2014 (EPA 2015a).[10] OUST provides UST release data annually, and over the time that E10 spread across the country, the number of releases has tended to decline from 2% of registered tanks in 2000 to 1.2% of USTs experiencing a release in 2014. Figure 3

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[10] A year is measured by the federal government's fiscal year from October 1 to September 30.

shows that as E10 was deployed over the last several years, the number of UST releases did not increase. Any problems associated with introducing a different fuel at an existing station usually happen soon after storing a different fuel. In interpreting these results, it should be noted that many releases are discovered and reported years after they first occurred when the tank is removed from service. Other releases are due to operator errors (such as overfilling or poor maintenance) and may be completely unrelated to the fuel stored.

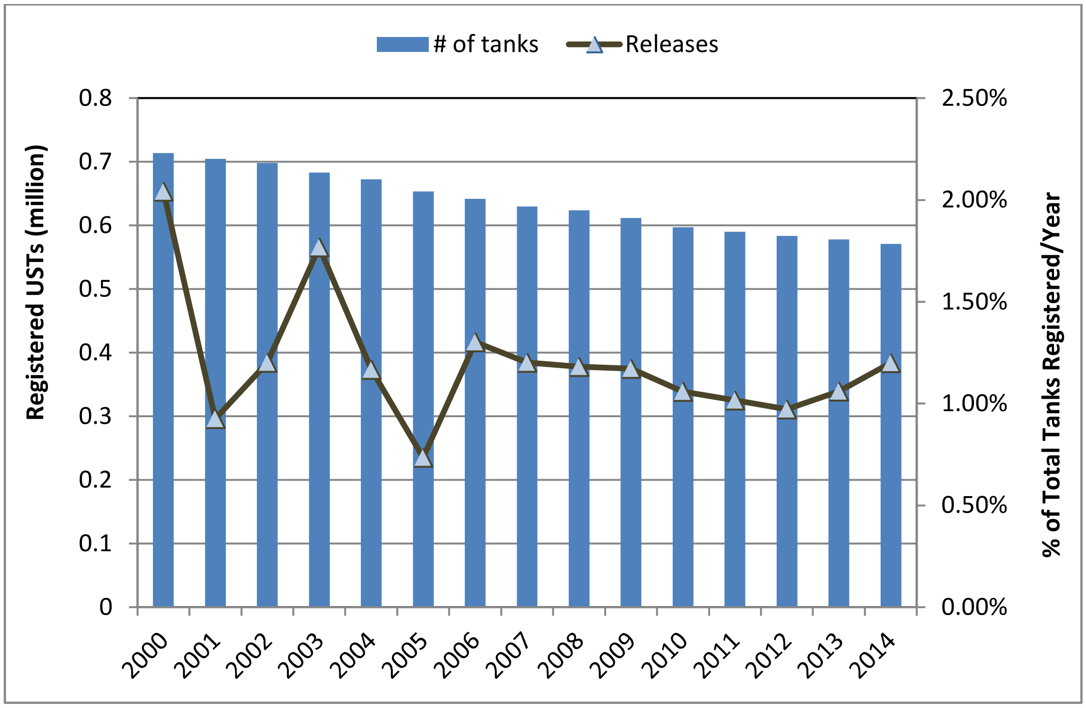

Figure 2. Registered USTs and releases

Source: UST Performance Measures. EPA OUST. Last accessed March 10, 2015: http://www.epa.gov/oust/cat/camarchv.htm

The Energy Policy Act of 2005 included a requirement for UST release reports to include a source and cause. A LUSTLine report analyzed 2009 data reports from 47 states reviewing 5,168 UST releases (Eighmey 2011). While the data point to some areas where leaks are common and uncommon, approximately one-third of leaks were listed as other or unknown. Some releases occur no matter what fuel is being delivered or stored. These releases include physical/ mechanical damage (14.9%), overfills (4.8%), spills (3.8%), and installation problems (1.0%). Transportation fuels can cause corrosion, and this study found corrosion caused 7.5% of releases. The topic of STP corrosion comes up as an issue, but a small scoping study performed for RFA found that STPs were not failing. This 2009 report shows the STP as the source of a release in just one of 5,168 incidents. The EPA reviewed 608 UST releases in 2004 and found causes of release were physical/mechanical (39.8%), other/unknown (27.0%), spill/overfill (26.6%), and installation (3.1%) (EPA 2004). Table 2 summarizes 2009 data for cause and source with detailed data available in Appendix A.

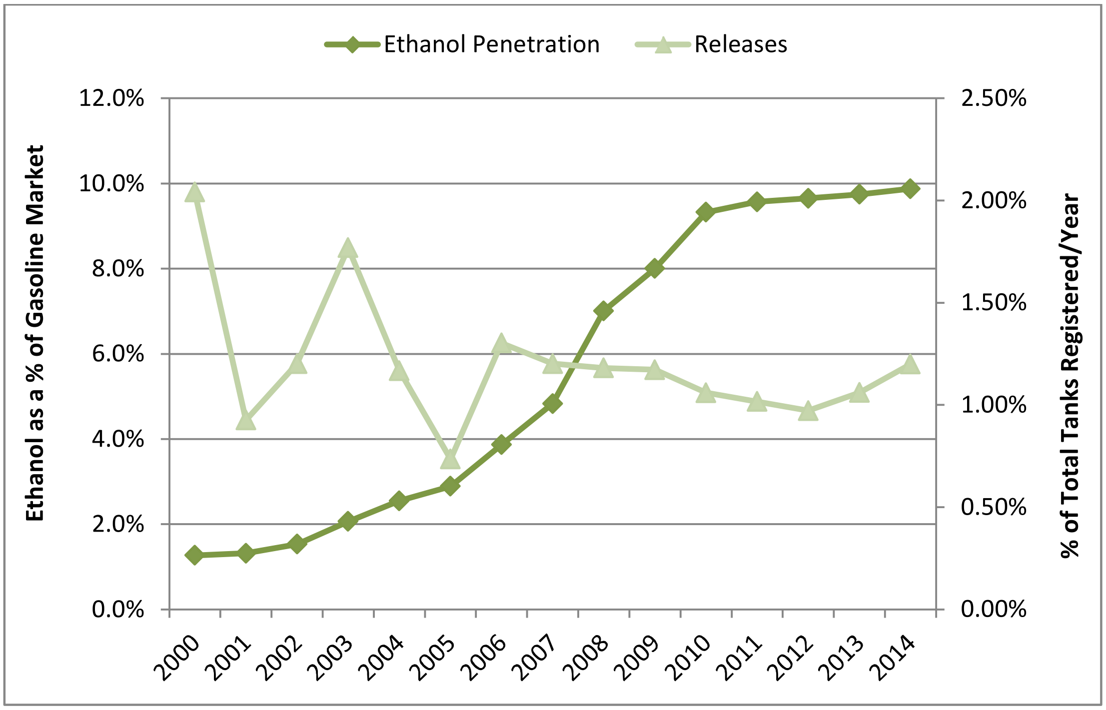

Figure 3. Ethanol penetration and UST releases

Source: Energy Information Agency U.S. Product Supplied of Finished Motor Gasoline: http://www.eia.gov/tools/faqs/faq.cfm?id=23&t=10 and Monthly Energy Review Table 10.3 Fuel Ethanol Overview: http://www.eia.gov/totalenergy/data/monthly/

Table 2. Sources and Causes of UST Releases

UST Releases	**2009 Data (5,168 releases)**	
Source	**#**	**%**
Tank	1,616	31.3%
Piping	720	13.9%
Dispenser	655	12.7%
STP	76	1.5%
Delivery Problem	342	6.6%
Other	564	10.9%
Unknown	1,195	23.1%
Physical/Mechanical Damage	770	14.9%
Spill or Overfill	441	8.5%
Corrosion	385	7.4%
Installation	54	1.0%
Other	466	9.0%
Unknown	3,051	59.0%

Source: Eighmey, C., March 2011, LUSTLine Bulletin #67. Accessed March 10, 2015: http://www.neiwpcc.org/lustline/lustline_pdf/lustline_67.pdf .

As of January 2003, FDEQ requires County Tanks Program inspectors to submit a leak autopsy form. A 2007 study reviewed Florida leak data and found the sources were spill buckets (48%), piping (14%), dispensers (12%), and tanks (10%) (Mott-Smith 2007). The causes were unknown (36%), overfill (25%), mechanical (16%), material (10%), and corrosion (7%). Spill buckets are designed to reduce leaks during fuel delivery. At the time of the report, Florida's E10 penetration was only 5%, so these results do not reflect E10 storage releases but do highlight the importance of maintenance and appropriate fill techniques.

The literature review was directed specifically at identifying ethanol sensitive equipment and included conversations with several leading infrastructure experts to determine if there was evidence and/or literature showing issues with E10 in USTs. Experts suggested that the long, slow introduction of E10 allowed time for refueling equipment manufacturers to adjust to it. None of the experts was aware of any reports and thought it would be unlikely to find any reports on E10 releases. There are examples of equipment failing such as Total Containment, Inc. flexible piping, but it was the opinion of experts that poorly made products would have failed with any fuel, and the failures of flexible piping occurred not long after their introduction and prior to the widespread use of E10. This is not to say that there were no issues during the deployment of E10, just that there were no known releases and no reports on this subject. An Oak Ridge National Laboratory study of E15 stated "UST stakeholders generally consider fueling infrastructure materials designed for use with E0 to be adequate for use with E10, and there are no known instances of major leaks or failures directly attributable to ethanol use. It is conceivable that many compatibility issues, including accelerated corrosion, do arise and are corrected onsite and, therefore do not lead to a release." (Kass et al. 2012).

Several experts cited EPA work on STP corrosion, and both EPA and Battelle work on ultra-low sulfur diesel (ULSD) corrosion. The National Renewable Energy Laboratory (NREL) previously reviewed the STP corrosion issue for RFA. STPs draw fuel from the UST and deliver it to pipes connected to an aboveground dispenser. The State of Tennessee and EPA OUST have investigated and presented on premature STP corrosion. The theory on the cause is that temperature differentials between sumps and UST systems in summer months (or in warm and humid climates) may enable vapors to enter the STP sumps. Vapors that may contain ethanol capable of dissolving in water may condense on metallic portions of an STP, which reacts with acetobacter and oxygen to form acetic acid, leading to corrosion. NREL spoke with numerous state UST offices and county-level experts and did not find any evidence that corrosion was leading to failures or early replacement of STPs. Accelerated corrosion of ULSD UST systems has been observed nationwide. These instances of corrosion started to be reported in 2007 when ULSD was first introduced. The cause of corrosion is currently under investigation, and an EPA OUST study on ULSD corrosion is expected in late 2015.

4 Equipment at Station

A service station consists of many interconnected pieces of refueling equipment necessary to deliver fuel to vehicles. There are approximately 60 pieces of equipment at a station designed to handle fuel and vapor. The equipment delivering fuel to a vehicle includes tanks, pipes, submersible turbine pump, dispenser, and hanging hardware. The remainder and majority of equipment are used to prevent, detect, and contain releases and there is equipment for fuel delivery. This category includes overfill protection, leak detection, shear valves, fill and vapor caps and adaptors, containment sumps and all associated fittings and accessories of these equipment types.

Figure 4 is a diagram of equipment at a station. Table 3 provides a list of the equipment shown in the diagram and includes the purpose of the equipment; common materials; if the equipment is listed by UL, and if it is UL listed, is it tested with fuel or not; if it was tested with fuel; and what the highest level of ethanol listing available under the standard is. Note that #1 in Figure 4 shows just the tank on the diagram, but the table includes information about steel, fiberglass, and aboveground storage tanks and their protections. This list is comprehensive, and not all stations will have equipment on this list. The table data were taken from the following sources: equipment list and diagram (Source North America); UL; equipment materials (manufacturer product websites and catalogs); and function (PEI Wiki and manufacturer product websites and catalogs).

All known manufacturer website product pages and catalogs were reviewed for every equipment type and model to determine if the products could be used with blends above E10. All known manufacturers were contacted to review compatibility lists. This resulted in an extensive list of equipment compatible with blends above E10. Appendix B provides an equipment list of UL-listed aboveground components for blends above E10. Appendix C provides a compatibility list of tanks. Appendix D is a list of compatible pipes. Appendix E provides information for other UST equipment with manufacturer, equipment type, model names/numbers, ethanol compatibility (%), if it is UL listed, and if it is listed for the ethanol fuel determined by the manufacturer. It is important to note that manufacturers typically keep product names over time but may change product model numbers. Also, manufacturers will introduce new product names, and there is a higher likelihood that these products will be compatible with E15.

Determination of compatibility of equipment with ethanol blends is determined by both regulations and manufacturer statements. Manufacturers have laboratories where they conduct fuels testing to determine if the materials they are using work with a range of fuels. Tanks are subject to EPA OUST regulations, and all existing tank manufacturers provided letters stating compatibility with ethanol blends (see Appendix A). Tanks, pipes, and most aboveground equipment are typically UL listed for specific fuels. This includes dispensers, breakaways, hoses, nozzles, swivels, shear valves, and STPs.

Some manufacturers of other UST equipment make an effort to obtain UL listing for all their products, some obtain it for certain products, and others do not obtain UL listing for their products. Many products are approved by the manufacturer for blends above E10 but are not UL listed for blends above E10. This is largely due to the recent availability of ethanol test fluids under UL testing standards, and over time it is expected that more equipment will be UL listed for blends above E10. In many instances, there is not a history of many manufacturers obtaining UL listing for certain product types such as fill equipment or containment sumps.

There is no regulation that requires station owners to keep records of their equipment, making determination of compatibility challenging for stations without equipment records. One potential source of tank information is the STI, which maintains a list of steel tanks if owners send in the warranty card. STI also provides a method to determine tank type and manufacturer (see Appendix F).

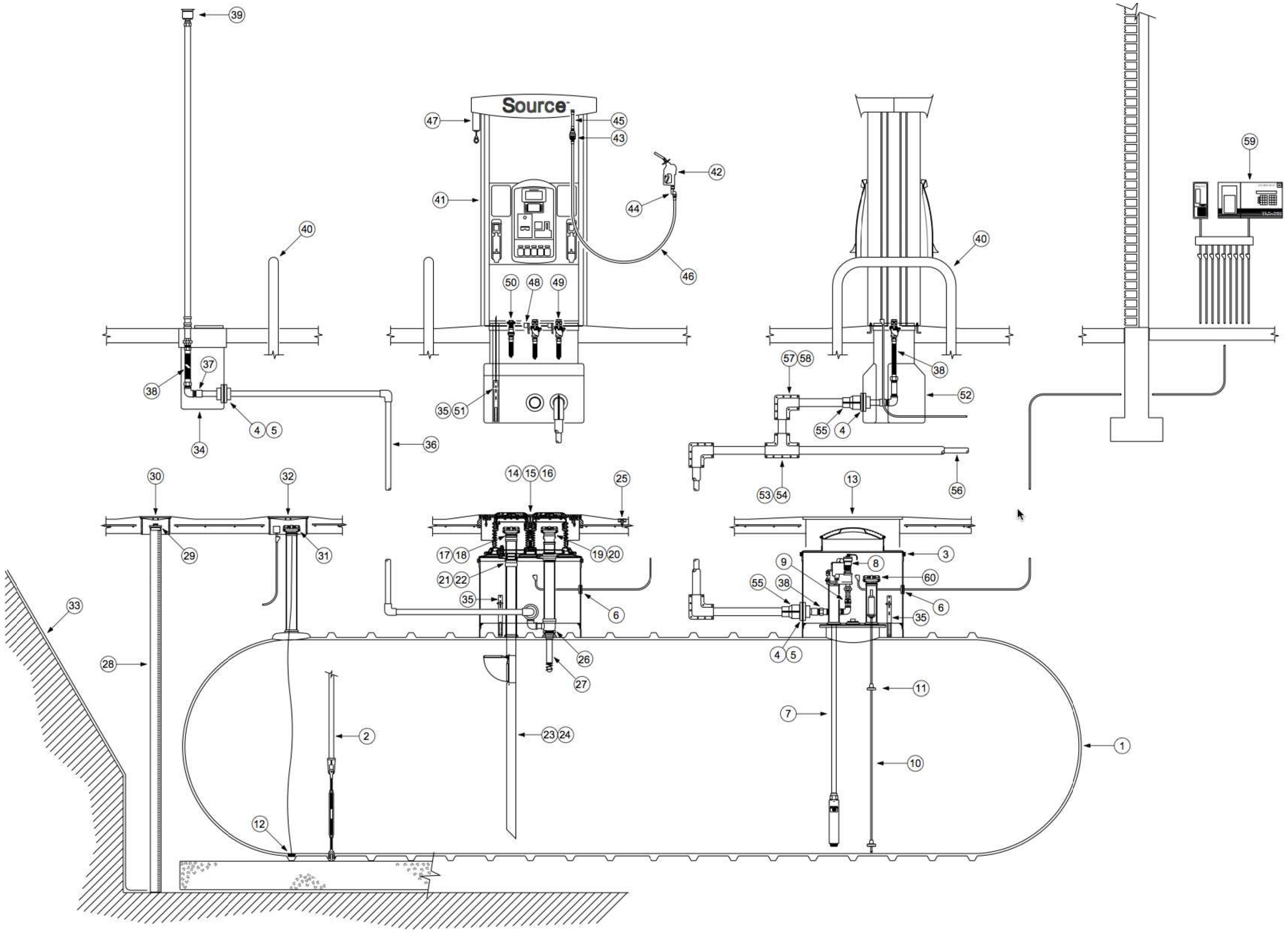

Figure 4. Station equipment diagram

Source: Diagram provided by Source North America, a fueling equipment distributor.

Table 2. Station Equipment List-Materials and Function

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
1	Tank-steel	yes	58	no	none	steel	Stores fuel.
1	Tank-fiberglass	yes	1316	yes	E100	fiberglass	Stores fuel.
1	Tank-external corrosion protection Jacketed steel tank	yes	1746	yes[a]	E100[a]		Protects tank from corrosion.
1	Tank-lining and upgrades	yes	1856	yes	E100		General tank protection.
1	Tank-above ground	yes	142/142A	no	none	fiberglass or steel	Stores fuel.
1	Tank-above ground fire protection	yes	2080/2085	no	none		Protects tank from fire.
2	Tank straps	no				metal, fiberglass, and other	Outside of tank and usually made of concrete. Devices installed in storage tank excavations to prevent tanks from floating out of the ground in event of a high level of groundwater in the excavation or a high groundwater level after the installation is complete.
3	Sump and cover (tank)	yes	2447	yes	E85	polyethylene, fiberglass	Contains spills from a tank.
4	Sump entry fitting (boot)	yes	2447	yes	E85	fiberglass, bronze, stainless steel, nitrile rubber	These seals provide a studded flange connection to create a positive and secure seal where the rubber contacts the sump wall and also around the pipe or conduit.
5	Sump penetration fittings	yes	2447	yes	E85	fiberglass or flexible plastic	A fitting that provides a liquid and vapor-tight seal around both the piping or conduit and the wall of a containment sump.
6	Flexible entry boots (conduit entry)	yes	no	no	none	glass filled nylon, nitrile	Pipe where electric wires are inserted.
7	Submersible turbine pump	yes	428 428A	yes	E10 E25 and/or E85	cast aluminum, steel, flurocarbon	Delivers fuel from the tank to the dispenser.
8	Mechanical line leak detector	yes	1238	no	none	brass, stainless steel, copper, fluorocarbon	A device used to detect the presence of a leak in the piping. Usually connected to the STP.
9	Ball valve	yes	842 842A	yes	E10 E25 and/or E85	brass, plated steal, vinyl, fluorocarbon	A valve in a piping system that allows or stops flow of fuel.
10	Magnetostrictive probe	yes	1238	no	none	stainless steel, nitrile rubber	A form of measurement technology used in in-tank electronic monitoring systems.This is a leak detection method that relies on sound waves and a magnet.
11	Float kit	yes	1238	no	none	nitrile rubber, fluoropolymer	Works in conjunction with the magnetostrictive probe to determine inventory and identify leaks.
12	Interstitial sensor	yes	1238	no	none		An electronic device that can detect the presence of water, liquid product, product vapors or a loss of pressure or vacuum in the interstice of a tank, a tank top sump, fuel dispenser sump, or observation well.
13	Manhole-composite	yes	2447	yes	E85	fiberglass, steel, resin, nitrile	Manhole covering the STP sump.

a-only part III provides ethanol listing for jacket tanks with secondary contaiments; other methods covered in parts I, II, and IV list for flammable liquids rather than specific fuels

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
14	Manhole-multi-port spill containment	no				fiberglass, steel, aluminum, iron, polyethelene, resin, nitrile	Provides spill containment for UST fill pipes and vapor recovery risers. They are installed on top of the tank sump.
15	Spill bucket	yes	2447	yes	E85	cast aluminum, cast iron, polyethylene, stainless steel, nitrile	Prevents spilled product from entering the soil near the fill and vapor return riser connections on underground storage tanks during normal tank filling operation, or if the tank overfilled.
16	Fuel grade ID tag	yes	969	no	none		Identifies fuel being stored.
17	Fill adaptor (top or side)	yes	2583	yes	E85	Bronze, nylon, stainless steel, nitrile rubber, fluorocarbon	A permanent fitting at the top of the fill pipe of an underground storage tank that allows for a delivery hose to be quickly connected to the fill pipe in a liquid tight manner.
18	Fill cap (top or side)	yes	2583	yes	E85	brass, epoxy coated aluminum	A cap that fits over the open end of a fill pipe.
19	Vapor adaptor	yes	2583	yes	E85	bronze, conductive nylon, stainless steel, nitrile	A special fitting in a Stage I vapor recovery system that is installed at the top of the vapor recovery riser in two-point and manifolded Stage I vapor recovery systems. The vapor recovery adaptor mates to the vapor recovery elbow attached by the fuel delivery driver prior to a delivery.
20	Vapor cap	yes	2583	yes	E85	aluminum, glass filled nylon, iron, copper, stainless steel, nitrile	A dust cover for the vapor recovery system.
21	Face seal adaptor (threaded riser adaptor)	yes	2583	yes	E85	aluminum	Connects fill pipe to swivel fill adaptor and Provides a flat, true sealing surface on threaded fill pipe where a gasket seal exists. is installed on the fill pipe riser below the spill container to provide a true sealing surface for the drop tube flange on the overfill prevention valves.
22	Jack screw kit	yes	2583	yes	E85	steel	The jack screw is designed to lock an overfill valve or a drop tube into an a spill container base below the outlet of the drain valve.
23	Overfill prevention valve	yes	2583	yes	E85	cast aluminum, nitrile rubber, fluoro based seals, acetal, stainless steel, acetal, closed cell foam	Prevents the overfill of underground storage tanks by providing a positive shut-off of product delivery.
24	Drop tube (often a part of #23)	yes	2583	yes	E85	stainless steel	Delivers fuel from fill cap to bottom of tank resultig in less vapors.
25	Fuel grade ID #	yes	969	no	none		Identifies fuel type.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
26	Extractor tee	yes	2583	yes	E85	cast iron, zinc	A fitting that allows access to ball valve be removed or repaired without the necessity of breaking concrete, digging down to the component, or cutting a hole in the tank.
28	Ball float vent valve (flow restriction device FRD)	yes	2583	yes	E85	Brass, chrome, fluoro based seals	During a product delivery, as the tank level rises, a counterweight stainless steel ball seats on the valve body and restricts flow of vapors back to the transport truck.
27	Monitoring well screen (pipe)	no	no	no	none	plastic, polypropylene (filter wrapping the pipe)	A slotted or screened tube or pipe, positioned vertically in an underground tank excavation, that permits an operator to check conditions in the excavation and, in particular, to determine whether there may be a leak in the tank system.
29	Well cap-monitoring	yes	2583	yes	E85	plastic, nitrile rubber	Provides access to well screen.
30	Manhole-monitoring	no				cast iron	Any tank opening, including those where delivery and vapor return hoses are connected.
31	Interstitial cap	yes	2583	yes	E85		Interstitial Caps are installed on tank riser pipes to help prevent vapors from escaping or water from entering the tank
32	Manhole	no				fiberglass, steel, resin, nitrile	Access to UST system.
33	Roll filter fabric	no				polypropylene, or polyester	A porous synthetic fabric, used in underground storage tank excavations, to provide a barrier between different types of soil, or between backfill and adjacent soil.
34	Transition sump-vent	yes	2447	yes	E85	polyethylene, fiberglass	A liquid tight container typically installed at a point where product piping from an aboveground storage tank transitions to underground piping. Other forms of transition sumps may accomodate piping from an UST tank to AST generators, or for piping that resides only below grade. The transition sump exists to contain any contaminants that may leak from any piping or their connectors and to isolate and protect metallic components or equipment from the elements.
35	Sump sensor	yes	1238	no	none		An electronic device that can detect the presence of water, liquid product, product vapors or a loss of pressure or vacuum in the interstice of a tank, a tank top sump, fuel dispenser sump, or observation well.
36	Pipe	yes	971	yes	E100	fiberglass or flexible plastic	Delivers fuel between different pieces of equipment in the refueling system.
37	Pipe adaptor	yes	971	yes	E100	aluminum, stainless steel, nitrile rubber or fluoro based elastomers	connect fuel delivery transport truck hoses or nozzles to the fill pipe of an aboveground storage tank
38	Flexible connector	yes	2039	yes	E85	stainless steel, fluoro based elastomers or nitrile rubber	Flexible Connectors can be used as a convenient means of connecting piping to pumps and dispensers and throughout the piping systems where connections and changes of direction are necessary.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
39	Vent	yes	2853	yes	E85	aluminum, brass	A pipe, usually 2 inches in diameter, that extends from a gasoline storage tank at a service station to a point 12 feet or more above grade level. The vent allows vapors that build up in the tank to escape and outside air to enter, thus keeping the tank at atmospheric pressure when liquids are added or removed.
40	Steel bumper	no				steel	Not fuel wetted. Designed to protect dispenser from vehicle impact.
41	Dispenser	yes	87 87A	yes	E10 E25 and/or E85	multiple parts/materials (metal, plastic, elastomers) in a dispenser-treated as a whole piece of equipment	The dispenser delivers fuel from the piping connected to the STP through the hanging hardware into a vehicle. It has numerous parts including meters, valves, seals, and electronics.
42	Nozzle	yes	2586 2586A	yes	E10 E25 and/or E85	aluminum, plastic, fluorocarbon	A device consisting of a spout, handle and operating lever, attached to the end of a hose and used for controlling the flow of a liquid motor fuel.
43	Breakaway	yes	567 567A	yes	E10 E25 and/or E85	steel, zinc, nylon, acetal, fluorocarbon	A device that disconnects dispenser from hanging hardware if a vehicle pulls away with the nozzle still in the vehicle gas tank.
44	Swivel	yes	567 567A	yes	E10 E25 and/or E85	aluminum, zinc, nitrile rubber	The swivel permits the nozzle to be rotated without rotating the hose at the same time.
45	Whip hose	yes	330 330A	yes	E10 E25 and/or E85	nitrile rubber	A short length of hose with threaded fittings at both ends that is usually installed adjacent to a breakaway valve. The whip hose ensures that forces exerted during a drive off are aligned with the axis of a breakaway valve.
46	Hose	yes	330 330A	yes	E10 E25 and/or E85	nitrile rubber	Delivers fuel to the nozzle.
47	Hose retractor	no				aluminum, polyester	A cable device, fixed to a gasoline station hose and dispenser, to pull the hose back to its storage position after it has been used. Usually used for longer hoses that allow refueling on either side of a vehicle.
48	Stablizer bar kit	yes	2447	yes	E85	steel	Provides support in a dispenser sump to attach the shear valve.
49	Shear valve	yes	842 842A	yes	E10 E25 and/or E85	cast iron, stainless steel, fluorocarbon	Cuts off the flow of fuel from the UST system in the event of vehicle impact, fire, or other catastrophe.
50	Shear valve-vapor (stage II only)	yes	842 842A	yes	E10 E25 and/or E85	cast iron, stainless steel, fluorocarbon	A fitting installed in the vapor piping at the base of a dispenser that is designed to “shear” or break off if the dispenser cabinet is dislodged from its base.

#	Equipment	UL	UL Std.	Test w/ fuel	Ethanol Test fluids	Materials	Function
51	Sensor tube	yes	1238	no	none		Contains the sump sensor.
52	Dispenser sump	yes	2447	yes	E85	fiberglass, flexible plastic	A container designed to contain leaks from dispensers
53	Pipe-secondary containment tee	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting connector
54	Pipe-product tee	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting connector
55	Concentric reducer	yes	2447	yes	E85		A seal that connects the sump entry/termination fitting to secondary containment pipe.
56	Pipe-product	yes	971	yes	E100	flexible plastic, fiberglass	Delivers fuel between tank and dispenser.
57	Pipe-secondary containment elbow	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting that makes a right-angle turn
58	Pipe-product elbow	yes	971	yes	E100	flexible plastic, fiberglass	A pipe fitting that makes a right-angle turn
40	Steel bumper	no				steel	Protects equipment from vehicle impact.
59	Console	yes	1238	no	none		A control unit, containing switches, keys, or similar elements, used to control the operation of a dispenser or other device at a gasoline dispensing facility.
60	Probe cap adaptor	yes	2583	yes	E85	cast aluminum, nitrile rubber	Monitoring Probe Caps are installed on tank riser pipes to help prevent vapors from escaping or water from entering the tank. Monitoring Probe Caps include a wire grommet fitting to accommodate the electronic tank gauge probe.

4.1 Dispensers, Hanging Hardware, Shear Valves, and STPs

There are multiple dispenser options to sell E15: retrofit an existing dispenser with a UL-listed kit, purchase a UL-listed E25 dispenser (minimal cost over conventional E10 dispenser), or purchase a UL-listed E85 blender pump dispenser (higher cost but more options for fuel offerings). Both Gilbarco and Wayne provide UL-listed dispensers for blends above E10. Credit card companies are requiring retail fueling stations to update their dispensers to accept new chip and PIN secure credit cards by October 2017, at which time fraud liability would switch to station owners if they have not updated their equipment. This presents an opportunity to increase E25 UL-listed equipment through either a retrofit kit if electronics are being upgraded to accommodate the new credit cards, or if a station must purchase a new dispenser, they could pay a minimal amount more for an E25 dispenser.

Hanging hardware includes hoses, nozzles, breakaways, and swivels (Figure 5). OPW obtained E25 listing for a conventional swivel and breakaway, for which there is no price premium. Husky offers UL-listed E25 and E85 nozzles while OPW offers a UL-listed E85 nozzle. EMCO Wheaton, IRPCO, and Veyance have hoses warrantied for E15, and Veyance has a UL-listed E85 hose product. A best practice is to replace all hanging hardware with E15-compatible equipment.

Shear valves are an important piece of safety equipment that cut off the flow of fuel from the UST to the dispenser to prevent a release in the event of an accident dislodging the dispenser or fire. UL-listed E85 shear valves are available from Franklin Fueling and OPW.

STPs draw fuel from the tank and into piping that delivers the fuel to the dispenser. Both Veeder-Root and Franklin Fueling offer UL-listed E85 pumps.

Appendix B lists specific manufacturers and models for use with blends above E10.

Figure 5. Aboveground equipment

(NREL 13531)

4.2 Tanks, Pipes, and Other UST Equipment

4.2.1 Compatibility of Tanks

Most tanks are compatible with ethanol blends above E10. Appendix B lists tank manufacturers and their compatibility with ethanol blends. If a station owner does not have equipment lists, the information in Appendix F describes methods to determine tank type.

All existing steel tank companies manufacturing tanks to store transportation fuels have issued signed letters stating compatibility with up to E100 per EPA OUST biofuels guidance. Tanks are listed under UL 58, which does not expose tanks to test fluids. All STI members who fabricate regulated fuel USTs in the United States have UL 58 listings. STI conducted independent testing and determined that steel tanks are compatible with all ethanol blends.

Xerxes and Containment Solutions manufacture fiberglass tanks, and both have E100 listing for their products under UL 1316.[11] Per EPA OUST's biofuels guidance, Containment Solutions issued a letter stating that all tanks it has manufactured are compatible all ethanol blends. Xerxes and Owens Corning (which no longer manufactures tank) have stated that compatibility depends on tank type and the year manufactured. Appendix C includes specific information on fiberglass tank compatibility.

The following is from a Fiberglass Tank and Pipe Institute paper on ethanol compatibility (Curran 2015):

> *"By 1990, Institute member fiberglass tank manufacturers had modified their tanks constructions to handle gasoline with any level of ethanol or methanol up to 100% for all double-wall fiberglass tanks and in some cases single- wall fiberglass tanks. In 1992, Owens Corning, the manufacturer of the oldest UL Listed fiberglass tanks for petroleum service, advised certain major oil companies that some tanks were approaching 30 years in age and their 30-year warranties would expire. As a result, the affected companies conducted surveys of these older tanks, including tanks in E-10 ethanol service (e.g., in the Midwest) and confirmed that the tanks were performing satisfactorily for continued service. In summary, technical evaluations and historical experience demonstrated that there is no material or technical reason why properly installed pre-1988 piping and tanks in conventional gasoline or MTBE service should not perform equally as well when handling 10 percent ethanol blends."*

4.2.2 Compatibility of Pipes

Installed pipes are evenly split between fiberglass and flexible plastic pipes. Piping is listed under UL 971. E100 became an eligible test fluid in 1988, and all existing pipe companies have E100 listing (Appendix D). Fiberglass was the primary pipe type for decades. NOV is the only existing company providing fiberglass piping in this market, and its products received E100 listing in 1990. NOV provides a 30-year warranty.

Flexible pipes entered the marketplace in the 1990s after EPA OUST recommended development of jointless pipes. There were some issues with initial deployment and failures of Total Containment piping. Total Containment is no longer in business, and its piping is largely

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[11] Decades-old fiberglass tanks may only be approved for use with E10; please refer to Appendix C.

believed to have been replaced. This occurred before E10 was widely available. Over time, more robust products were developed, and all existing flexible plastic pipe manufacturers have UL listing for E100. These manufacturers include Advantage Earth Products, Brugg Pipesystems,[12] Franklin Fueling, NUPI, Omega Flex, and OPW. Both Franklin Fueling and Omega Flex require the use of stainless steel pipe fittings for blends above E10. A typical warranty for flexible pipes is 10 years.

It is likely that there are stations using piping from companies no longer in business, and the compatibility with ethanol blends for these products is unknown.

4.2.3 Other UST Equipment

Other associated UST equipment includes sumps and accessories, manholes, flexible connectors, fill caps and adaptors, entry fittings, overfill prevention, leak detection, sensors, drop tubes, vents, and similar. Per EPA OUST's biofuels guidance, several manufacturers have issued letters for specific products and model numbers stating compatibility with various ethanol blends above E10. Some major manufacturers have not issued letters but have provided statements on their website product pages that the products are compatible with various ethanol blends, including E15, E85, and E100. Most manufacturers have their own laboratories where they test their products with fuels. Some smaller manufacturers likely rely on materials analysis to determine compatibility. Appendix D provides a list by manufacturer of compatible equipment.

While UL now has listing standards for most of this equipment, few products have UL listing for E10 and even fewer for blends above E10. This does not mean that the products are not compatible, just that manufacturers have yet to obtain listings.

Retailers should specifically investigate if their leak detection equipment is compatible with E15 (refer to Appendix E). Leak detection equipment is required by federal regulations developed by EPA OUST (EPA 2015b). All federally regulated UST systems (tanks and piping) storing motor fuel must have leak detection equipment to detect any potential releases so the spread of contamination can be stopped before significant environmental impact occurs. Regulations allow for several types of leak detection methods. The National Work Group on Leak Detection Evaluations has developed test protocols for various technologies with blends above E10 (NWGLDE 2011). It is expected that some will function with ethanol blends while others may require testing to determine functionality.

In 2011, Battelle conducted a test of ethanol-blended fuels and an automatic tank gauging system to determine water detection functionality (Carvitti and Gregg 2010). E0 was used as a baseline, and E15 and E85 were tested. Fuel was tested at two tank levels—25% and 65% full. Two methods of water ingress were used: a continuous stream of water into a tank, and a quick water dump followed by a fuel dump. An automatic tank gauging system has a float that performs two functions: product level monitoring that leads directly to leak detection; and water detection. The water detection function detected the water stream with E0 and E15 but was not conclusive for E85.

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[12] Brugg Pipesystems manufacturers stainless steel pipes, which are rarely used at United States stations.

As a result of the E15 waiver request, the American Petroleum Institute funded a study to determine compatibility of some associated UST equipment, specifically tank vapor recovery equipment and overfill protection devices with E15 (Ken Wilcox Associates 2011). The testing protocol was to expose equipment to test fluids E10 (control) and aggressive E17 (test fluid formula from UL) for four weeks at 140°F followed by performance testing. The following equipment was tested: ball float vent valve, monitoring probe cap, overfill prevention valve, replacement drain valve kit (used to drain spill container after an overfill during delivery), swivel product adaptor, and swivel vapor adaptor. The report states that most of the equipment performed well during testing. All ball float vent valves, monitoring probe caps, and replacement drain valve kits passed. Two of three overfill prevention valves passed; the failing product was stuck in the OFF position during performance testing. Swivel product adaptor results were mixed, with one product failing on E10 and passing on aggressive E17 while the other product failed on both fuels. Swivel vapor adaptors did not perform well either with one failing on both test fluids and a second product failing on the E17 test fluid. The adaptor failures happened during performance testing due to leaks in sealing materials. Most manufacturers have upgraded sealing materials in the past few years after this test was performed to address the introduction of more ethanol and ULSD into the market.

The subject of older pipe dopes/sealants and their compatibility with ethanol fuels came up in the course of the original E15 infrastructure work performed by U.S. Department of Energy national laboratories. Pipe dope, also referred to as pipe thread sealant, is a sealing product used to make pipe thread joints leak proof and pressure tight. Refueling equipment with threaded ends is designed to achieve a tight fit during proper assembly but it is a regular practice to use pipe dope in some instances. Appendix G is a diagram of where pipe dope might be used in a refueling system. Jobbers who install, fix, and replace equipment at stations always have a jar of pipe dope available for use and the two main brands are RectorSeal and Gasoila. Gasoila's pipe thread sealants have used the same formula for decades and are compatible with ethanol blends up to 20%.[13] RectorSeal No.5 is their best selling product for use at refueling station and the manufacturer said it has long been compatible with ethanol blends including E15.[14]

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[13] Gasoila pipe thread sealants are compatible with up to 20% ethanol. Blends above E20 need to use their Gasoila E-Seal product. http://www.gasoila.com/products/pipe-thread-sealants.html

[14] RectorSeal's Pipe Thread Sealant Chart shows No.5 as compatible with gasohol (10%), however, NREL spoke with their technical staff who said it is compatible with E15.

5 Conclusions

This study found that significant changes to safety testing standards have incorporated fuel blends with more than 10% volume ethanol. This has led to many refueling equipment products compatible with E15. A station owner can compare its equipment records against the compatibility list in the appendices of this report to determine if there is a need to update or upgrade any equipment to sell E15. The majority of tanks are compatible as existing pipe manufacturers have had listing for E100 for many years, UL-listed E25 dispensers and retrofit kits are available, as is hanging hardware (a combination of E25 and E85 UL-listed equipment). Many manufacturers' models, as well as other UST equipment including fill equipment, leak detection, overfill prevention, and containment, are compatible with E15.

A literature review was conducted to determine if there were any negative impacts during the multi-year deployment of E10 nationwide. No incidents of E10 causing releases were identified, and no infrastructure industry experts suggested that there were widespread issues with E10.

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Appendix A. EPA OUST Release Data

2009 release data from 47 states:

			Cause													
Source	**Total**		**Spill**		**Overfill**		**Phys/Mech Damag**		**Corrosion**		**Install Problem**		**Other**		**Unknown**	
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#	%
Tank	1616	31.3%	37	19.0%	59	24.0%	179	23.3%	321	83.2%	9	16.7%	157	33.7%	854	28.0%
Piping	720	13.9%	9	4.6%	6	2.4%	190	24.7%	48	12.4%	25	46.3%	43	9.2%	399	13.1%
Dispenser	655	12.7%	38	19.5%	31	12.6%	160	20.8%	8	2.1%	9	16.7%	49	10.5%	360	11.8%
STP	76	1.5%	4	2.1%	2	0.8%	36	4.7%	1	0.3%	5	9.3%	9	1.9%	19	0.6%
Delivery Problem	342	6.6%	92	47.2%	121	49.2%	100	13.0%	0	0.0%	1	1.9%	14	3.0%	14	0.5%
Other	564	10.9%	14	7.2%	6	2.4%	97	12.6%	6	1.6%	4	7.4%	171	36.7%	266	8.7%
Unknown	1195	23.1%	1	0.5%	21	8.5%	8	1.0%	2	0.5%	1	1.9%	23	4.9%	1139	37.3%
Totals	5168		195		246		770		386		54		466		3051	

Source: Eighmey, C. LUSTLine Bulletin #67. March 2011

Appendix B. Aboveground Compatibility

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?
Franklin Fueling	Shear valve	662 models (UL listing for #662502902)	E85	yes	yes
Franklin Fueling	Submersible turbine pump	FE Petro STPAG, IST	E85	yes	yes
Gilbarco	Dispenser, Retofit Kit	E25 option on any dispenser; E25 retrofit kit	E25	yes	yes
Gilbarco	Dispenser	Encore Flex Fuel	E85	yes	yes
EMCO Wheaton	Breakaway	A2119, A2219, A3019, A3219, A4119EVR	E15	yes	no
EMCO Wheaton	Breakaway	A4119-020E	E85	no	
EMCO Wheaton	Hose	all	E15	yes	no
EMCO Wheaton	Nozzle	A4005-002, A4005-004, A4015-002, A4015-004	E15	yes	no
EMCO Wheaton	Nozzle-balance vapor recov	A4005-002E, A4015-002E	E85	yes	no
EMCO Wheaton	Swivel	A0360 (not listed), A4110EVR (UL listing)	E15	yes	no
Husky	Nozzle	X E25, X E25, XSE25	E25	yes	yes
Husky	Nozzle	X E85, X E85 Cold Weather, XS E85, XS E85 Cold Weather	E85	yes	yes
IRPCO	Hose-dispenser	Steelflex Ultra Hardwall, Softwall (2 Braid, 4SP), Marina	E15	yes	no
OPW	Breakaway	66V-0300	E25	yes	yes
OPW	Breakaway	66V-0492	E85	yes	yes
OPW	Nozzle	21GE, 21GE-A	E85	yes	yes
OPW	Swivel	241TPS-0492	E85		
OPW	Swivel	241TPS-0241, 241TPS-1000, 241TPW-0492	E25	yes	yes
OPW	Shear valve	10P-0142E85, 10-P-4152E85	E85	yes	yes
Veeder-Root	Submersible turbine pump	Redjacket, Redjacket AG,	E100	yes	no
Veyance	Hose	Flexsteel Futura Ethan-all	E85	yes	yes
Veyance	Hose	Flexsteel Futura	E15	yes	no
Wayne	Dispenser	E25 option on any dispenser; E25 retrofit kit	E25	yes	yes
Wayne	Dispenser	Ovation E85, Helix E85	E85	yes	yes

For compatibility of older dispensers with E85, please refer to: DOE Clean Cities. *Handbook for Handling, Storing, and Dispensing E85 and Other Ethanol-Gasoline Blends*. September 2013. http://www.afdc.energy.gov/uploads/publication/ethanol_handbook.pdf

Appendix C. Tank Compatibility

Tank Manufactuer Compability with Ethanol Blends	
Manufacturer	**Compatibility Statement with Ethanol Blends**
FIBERGLASS[1]	
Containment Solutions	Tanks manufactured after January 1, 1995 are all compatible with ethanol blends up to 100% (E100) (UL Listed)
Owens Corning	
Single Wall Tanks	Tanks manufactured between 1965 and 1994 are approved to store up to 10% ethanol (E10)
Double Wall Tanks	Tanks manufactured between 1965 and July 1, 1990 are approved to store up to 10% ethanol (E10) .
	Tanks manufactured between July 2, 1990 and December 31, 1994 were warranted to store any ethanol blend.
Xerxes	
Single Wall Tanks	Tanks manufactured prior to 1981 are not compatible with ethanol blends
	Tanks manufactured from February 1981 through June 2005 are designed for the storage of ethanol fuel up to a 10% blend (E10)
	Tanks manufactured from July 2005 to date are designed for the storage of ethanol fuel blends up to 100% (E100) (UL Listed)
Double Wall Tanks	Tanks manufactured prior to April 1990 were designed for the storage of ethanol fuel up to a 10% blend (E10)
	Tanks manufactured from April 1990 to date are designed for the storage of ethanol fuel blends up to 100% (E100) (UL Listed)
STEEL[2]	
Acterra Group Inc.	Compatible with all blends up to 100% (E100)
Caribbean Tank Technologies Inc.	Compatible with all blends up to 100% (E100)
Eaton Sales & Service LLC	Compatible with all blends up to 100% (E100)
General Industries	Compatible with all blends up to 100% (E100)
Greer Steel, Inc.	Compatible with all blends up to 100% (E100)
Hall Tank Co.	Compatible with all blends up to 100% (E100)
Hamilton Tanks	Compatible with all blends up to 100% (E100)
Highland Tank	Compatible with all blends up to 100% (E100)
J.L. Houston Co.	Compatible with all blends up to 100% (E100)
Kennedy Tank and Manufacturing Co.	Compatible with all blends up to 100% (E100)
Lancaster Tanks and Steel Products	Compatible with all blends up to 100% (E100)
Lannon Tank Corporation	Compatible with all blends up to 100% (E100)
Mass Tank Sales Corp.	Compatible with all blends up to 100% (E100)
Metal Products Company	Compatible with all blends up to 100% (E100)
Mid-South Steel Products, Inc	Compatible with all blends up to 100% (E100)
Modern Welding Company	Compatible with all blends up to 100% (E100)
Newberry Tanks & Equipment, LLC	Compatible with all blends up to 100% (E100)
Plasteel[1]	Compatible with all blends up to 100% (E100)
Service Welding & Machine Company	Compatible with all blends up to 100% (E100)
Southern Tank & Manufacturing Co., Inc.	Compatible with all blends up to 100% (E100)
Stanwade Metal Products	Compatible with all blends up to 100% (E100)
Talleres Industriales Potosinos	Compatible with all blends up to 100% (E100)
Tanques Antillanos C. x A.	Compatible with all blends up to 100% (E100)
Watco Tanks, Inc.	Compatible with all blends up to 100% (E100)
We-Mac Manufacturing Company	Compatible with all blends up to 100% (E100)
Letters stating compability 1 PEI http://www.pei.org/PublicationsResources/ComplianceFunding/USTComponentCompatibilityLibrary/tabid/882/Default.aspx 2 STI http://www.steeltank.com/Publications/E85BioDieselandAlternativeFuels/ManufacturerStatementsofCompatibility/tabid/468/Default.aspx	

Appendix D. Pipe Compatibility

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?
Advantage Earth Products	Pipe	1.5", 2", 3", 4"	E100	yes	yes
Brugg Pipesystems	Pipe	FLEXWELL-HL, SECON-X, NIROFLEX, LPG	E100	yes	yes
Franklin Fueling	Pipe	XP, UPP	E100	yes	yes
Franklin Fueling	Pipe ducting	APT, UPP	E100	yes	yes
Franklin Fueling	Pipe fittings	XP stainless steel (ELB-XP-150, ELB-XP-175, ELB-XP-200, GSHP-150, GSHP-200, MS-XP-150-150SS, MS-XP-175-200SS, MS-XP-200-200SS, MS-100-100SS, MS-XP-150-150, MS-XP-SW-175-200, MS-XP-SW-200-200, QRS-XP-150-200, QRS-XP-175-200, QRS-XP-200-200, SSC-150, SSC-200, SSE90-150, SSE90-200, SSE90-150, SST-150, SST-200, SSU-150, SSSHP-150, TEE-XP-150, TEE-XP-175, TEE-XP-200) UPP stainless fittings	E85	yes	yes
NOV Fiberglass	Red Thread IIA	fiberglass	E100	yes	yes
NUPI	Smartflex	flexible plastic	E100	yes	yes
OMEGAFLEX	DoubleTrac	flexible plastic (must use stainless steel fittings)	E100	yes	yes
OPW	Pipe	FlexWorks, Pisces (discontinued)	E100	yes	yes
OPW	Pipe adaptors, couplers, fittings	FlexWorks	E100	yes	yes

Appendix E. Other UST Equipment Compatibility

Note: “UN” in the E% column indicates the manufacturer does not know if it is compatible with ethanol blends. ? = waiting on information from OEM

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Clay and Bailey	AST anti-siphon valve	405	E10	no		
Clay and Bailey	AST manhole	API-650	E85	no		
Clay and Bailey	AST alarm	1400	E10	no		
Clay and Bailey	AST overfill prevention valve	1228	E85	yes	no	
Clay and Bailey	AST pressure vacuum vent	88	E10	no		
Clay and Bailey	AST spill containment	all	E85	no		
Clay and Bailey	AST emergency vent	354, 365, 366, 367, 368, 369, 370	E85	yes	no	
Clay and Bailey	Manhoes	all	E10	no		
Clay and Bailey	Ball valve	736	E10	no		
Clay and Bailey	Fill cap	94, 232, 233, 234, 235, 254	E85	no		
Clay and Bailey	Vent-upflow	395	E10	no		
Cimtek	Filter	300, 400, 450, 475	E15	yes	no	
Cimtek	Filter	800	E85	yes	no	
EMCO Wheaton	Nozzle-balance vapor recovery	A4005-002E, A4015-002E	E85	yes	no	CARB EVR
EMCO Wheaton	Nozzle-balance vapor recovery	A4005-002, A4005-004, A4015-002, A4015-004	E15	yes	no	CARB EVR
EMCO Wheaton	Breakaway	A4119-020E	E85	no		
EMCO Wheaton	Breakaway	A2119, A2219, A3019, A3219, A4119EVR	E15	yes	no	CARB EVR (A4119 only)
EMCO Wheaton	Swivel	A0360, A4110EVR	E15	yes (EVR only)	no	CARB EVR (A4110 only)
EMCO Wheaton	Hose	all	E15	yes	no	
EMCO Wheaton	Adaptors	A0030, A0030-142, A0076, A0076-142S A0089, A0096,	E15	no		CARB EVR (both A0030 and A0076)
EMCO Wheaton	Ball float	A0075E, A0078E	E85	no		CARB EVR (A0078)
EMCO Wheaton	Ball float	A0075, A0078	E15	no		CARB EVR (A0078)
EMCO Wheaton	Caps	A0097-005, A0097-004LP, A0097-010, A0099-002, A0099-004LP	E15	no		CARB EVR (A0097-005, A0099-02)
EMCO Wheaton	Drop tube	A0020-004E, A0020-005E, A0020-007E	E15	no		CARB EVR (A0020, A0088)
EMCO Wheaton	Drop tube	A0020-004, A0020-005, A0020-007, A0020-008, A0020-021, A0020-133, A0020-144, A0070, A0088	E15	no		CARB EVR (A0020, A0088)
EMCO Wheaton	Extractor fittings	A0079	E85	yes	no	CARB EVR
EMCO Wheaton	Overfill prevention valve	A1100-010E, A1100-056SE, A1100-055SERF, A1100-056SERF, A1100EVR-057E, A1100-067E, A1100-087E	E85	no		CARB EVR
EMCO Wheaton	Overfill prevention valve	A1100-010, A1100-011, A1100-054S, A1100-054SC, A1100-054SCN, A1100-055SRF, A1100-056SRF, A1100-053S, A1100-055S, A1100EVR-055, A1100-056S, A1100EVR-056, A1100-057S, A1100EVR-057, A1100-058S, A1100EVR-058, A1100-065S, A1100-066S, A1100-067S, A1100-085S, A1100-087S, A1100-087S	E15	no		CARB EVR (only models with EVR in model no.)
EMCO Wheaton	Ball valve	A0750	E15	no		
EMCO Wheaton	Check valve	A0066, A0732	E15	no		
EMCO Wheaton	Shear valve	A0060 with stainless steel body	E85	yes	no	
EMCO Wheaton	Shear valve	A0060 with cast iron body, A0063	E15	yes	no	
EMCO Wheaton	Vent	A0084, A0085, A4103, A0785	E15	yes (A4103 only)	no	
Husky	Pressure vacuum vents	4620, 4885, 5885, 8060	E85	yes	yes	

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?	Other Approval
STP Equipment						
Franklin Fueling	Mechanical line leak detector	MLD+AG	E85	yes	?	
Franklin Fueling	Mechanical line leak detector	STP-MLD	E10	yes	yes	
Franklin Fueling	Shear valve (emergency shear	662 models	E85	yes (662502902)	yes	
Franklin Fueling	Shear valve-vapor	362 models	UN	no		
Franklin Fueling	Submersible pump controller	MagVFC IST,	E85	yes		
Franklin Fueling	Submersible turbine pump	STP	E10	yes	yes	
Franklin Fueling	Submersible turbine pump	FE Petro STPAG, IST	E85	yes	yes	
Fill Equipment						
Franklin Fueling	Ball float vent valve	308 models	E85	no		EVR CARB
Franklin Fueling	Drop tube	306 and 708 models, 782-204-30-2, 782-204-32-2, 782-202-12, 782-203-12, 782-204-10-2, 782-204-12-2, 782-204-15-2	E85	no		
Franklin Fueling	Extractor vent valve (tee)	300 series models	E85	no		
Franklin Fueling	Fill adaptor-side	776-300-01, 776-300-31	E85	no		
Franklin Fueling	Fill adaptor-swivel	SWF-100-SS, SWFV-PKGSS	E85	no		EVR CARB
Franklin Fueling	Fill adaptor-swivel	SWFV-PKG, 705-412-01, 705-412-02	E85	no		
Franklin Fueling	Fill adaptor-top	778-301-05	E85	no		EVR CARB
Franklin Fueling	Fill adaptor-top	776-300-01, 776-300-31, 778-301-01, 778-301-02, 778-301-06, 778-301-32, 778-301-01, 778-302-31, 778-303-02, 778-303-32, 780-200-01	E85	no		
Franklin Fueling	Fill cap-side	775 series	E85	no		
Franklin Fueling	Fill cap-top	777-201-02	E85	no		EVR CARB
Franklin Fueling	Fill cap-top	777-202-01, 777-202-02, 779-200-01, 774-202-03	E85	no		
Franklin Fueling	Vapor cap	304-301-03	E85	no		EVR CARB
Franklin Fueling	Vapor cap	304-200-01, 304-200-02, 304-301-01, 304-301-02	E10	no		EVR CARB (301-01 only)
Franklin Fueling	Vapor pipe adaptor	SWV-101-SS, SWFV-PKGSS	E85	no		EVR CARB
Franklin Fueling	Vapor pipe adaptor	SWV-101-B, SWFV-PKG, 705-413-01, 705-413-02	E10	no		
Franklin Fueling	Vapor recovery adaptor	306 and 708 models	E85	no		
Franklin Fueling	Overfill prevention valve	708-491-31, 708-491-32, 708-492-21, 708-492-22, 708-492-31, 708-492-32, 708-498-11	E85	yes	?	EVR CARB (ending in 11 or 12)
Franklin Fueling	Overfill prevention valve	708-491-01, 708-491-02, 708-491-11, 708-491-12, 708, 491-21, 708-492-01, 708-492-02, 708-498-11, 708-493-03, 708-493-04, 708-493-23, 708-493-24, 708-340-901, 708-494-02, 708-494-03, 708-494-04, 708-498-01, 708-498-02, 708-498-03	E10	yes	?	EVR CARB
Franklin Fueling	Probe cap and adaptor kit	90037-E	E85	no		EVR CARB
Franklin Fueling	Spill container (bucket)	702, 703, 705, 715	E10	yes (705 and 715 models only)		yes (705 and 715 models only)
Franklin Fueling	Spill container (bucket)	Phil-Tite series, Defender Series	E85	yes	?	EVR CARB
Franklin Fueling	Tank bottom protector	TBP-3516-E	E85	no		
Franklin Fueling	Tank bottom protector	785-200-02	E10	no		
Franklin Fueling	Vent valve (pressure/vacuum)	PV-ZERO models	E85	yes	?	EVR CARB

Manufacturer	Product	Model	E%	UL listed	UL listed for this fuel?	Other Approval
UST Equipment						
Franklin Fueling	API adaptor	880-500-04	E85	no		
Franklin Fueling	Automatic tank gauge	TSP	E10	yes	yes	
Franklin Fueling	Ball valve (for pipe)	FLEX-ING	E85	yes	no	CSA
Franklin Fueling	Check valve	622-300-01, 65, 515, 516, 615, 635, 650	E10	no		
Franklin Fueling	Dispensing cutoff system	DC400	E10	no		
Franklin Fueling	Flexible connectors	FLEX-ING	E10			
Franklin Fueling	Flexible connectors	FIREFLEX	E85	yes	no	
Franklin Fueling	Float kit	TSP-IGF4P	E15	no		
Franklin Fueling	Float kit	TSP-IGF4D3, TSP-IGF4D	E85	no		
Franklin Fueling	Foot valve	50-201, 320	E10	no		
Franklin Fueling	Interstitial sensor	TSP-HIS, TSP-DIS, TSP-EIS, TSP-HFS	E85	no		
Franklin Fueling	Level sensor	TSP-HLS	E85	no		
Franklin Fueling	Magnostrictive probe	Moorman	E85	no		
Franklin Fueling	Manhole	14U, 20UR, 780, 781, 789, 808, 810, 814, 987, Defender, SSQ, SR series	E10	no		
Franklin Fueling	Monitoring test well	772, 773, 808, 810	E10	no		
Franklin Fueling	Monitoring well cap	TSP-KW4	E10	no		
Franklin Fueling	Monitoring well sensor	TSP-MWS	E0	no		
Franklin Fueling	Probe installation kit	FFS	E10	no		
Franklin Fueling	Pipe fittings	GC-150, GC-200, GE90-150, GE90-200, GE90-215, GE90-252, GHB-200-150, GT-150, GT-200, GT-215, GT-252, GU-150, GU-200, GHB-200-150, GSHP-150, GSHP-200, XP brass (MS-XP-150-150, MS-XP-175-200, MS-XP-200-200	E10	yes	yes	
Franklin Fueling	Sumps	2400, 4542 (UL), 4736, APT, AST, LM, TS, UPP (UL) models	E85	yes	no	
Franklin Fueling	Sump accessories, fittings, boots	APT	E85	yes	no	
Above-ground Equipment						
Franklin Fueling	Nozzle	400, 600, 708, 709, 800, 900 series (all vapor recovery II)	E10	no		EVR CARB (400, 600, 900)
Franklin Fueling	Breakaway	697, 698, ACCUBREAK, SAFETY-SEVER	E10	yes	yes	
Franklin Fueling	Hoses	FLEX-ING	E10	no		
Franklin Fueling	Hoses	FLEX-ON	E15	yes	no	
Franklin Fueling	Swivel	465	E10	no		
Franklin Fueling	Swivel	FLEX-ING multi-plane	E10	no		
AST Equipment						
Franklin Fueling	Anti-siphon valve	636-300-11, 636-300-12	E85	no		
Franklin Fueling	Anti-siphon valve	605-300-01, 606-300-01, 616-300-01, 616-300-02, 616-300-03	E10	no		API/RP 2000
Franklin Fueling	AST emergency vent	803	E10	yes		
Franklin Fueling	AST fill cap	751, 770	E10	no		
Franklin Fueling	AST overfill prevention valve	709	E10	no		
Franklin Fueling	AST Pressure regulator valve	620, 621, 622, 644	E10	yes		API/RP 2000
Franklin Fueling	AST pressure vacuum vent	802	E10	no		
Franklin Fueling	AST spill container (bucket)	706	E10	no		
Franklin Fueling	AST tank vent	800	E10	no		

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Morrison Bros	Adaptor-coaxial	605	UN	no		
Morrison Bros	Anodized Farm Nozzle	200S	E85	no		
Morrison Bros	Anti-Syphon Valve	912	E85	no		
Morrison Bros	AST adaptor	927	E85	no		EVR CARBa (some)
Morrison Bros	AST adaptor	926, 927B	UN	no		
Morrison Bros	AST clock gauge	818, 818C, 818F, 818MET, 818MEF, 918F, 918FT, 918MEF, 918MET, 918T, 1018GM, 8181	UN	no		EVR CARBa (some)
Morrison Bros	Ball Valves	691BSS	E85	no		
Morrison Bros	Cap relief	779	UN	no		
Morrison Bros	Caps	305C	E85	no		EVR CARBa (some)
Morrison Bros	Caps-monitoring well	305XP, 305XPU	UN	yes (XPU)		EVR CARBa (some)
Morrison Bros	Cap-test well	178XAT, 178XB, 178XA, 305XA, 678XA	UN	no		
Morrison Bros	Clock Gauge with Alarm	918	E85	no		
Morrison Bros	Clock Gauges	818	E85	no		
Morrison Bros	Combination Vent/Overfill Alarm	922	E85	no		
Morrison Bros	Diffuser	539TO, 539TC	E85	no		EVR CARBa (some)
Morrison Bros	Diffuser	539, 539EXT, 539TC, 539TO	UN	no		EVR CARBa (some)
Morrison Bros	Double Tap Bushing	184	E85	no		
Morrison Bros	Drop Tubes	419A	E85	no		
Morrison Bros	Drop tubes	275, 419, 419SOS	UN	no		EVR CARBa (some)
Morrison Bros	Emergency Vents	244	E85	yes	yes	EVR CARBa (some)
Morrison Bros	Expansion Relief Valve	076DI, 078DI	E85	no		
Morrison Bros	External Emergency Valves	346DI, 346FDI, 346SS, 346FSS	E85	no		
Morrison Bros	Extractor pipe cap	578, 578P	UN	no		
Morrison Bros	Extractors	560/561/562/563	E85	no		
Morrison Bros	Fill cap	178, 178DT, 179, 179CI, 179M, 179MCI, 180M, 305CU, 379, 405C	UN	no		EVR CARBa (some)
Morrison Bros	Fill cap and adaptor	307	UN	no		
Morrison Bros	Fill swivel adaptor	305SA	UN	no		
Morrison Bros	Flame Arrester	351S	E85	no		
Morrison Bros	Float Vent Valves	317	E85	no		
Morrison Bros	Frost Proof Drain Valve	128DIS	E85	no		
Morrison Bros	Indicator paste	490G, 490W, SAR-GEL	UN	no		
Morrison Bros	In-Line Check Valve	958	E85	no		
Morrison Bros	Internal Emergency Valves	272DI, 72HDI	E85	no		
Morrison Bros	Interstitial sensor	918TCPS, 924LS	UN	no		
Morrison Bros	Manholes	318, 318L, 318TM, 318VR, 318XA, 418, 418L, 418TM, 418XA, 418XAP, 418XAH, 418XAW, 418LC, 424, 519, 524, 524H	UN	no		

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Morrison Bros	Mechanical gauge	1018GM	UN	no		
Morrison Bros	Overfill Alarm	918TCP	E85	no		
Morrison Bros	Overfill Prevention Valve	9095A-AV, 9095SS	E85	no		
Morrison Bros	Overfill Prevention Valve	9095AA, 9095GBT	E85	no		
Morrison Bros	Pressure Vacuum Vent	948A	E85	yes	yes	
Morrison Bros	Probe cap and adaptor	307P	UN	no		
Morrison Bros	Solenoid Valves (3" Must be all Teflon version)	710SS	E85	no		
Morrison Bros	Spill Containers	515/516/517/518	E85	no		EVR CARBa (516)
Morrison Bros	Strainer	285	E85	no		
Morrison Bros	Strainer	284B, 284S, 285AL, 285DI, 285FDI, 286, 286FDI, 286U	UN	no		
Morrison Bros	Swing Check Valves	246ADI, 246DRF	E85	no		
Morrison Bros	Tank gauge	618	UN	no		
Morrison Bros	Tank Monitor Adaptor and Cap	305XPA	E85	no		
Morrison Bros	Vapor Recovery Adaptor	323	E85	no		EVR CARBa
Morrison Bros	Vapor Recovery Caps	323C	E85	no		
Morrison Bros	Vent-double outlet (small UST)	155	E85	no		
Morrison Bros	Vent-double outlet (small UST)	155S, 155FA	UN	no		
Morrison Bros	Vent-pressure vacuum	548, 748, 749	E85	no		
Morrison Bros	Vent-updraft	354	E85	no		
Morrison Bros	Vent-updraft	354T	UN	no		
Morrison Bros		571, 571P	UN	no		
National Environmental Fiberglass	Sumps-tank	All	E85	yes	no	EVR CARB
National Environmental Fiberglass	Sumps-transition	All	E85	yes	no	EVR CARB
National Environmental Fiberglass	Sumps-dispenser	All	E85	yes	no	EVR CARB

Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Above Ground Equipment						
OPW	Balance Adaptor	28CS	E25	no		
OPW	Breakaway	66V-0492	E85	yes	yes	
OPW	Breakaway	66V-030RF	E25	yes	yes	
OPW	Breakaway	66V-0300, 66RB-2000, 68EZR-7575, 66REC-1000, 66SB-7575, 66SB-1010, 66CAS-0300, 66ISU-5100, 66ISB-5100, MFVA, 66CLP-5100, 66CSU-5200	E10	yes	yes	
OPW	nozzle	21GE-0992	E85	yes	yes	
OPW	Nozzle	11AP-0100-E25, 11AP-0300-E25, 11AP-0400-E25, 11AP-0900-E25, 11BP-0100-E25, 11BP-0300-E25, 11BP-0400-E25, 11BP-0900-E25	E25	yes	yes	
OPW	Nozzle	11AP / 11BP Series	E10	yes	yes	
OPW	Swivel	241TPS-75RF	E25	yes	yes	
OPW	Swivel	36S series, 241TPS series, 20S series, 45 series	E10	yes	yes	
OPW	Swivel	241TPS-0492	E85	yes	yes	
OPW	Emergency shear valve	10 series	E100	yes	no	
OPW	Vapor shear valve	60VS	E100	yes	no	EVR CARBa
AST Equipment						
OPW	AST anti-siphon valve	199ASV	E85	yes	no	
OPW	AST ball valve	21BV SS	E85	yes	no	
OPW	AST check valve	175, 1175	E85	no	no	
OPW	Drop tube	61FT	E25	no	no	EVR CARBa
OPW	AST emergency shut off valve	178S	E85	no	no	
OPW	AST emergency vent	201, 202	E85	yes	no	
OPW	AST emergency vent	301	E86	yes	no	EVR CARBa
OPW	AST mechanical gauge	200TG	E85	yes	no	EVR CARBa
OPW	AST overfill prevention valve	61fSTOP A or M versions	E85	yes	no	EVR CARBa
OPW	AST overfill prevention valve	61ƒSTOP	E25	yes	no	
OPW	AST pressure vacuum vent	523V, 623V	E100	yes	no	
OPW	AST solenoid valve	821	E25	yes	no	
OPW	AST spill container	211-RMOT, 331, 332	E85	yes (uld	no	EVR CARBa
OPW	AST swing check valve	all	E85	no	no	
OPW	AST tank alarm	444TA	E85	no (ETL	no	
OPW	AST vapor adaptor	1611AVB-1625	E85	no		
OPW	AST vapor cap	1711T-7085-EVR, 1711LPC-0300	E85	no		

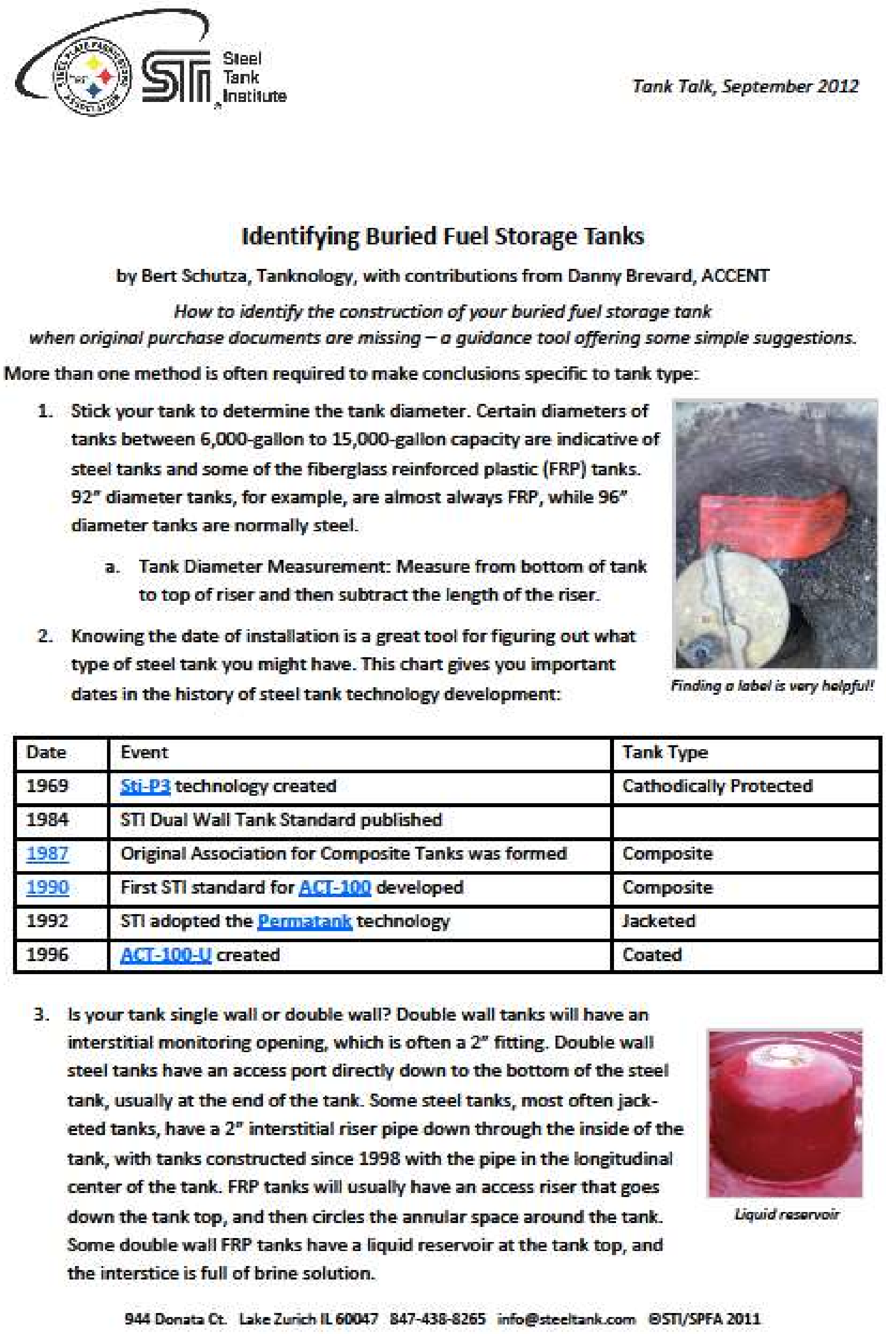
Company	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
UST Equipment						
Caps and adaptors						
OPW	Fill adaptor-top	633T, 633TC	?	yes	no	
OPW	Fill-swivel adaptor	61SALP-MA, 61SALP-1020-EVR	E85	yes	no	CARB EVR
OPW	Vapor swivel adaptor	61VSA	?	yes	no	CARB EVRa
OPW	Fill-swivel adaptor (vapor)	61VSA-MA, 61VSA-1020-EVR	E85	yes	no	CARB EVR
OPW	Fill cap-side	62TT	?	yes	no	
OPW	Fill adaptor-side	61AS	?	yes	no	
OPW	Vapor adaptor	1611AV, 1611AVB	E100	yes	no	CARB EVR
OPW	Vapor Cap	1711T	E85	yes	no	CARB EVR
OPW	Monitoring well probe cap	62M, 116M	E100	yes	no	
OPW	Monitoring well probe cap	62M-MA	E85	yes	no	CARB EVR
OPW	Monitoring well cap kit	634TTM, 62PMC	?	yes	no	
OPW	Monitoring test well	61SPVC	?	no		
Extractors, Manholes, Multi-ports						
OPW	Extractor fittings and plug	233, 233VP	E85	no		CARB EVR
OPW	Multi-port spill containment	411, 511, 521, Fiberlite,	E100	no		CARB EVR
OPW	Jack screw	71JSK	E85	no		
OPW	Jack screw	61JSK	?	no		
OPW	Face seal adaptor (threaded riser adaptor)	FSA-400	?	no		CARB EVR
OPW	Manhole	Conquistador, Fiberlite, 104AOW-1200, 104C,	?	no		
Overfill Prevention						
OPW	Overfill prevention valve	61SOM-412C-EVR, 61SOCM-4000, 71SO, 71SO-T, 71SOM	E85	no		CARB EVR
OPW	Overfill prevention valve	61SOC-4001, 61SOC-4011, 61SOP-4002, 61SOP-4012	E10	no		
OPW	Float kit	61SOK-0001	E10	no		
OPW	Ball float vent valve	21BV, 53VML, 30MV	E85	no		
OPW	Drop tube	61T, 61TC, 61TCP	E10	no		
OPW	Drop tube	61TSS	E85	no		CARB EVR
OPW	Spill container (bucket)	1-2100, 1SC-2100, EDGE	E100	yes	no	CARB EVRa
OPW	Spill container (bucket)	1-2105, 1-2200, 101-BG2100	E100	yes	no	
OPW	Tank bottom protectors	6111, 61TP	E10	no		
Check Valve, Flexible Connectors, Vents						
OPW	Flexible connectors	All	E100	yes	no	SA
OPW	Check valve	70, 70S	E85	yes	no	
OPW	Pressure vacuum vent	523V, 623V	E85	yes	no	
OPW	Pressure vacuum vent	23	?	yes		
OPW	Vent	514, 515	?	?		
Sumps						
OPW	Dispenser sumps	FlexWorks	E85	yes	no	
OPW	Tank sumps	Fiberlite, FlexWorks	E85	yes	no	
OPW	Transition sumps	FlexWorks	E85	yes	no	
OPW	Sump accessories	FlexWorks	E85	yes	no	

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Petroleum Containment	Sump-dispenser	CLE, DCL, EZ-PLUMB, MVR	?	no		
Petroleum Containment	Sump-tank	4200	E100	no		
Petroleum Containment	Sump-transition	all	?	no		
Pneumercator	Magnetostrictive probe	MP450S, MP451S, MP452S, MP461S, MP462S, MP463S, MP464S MP550S, MP551S, MP552S, MP561S, MP562S, MP563S, MP564S	E100	yes	no	
Pneumercator	Leak sensors	ES825-100F, ES825-100XF,ES825-100CF, ES825-200F, ES825-200XF ES825-300F, ES825-300XF,ES825-300CF, ES825-400F, ES825-400XF HS100D, HS100ND LS600LD, LS600S, LS610 RSU800-2, RSU801F, RSU810	E100	yes	no	
Pneumercator	Single/Multi-Point Level Sensors	LS600, LS600F4, LS600M, LS600W, LS600X	E100	yes	no	
Pneumercator	Mechanical Gauges	DR-1-10, P5, P14	E100	no	no	
S. Bravo Systems	Fiberglass Fittings	Series F, FF, FPE, FR, Retrofit-S, D-BLR-S, D-INR-S, FLX, FLX-INR, FPS, TBF	E100	yes	no	
S. Bravo Systems	Spill Buckets	B3XX	E100	yes	no	
S. Bravo Systems	Tank Sumps & Covers	B4XX	E100	yes	no	
S. Bravo Systems	Transition Sumps	B5XX, B6XX, B7XX, B8XX	E100	yes	no	
S. Bravo Systems	Under Dispenser Containment Sumps	B1XXX, 7XXX, B8XXX, B9XXX	E100	yes	no	
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 without stainless steel tubing/fittings	E20	yes	no	
Vaporless Manufacturing	Leak detector	99LD-2000/2200/3000 with stainless steel tubing/fittings	E100	yes	no	
Vaporless Manufacturing	Overfill prevention valve	OPF-2/3 without stainless steeltubing/fittings	E20	yes	no	
Vaporless Manufacturing	Overfill prevention valve	OPF-2/3 with stainless steel tubing/fittings	E100	yes	no	

Manufacturer	Product	Model	E%	UL Listed	UL listed for this fuel	Other Approval
Veeder-Root	AST probe	Mag-FLEX	E15	yes	no	
Veeder-Root	Float kit	846400	E15	yes	no	
Veeder-Root	Magnostrictive probes	Mag Plus Probe for Alternative Fluids with Water Detection P/N 846391-1xx or -2xx, Inventory Only Mag Plus Probe for Alternative Fluids with Water Detection P/N 846391-3xx	E20	yes	no	
Veeder-Root	Magnostrictive probes	Mag Plus Probe for Alternative Fluids without Water Detection P/N 846391-4xx or -5xx, Mag Plus Probe for Alternative Fluids without Water Detection P/N 846391-6xx	E100	yes	no	
Veeder-Root	Magnostrictive probes	Mag-D Density Probe, MagPlus Leak Detection Probe, MagPlus Inventory Measuremeant Probe	E15	yes	no	
Veeder-Root	Mechanical line leak detect	Red Jacket FXV	E100	yes	no	
Veeder-Root	Phase separation float	Phase-2	E15	yes	no	
Veeder-Root	Sensor-dispenser and sump	Discriminating and Non Discriminating Dispenser Pans and Containent Sensors, Sump sensor (piping), Mag Sump Sensor, Stand-alone Dispenser Pan Sensor	E15	yes	no	
Veeder-Root	Sensor-dispenser and sump	Position Sensitive Interstitial Sensor	E85	yes	no	
Veeder-Root	Sensor-groundwater	Groundwater Sensor	E15	yes	no	
Veeder-Root	Sensor-tank	Discriminating Interstitial Sensor Double Wall Fiberglass, Interstitial Sensors for Fiberglass Tanks, Intersitial Sensors for Steel Tanks	E15	yes	no	
Veeder-Root	Sensor-tank	Discriminating Interstitial Sensor Double Wall Fiberglass, Interstitial Sensors for Fiberglass Tanks-High Alcohol, Interstitsial Sensors for Steel Tanks-High Alcohol, MicroSensor (steel tanks, fill riser)	E85	yes	no	
Veeder-Root	Sensor-vapor	Vapor Sensor	E15	yes	no	
Western Fiberglass	Co-Flex piping	all	E100	yes	no	
Western Fiberglass	Cuff fittings	all	E100	no		
Western Fiberglass	Sumps (tank, dispenser, transition, vapor, vent)	all	E100	yes	no	
Western Fiberglass	Co-flow hydrostatic Monitoring systems	all	E100	no		

Appendix F. Methods to Identify Underground Storage Tanks

http://www.steeltank.com/Portals/0/TTNewsletter/September2012/TankTalk_September2012.pdf



Steel Tank Institute

Tank Talk, September 2012

Identifying Buried Fuel Storage Tanks

by Bert Schutza, Tanknology, with contributions from Danny Brevard, ACCENT

How to identify the construction of your buried fuel storage tank when original purchase documents are missing – a guidance tool offering some simple suggestions.

More than one method is often required to make conclusions specific to tank type:

1. Stick your tank to determine the tank diameter. Certain diameters of tanks between 6,000-gallon to 15,000-gallon capacity are indicative of steel tanks and some of the fiberglass reinforced plastic (FRP) tanks. 92" diameter tanks, for example, are almost always FRP, while 96" diameter tanks are normally steel.
    a. Tank Diameter Measurement: Measure from bottom of tank to top of riser and then subtract the length of the riser.
2. Knowing the date of installation is a great tool for figuring out what type of steel tank you might have. This chart gives you important dates in the history of steel tank technology development:

Finding a label is very helpful!

Date	Event	Tank Type
1969	Sti-P3 technology created	Cathodically Protected
1984	STI Dual Wall Tank Standard published	
1987	Original Association for Composite Tanks was formed	Composite
1990	First STI standard for ACT-100 developed	Composite
1992	STI adopted the Permatank technology	Jacketed
1996	ACT-100-U created	Coated

3. Is your tank single wall or double wall? Double wall tanks will have an interstitial monitoring opening, which is often a 2" fitting. Double wall steel tanks have an access port directly down to the bottom of the steel tank, usually at the end of the tank. Some steel tanks, most often jacketed tanks, have a 2" interstitial riser pipe down through the inside of the tank, with tanks constructed since 1998 with the pipe in the longitudinal center of the tank. FRP tanks will usually have an access riser that goes down the tank top, and then circles the annular space around the tank. Some double wall FRP tanks have a liquid reservoir at the tank top, and the interstice is full of brine solution.

Liquid reservoir

944 Donata Ct. Lake Zurich IL 60047 847-438-8265 info@steeltank.com ©STI/SPFA 2011

Appendix G. Pipe Dope Diagram

This diagram shows areas at a refueling station where pipe dope/pipe thread sealant might be used.

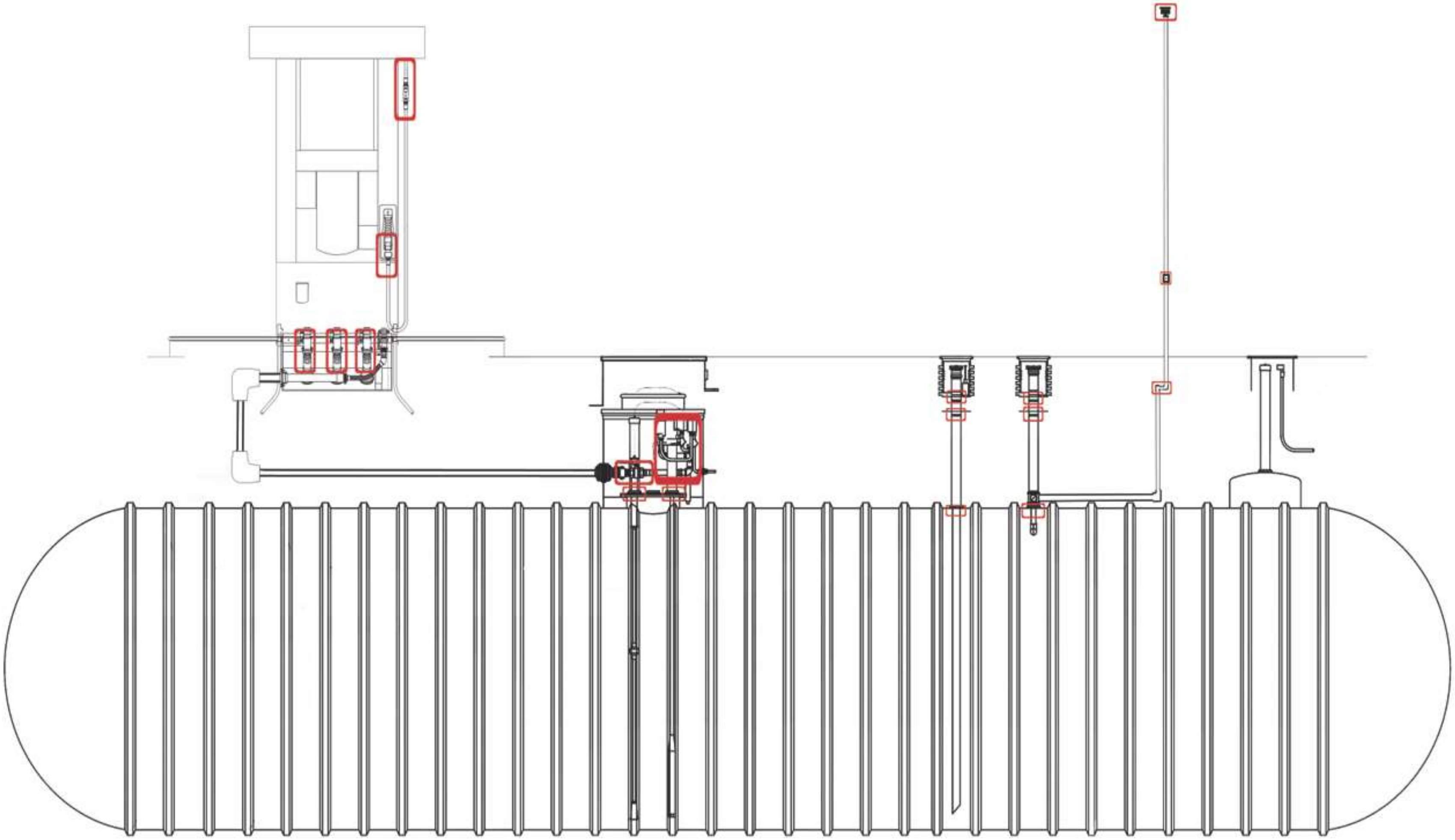


Diagram provided by Source North America, a fueling equipment distributor

Attachment 3

OAK RIDGE
NATIONAL LABORATORY
MANAGED BY UT-BATTELLE
FOR THE DEPARTMENT OF ENERGY

ORNL/TM-2012/182

Analysis of Underground Storage Tank System Materials to Increased Leak Potential Associated with E15 Fuel

July 2012

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ORNL/TM-2011/XXX

ANALYSIS OF UNDERGROUND STORAGE TANK SYSTEM MATERIALS TO INCREASED LEAK POTENTIAL ASSOCIATED WITH E15 FUEL

Michael D. Kass, Timothy J. Theiss, Christopher J. Janke, and Steve Pawel

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ACRONYMS

ASTM	American Society for Testing and Materials
DOE	Department of Energy
E10	Gasoline containing 10% ethanol by volume
E15	Gasoline containing 15% ethanol by volume
E50	Gasoline containing 50% ethanol by volume
E85	Gasoline containing 85% ethanol by volume
EISA	Energy Independence and Security Act
EPA	U. S. Environmental Protection Agency
F-HDPE	Fluorinated high density polyethylene
Fuel C	A gasoline representative test fuel composed of 50%vol. toluene and 50%vol. isooctane
FRP	Fiber-reinforced plastic
FFV	Flex-Fuel Vehicle
HDPE	High density polyethylene
HSP	Hansen Solubility Parameter
ISO	International Organization for Standardization
LG	Leaded gasoline
MIC	Microbial-induced corrosion
MTBE	Methyl tertiary butyl ether
NBR	Acrylonitrile (or nitrile) butadiene rubber
NREL	National Renewable Energy LaboratoryOBP DOE Office of Biomass Program
ORNL	Oak Ridge National Laboratory
PBT	polybutylene terephthalate
PEI	Petroleum Equipment Institute
PET	polyethylene terephthalate
PP	polypropylene
PTFE	polytetrafluoroethylene
PCV	polyvinyl chloride
PVDF	polyvinylidene fluoride
RFS	Renewable Fuel Standard
S	Siemens (unit of electrical conductivity)
SAE	Society of Automotive Engineers
SBR	Styrene butadiene rubber
UL	Underwriters Laboratories
UST	Underground Storage Tank
VS	Volume swell
VTP	DOE Vehicle Technologies Program

FOREWARD

It is not the purpose of this report to define the acceptable limits of material performance or to rate individual materials. Rather, the purpose of this study was to assess critical property changes (volume, hardness, mass, etc.) for representative classes of materials used in underground storage tank systems with exposure to E15.

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This report and the work described were sponsored by the United States Environmental Protection Agency Office of Underground Storage Tanks (EPA OUST). The authors gratefully acknowledge the support and editorial guidance of Andrea Barbery, Linda Gerber, Mark Barolo, and Paul Miller from the EPA OUST. This manuscript was greatly improved by the thorough reviews of Ed English of Fuel Quality Services, and Ken Boyce and Tom Chapin of Underwriters Laboratories. The authors are especially appreciative of their effort.

EXECUTIVE SUMMARY

E.1 Background

The Energy Independence and Security Act (EISA) of 2007 was an omnibus energy policy law designed to move the United States toward greater energy security and independence.[1] A key provision of EISA modified the Renewable Fuel Standard (RFS) which requires the nation to increase the volume of renewable fuel blended into transportation fuels from 7.5 billion gallons by 2012 to 36 billion gallons by 2022. Ethanol is the most widely used renewable fuel, and increasing the ethanol content in gasoline to 15% offers a means of getting significantly closer to the 36 billion gallon goal. In March 2009, Growth Energy (a coalition of ethanol producers and supporters) requested a waiver from the United States Environmental Protection Agency (EPA) to allow the use of 15% ethanol in gasoline.[2] In response the US EPA granted two partial waivers that allow (but do not require) E15 in 2001 and newer light-duty vehicles. Prior to the waiver being granted, uncertainties arose as to whether the additional fuel ethanol (from 10% to 15%), would cause an increase in leaking of underground storage tank (UST) systems, which include not only the tank but also the piping and connecting hardware.

The USEPA Office of Underground Storage Tanks was interested in determining how many (of the nearly 600 thousand) federally regulated underground storage tank (UST) systems across the U.S. could have releases or other failures if the ethanol content in gasoline increases from 10 volume percent to 15 volume percent. To better assess the leak potential, the EPA commissioned a study at Oak Ridge National Laboratory to develop a means to determine the potential of changes in releases and other failures if E15 fuel is stored in UST systems. Part of this effort was to develop an approach to estimate likelihood of failures and approaches for mitigating consequences associated with these failures. Currently, the lack of availability of data is the most significant barrier that prevents EPA from being able to perform the analysis.

The initial approach was to develop and apply a probabilistic failure analysis tool based on expert elicitation to estimate how many more releases would occur if E15 replaced E10 in regulated UST systems. The key resources needed to establish this tool were opinions provided by industry and regulatory experts to quantify (most likely values and uncertainties) the critical variables that impact failure likelihood estimates. Unfortunately, over the course of the investigation, it was discovered that there was no information on the performance of existing UST systems with E15 and the state/industry experts were unable to speculate on E15's impact to UST systems. As a result, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when switching from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study.[3] The ORNL study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, and E25. Later studies investigated material compatibility to E50 and E85.

The elastomeric and metallic materials were exposed to Fuel C, CE10a, and CE17a test fuels, which are based on standard fluids described by the American Society for Testing and Materials (ASTM) and the Society of Automotive Engineers (SAE) for use in fuel-material compatibility studies. SAE Reference Fuel C (also known as Fuel C) is a 50:50 mix of isooctane and toluene, and was used as the base fuel in the ethanol-blended test fuels, where it is represented by the "C" nomenclature. The ethanol was made to an aggressive formulation per SAE J1681,[4] and is indicated by the letter "a". CE17a was chosen to represent E15 since fuel surveys have shown that the actual ethanol content in gasoline can vary by ±2%. Plastic materials were only evaluated in Fuel C and CE25a. Therefore it was necessary to assess E10 and E15 performance through an interpolation process using the known solubility parameters for these materials and their performance in Fuel C and CE25a.

E.2 Experimental Approach

The approach was to use the swell, mass change, and hardness data from the ORNL study to assess the risk of moving from E10 to E15. An extensive literature review was undertaken which was initially based on the EPA 22 state study[5] to accurately identify materials used in UST systems. The system components of interest included tanks, piping, sealants, and joined couplings. Piping was divided into three areas: metal, flexible plastic, and rigid fiberglass-reinforced plastic. Because most of the installed piping systems are plastic, these systems are discussed in greater detail. For the elastomeric and metallic materials, analysis was performed using results obtained from exposure to test fuels containing 10% and 17%. On the other hand, plastic materials were only exposed to Fuel C and CE25a. In order to estimate the level of swell (or solubility) for representative plastics in E10 and E15, an analysis was performed using the results obtained from the Fuel C and CE25a exposures and incorporating solubility theory. An estimate of the volume swell (at E10 and E15) was made by interpolating the results for Fuel C and CE25a.

E.3 Discussion and Analysis

Underground Storage Tanks and Piping Made of Steel

For metal-based tanks and piping, corrosion via oxidation of the metal can directly lead to the creation of a leak. Another potential concern with higher ethanol content is the initiation of a new phase of corrosion, such that previously passivated areas (rust plugs) are attacked and removed, thereby leading to potential leaks. All metal USTs are composed of mild-carbon steel and around 98% of metal piping is also mild-carbon steel.[5] The other metal of interest is aluminum since aluminum parts are used on submersible turbine pumps, connections and dispenser nozzle. The ORNL intermediate-blend study included both steel and aluminum; the study showed negligible corrosion of either steel or aluminum immersed in either CE10a or CE17a.[3] However, the test conditions may not accurately reflect actual field situations, whereby the metal structure may be under stress or exposed to fuel that has become separated into two phases, one of which is aqueous. Both of these conditions (stress and exposure to aqueous liquid) are considered to be more conducive to corrosion. The specimens evaluated in the ORNL intermediate-blends study were not placed under stress, so the stress corrosion cracking potential of steel to either E10 or E15 cannot be ascertained.

Phase separation (of water) is another scenario that needs to be addressed. The level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. Therefore, under identical conditions of phase separation (such as temperature excursions causing evaporation and condensation) E15 has the potential to generate twice the volume of aqueous phase than E10, which could translate to a higher corrosion (and therefore leak) potential. The presence of an aqueous phase is also a precondition for supporting microbial-induced corrosion (MIC), and if E15 has a higher potential for water formation, then MIC may also result in increased corrosion. If precautions are undertaken to keep water out of tanks, and stress corrosion cracking is not a factor, then the corrosion potential is minimized and E15 offers no added risk to metal corrosion than E10.

Underground Storage Tanks and Piping Made of Fiberglass-reinforced Plastic (FRP)

The other material used in the construction of USTs is fiberglass-reinforced plastic (FRP). FRP construction consists of initially placing an approximately 0.5mm thick layer of resin on a mandrel followed by adding an additional ~6mm layer of resin reinforced with fiberglass. The inner bare resin surface serves as the barrier layer to prevent fuel permeation and the fiberglass-reinforcement provides strength and elasticity. Some legacy designs also may incorporate a separate plastic film that was glued to the inside surface to provide a fuel-resistant barrier layer. The ORNL intermediate-blend materials compatibility study[3] had evaluated four resin types representative of those used in legacy and modern FRP UST construction. One resin was used extensively prior to 1990 and therefore may not have been designed for E10 compatibility. Two of the test resins were introduced during the 1990s (post-1990), during which time E10 was beginning to be used in the marketplace. The fourth resin type was a new advanced resin developed for improved resistance to ethanol fuels. These four resins were made into test coupons (with no added fiberglass) and exposed to test fuels of Fuel C and CE25a.

Because E15 and E10 test fuels were not used in this evaluation, it was necessary to estimate resin performance in E10 and E15 using the swelling data obtained from the Fuel C and CE25a exposures. This estimation was performed by interpolating the measured swelling data using the differences in the known total Hansen Solubility Parameters (HSPs) for the resins and test fuels. (This procedure is described in detail in Section 2.1.1.) The solubility parameter is based on the free energy of mixing and is useful in predicting the mutual solubility (and therefore swell) between liquids and solid hydrocarbon materials. The pre-1990 resin was severely damaged from exposure to CE25a, along with one of the post-1990 resins. The remaining post-1990 resin and the advanced resin type both remained intact after exposure to CE25a, but they did swell to over 20% from their original volume with addition of ethanol. However, interpolation of these results using the Hansen Solubility Parameters suggests that the additional swell achieved from E10 to E15 will be around 1.5% (which is low). It is also important to keep in mind that the addition of fiberglass reinforcement to any of these resins will prevent significant swelling and debonding of the composite structure, since the fibers themselves do not swell.

The ORNL intermediate-blend materials compatibility study later included three legacy FRP UST specimens for evaluation, but they were only exposed to Fuel C, CE50a, and CE85a. One sample had a green coloration and contained a separate plastic barrier liner glued to the inner resin layer. The other two samples were amber in appearance, and of typical construction which consisted of an inner resin-only layer which was surrounded by a 6mm thick layer of fiberglass-reinforced resin. The resin used in the green UST survived Fuel C exposure but was severely degraded following exposure to CE50a and CE85a. In each case, the glue holding the plastic liner to the resin surface had dissolved, but, the plastic liner was unaffected. Unfortunately, the plastic composition of the liner was unknown, making it impossible to assess compatibility to E10 and E15. This particular UST design may be uncommon since, of the over two dozen samples provided to ORNL, it was the only one which had a separate inner liner and green resin. The other two USTs did not experience noticeable degradation or swell associated with exposure to the CE50a and CE85a test fuels. Because the difference in HSPs for resin and ethanol-blended gasoline increases with decreasing ethanol content, these epoxy resins should be more soluble in E50 and E85 than for intermediate E10 and E15 levels. Therefore, it is expected that USTs composed of amber resins will be compatible with gasoline containing 10 and 15 percent ethanol.

As of 2009, rigid FRP piping makes up around 58% of all installed piping systems.[5] The technology and materials used in the manufacture of FRP tanks also applies to underground FRP piping systems as well. Therefore the compatibility of FRP piping systems should be the same or similar to FRP underground storage tanks.

Flexible Plastic Piping

As of 2009, flexible plastic piping is estimated to make up around 13% of all installed piping systems,[5] but many new systems employ flexible plastic piping since these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to other piping systems over the next 10 years. Typical compositional arrangement of most flexible piping includes an inner barrier liner with a layer of reinforcement (to provide strength) and an outer cover. Many of the outer layers are not compatible with ethanol and are only added to provide exterior protection and strength. The primary inner layer provides chemical resistance and a survey of flexible piping systems shows that the most common inner permeation barrier material is polyvinylidene difluoride (PVDF). Other plastics used as permeation barriers are nylons and polyethylene terephthalate (PET). PVDF, PET, and several grades of nylon were evaluated in the ORNL intermediate-blends study along with the other plastic materials that were exposed to Fuel C and CE25a. As with the UST resins, the performance (volume swell) with exposure to E10 and E15 was estimated using the measured volume swelling for exposure to Fuel C and CE25a and the known HSPs for these materials. The resulting analysis indicates that flexible piping permeation barrier materials will not have added significant swell (less than 1%) when moving from E10 to E15. Therefore, the increase in risk associated with leaking when switching from E10 to E15 will be low.

Elastomers, Sealants, Couplings and Fittings

Couplings and fittings used to connect piping, the submersible turbine pump, and valves represent one of the highest potential locations for leaking in UST systems. There are two potential locations/sources of leaks associated with fittings. One is where the coupling attaches to the piping and the other one is at the fitting-to-fitting seal interface. In many (but not all) cases fluorocarbons are used as interfacial seals between fittings. Fluorocarbons have been shown to be compatible with ethanol and it is unlikely that a properly installed fluorocarbon elastomer will leak when exposed to either E10 or E15. For metal and some rigid FRP piping systems, pipe thread sealants may be employed to seal fittings via threaded attachments. Some legacy pipe thread sealants were shown to be incompatible with gasoline containing 10% aggressive ethanol and would clearly not be acceptable for E15 use either. Newer engineered products (such as fluoroelastomers) have been developed for ethanol-blended gasoline and these sealants have been shown to be compatible with gasoline containing up to 25% aggressive ethanol.

For flexible piping systems a stainless steel coupling is normally compression fitted to the outer surface of the pipe so the leak potential is very low for properly installed couplings. In contrast fittings attached to rigid FRP systems typically utilize an adhesive to maintain a seal between the coupling and the outer pipe wall. Adhesives designed for fuel ethanol use are available. This material type was not included in the ORNL intermediate-blend study and its performance in either E10 or E15 was not ascertained. For rigid FRP pipe-to-pipe joining, fiberglass reinforced resin is also frequently applied to the joined ends in a butt-and-wrap arrangement. Since the wrapping is composed of fiberglass-reinforced resin similar to the piping itself, the leak potential with exposure to E15 for a properly installed joint should be low since the increase of swell associated with E15 (relative to E10) is estimated to be small (1.5%). It is important to note that the joined sections have lower structural integrity (mechanical strength) than the pipe as a whole, but should not leak as a primary result of the fuel exposure.

E.4 Conclusions

In general, the materials used in existing UST infrastructures would not be expected to exhibit compatibility concerns when moving from E10 to E15. The volume swell and hardness results of tested polymer materials were not significantly different when exposed to either CE10a or CE15a, although significant changes were observed when these fuels are compared to the E0 formulation. The indication is that UST systems were affected by switching from E0 to E10. However, since E10 and E15 produce similar results, compatibility is not expected to be altered noticeably when moving from E10 to E15. The metallic materials showed negligible corrosion as long as phase separation did not occur. If an aqueous phase is formed, then the possibility for aggressive corrosion exists. Therefore, the proper application of biocides and water monitoring is likely to be more critical at preventing corrosion for gasoline fuel containing ethanol.

1. INTRODUCTION

1.1 HISTORY AND BACKGROUND

In the United States oil dependence is driven primarily by the transportation sector. Transportation accounts for 69% of the total oil consumption in the United States, and the industry itself is around 90% oil dependent (and the remainder being natural gas, propane, electric and ethanol).[6] In 2008 the average daily oil consumption equivalent used the U.S. transportation sector was approximately 14 million barrels. This rate is projected to increase to around 16 million barrels per day by 2025.[7] Currently, the bulk of our oil usage is provided by other countries as foreign oil imports and makes up around 57% of the total oil usage.[8] This dependency impacts our nation's security, since our oil supply is determined partly by other countries, some of whom are not friendly to the United States. Foreign disruption has been shown to negatively impact the nation's economy and makes the U. S. more vulnerable during times of international crisis.

The Energy Independence and Security Act (EISA) of 2007 was enacted by Congress to move the nation toward increased energy independence by increasing the production of renewable fuels to meet its transportation energy needs. The law establishes a new renewable fuel standard (RFS) that requires the nation to use 36 billion gallons annually (2.3 million barrels per day) of renewable fuel in its vehicles by 2022. Ethanol is the most widely used renewable fuel in the United States, and its production has grown dramatically over the past decade. According to EISA and RFS, ethanol (produced from corn as well as cellulosic feedstocks) will make up the vast majority of the new renewable fuel requirements. However, ethanol use limited to E10 and E85 (in the case of flex fuel vehicles or FFVs) will not meet this target. Even if all of the E0 gasoline dispensers in the country were converted to E10, such sales would represent only about 15 billion gallons per year.[9] If 15% ethanol, rather than 10% were used, the potential would be up to 22 billion gallons. The vast majority of ethanol used in the United States is blended with gasoline to create E10, that is, gasoline with up to 10 % ethanol. The remaining ethanol is sold in the form of E85, a gasoline blend with as much as 85% ethanol that can only be used in FFVs. Although the U. S. Department of Energy (DOE) remains committed to expanding the E85 infrastructure, that market will not be able to absorb projected volumes of ethanol in the near term. Given this reality, DOE and others have begun assessing the viability of using intermediate ethanol blends as one way to transition to higher volumes of ethanol.

In October of 2010, the U. S. Environmental Protection Agency (EPA) granted a partial waiver to the Clean Air Act allowing the use of fuel that contains up to 15% ethanol for the model year 2007 and newer light-duty motor vehicles. This waiver represents the first of a number of actions that are needed to move toward the commercialization of E15 gasoline blends. On January 2011, this waiver was expanded to include model year 2001 light-duty vehicles, but specifically prohibited use in motorcycles and off-road vehicles and equipment.[2]

UST stakeholders generally consider fueling infrastructure materials designed for use with E0 to be adequate for use with E10, and there are no known instances of major leaks or failures directly attributable to ethanol use. It is conceivable that many compatibility issues, including accelerated corrosion, do arise and are corrected onsite and, therefore do not lead to a release. However, there is some concern that higher ethanol concentrations, such as E15 or E20, may be incompatible with current materials used in standard gasoline fueling hardware. In the summer of 2008, DOE recognized the need to assess the impact of intermediate blends of ethanol on the fueling infrastructure, specifically located at the fueling station. This includes the dispenser and hanging hardware, the underground storage tank, and associated piping.

The DOE program has been co-led and funded by the Office of the Biomass Program and Vehicle Technologies Program with technical expertise from the Oak Ridge National Laboratory (ORNL) and the National Renewable Energy Laboratory (NREL). The infrastructure material compatibility work has been supported through strong collaborations and testing at Underwriters Laboratories (UL). ORNL performed a compatibility study investigating the compatibility of fuel infrastructure materials to gasoline containing intermediate levels of ethanol. These results can be found in the ORNL report entitled *Intermediate Ethanol Blends Infrastructure Materials Compatibility Study: Elastomers, Metals and Sealants* (hereafter referred to as the ORNL intermediate blends material compatibility study).[3] These materials included elastomers, plastics, metals and sealants typically found in fuel dispenser infrastructure.

The test fuels evaluated in the ORNL study were SAE standard test fuel formulations used to assess material-fuel compatibility within a relatively short timeframe. Initially, these material studies included test fuels of Fuel C, CE10a, CE17a, and CE25a. The CE17a test fuel was selected to represent E15 since surveys have shown that the actual ethanol upper limit can be as high as 17%. Later, CE50a and CE85a test fuels were added to the investigation and these results are being compiled for a follow-on report to be published in 2012. Fuel C was used as the baseline reference and is a 50:50 blend of isooctane and toluene. This particular composition was used to represent premium-grade gasoline and was also used as the base fuel for the ethanol blends, where it is denoted by "C" in the fuel name. The level of ethanol is represented by the number following the letter E. Therefore a 10% blend of ethanol in Fuel C is written as CE10a, where "a" represents an aggressive formulation of the ethanol that contains water, NaCl, acetic and sulfuric acids per the SAE J1681 protocol.

1.2 ETHANOL COMPATIBILITY AND SOLUBILITY

Pure ethanol, by itself, is not generally considered corrosive toward most metallic materials; however, as a polar molecule, ethanol will be more susceptible to having compatibility issues with both metals and polymers due to (1) increased polarity relative to gasoline, (2) adsorption of water, and (3) a higher solubility potential relative to gasoline. The first two factors are relevant to metals and alloys, while the latter affects primarily polymers. The corrosion potential is directly related to the electrical conductivity of a solution. Kirk[10] measured the electrical conductivity for gasoline as a function of ethanol concentration and dissolved water level. A plot of the electrical conductivity as a function of ethanol concentration in gasoline is shown in Fig. 1. As shown in the figure, the electrical conductivity is low for ethanol-blended gasoline increases marginally with ethanol concentrations up to 20%. However, although the conductivity numbers are low, relatively speaking, E15 is 10 times more conductive than E10. As the ethanol concentration increases from 20% to 50%, the corresponding conductivity increases by almost two orders of magnitude. As a result, metal corrosion becomes a significant concern for gasoline blends containing 50% or more ethanol.

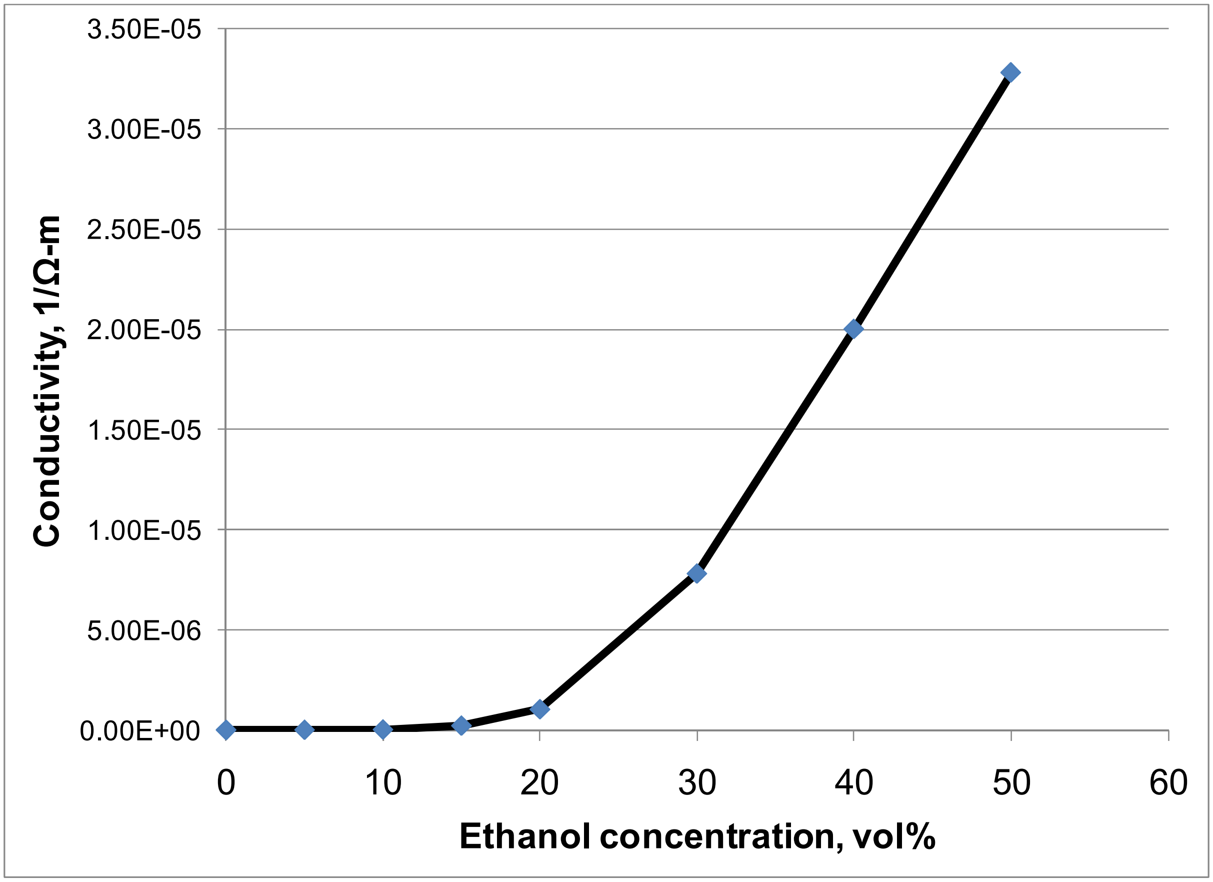

Fig. 1. Electrical conductivity of gasoline as a function of ethanol concentration. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

The level of dissolved water also has a pronounced effect. The results in Fig. 2 show the effect of water concentration in addition to ethanol level. In this figure, the electrical conductivity (listed as S in Fig. 2 and 1/Ω in Fig. 1) is plotted for blends containing 5, 10, 15, 20, 30 and 40% ethanol by volume. As the level of ethanol increases, the conductivity curves for each blend increase as well, and for each set of curves the conductivity also increases with the level of dissolved water. In fact, the water solubility limit increases the conductivity by an order of magnitude when going from E10 to E15. In addition, water itself is a solvent for NaCl and acids, which can lead to even higher rates of corrosion.

Ethanol also affects the material-fluid mutual solubility associated with the fuel blend, which is an important parameter for gauging the compatibility of fuels with polymers. The influence of the solubility parameter is complex; however, solvents and solutes having similar solubility parameters will have a greater affinity for permeation and dissolution.[11] The solubility parameter, or more specifically, the difference in parameters between the solute (polymer) and solvent (fuel), is important in predicting and understanding the solubility of a system. As the solubility parameter values for the solute and solvent converge, the propensity for the two components to mix (or allow the solvent to permeate into the solute) becomes thermodynamically possible. For an elastomer or plastic, this effect will be an increase in swelling of the polymer.

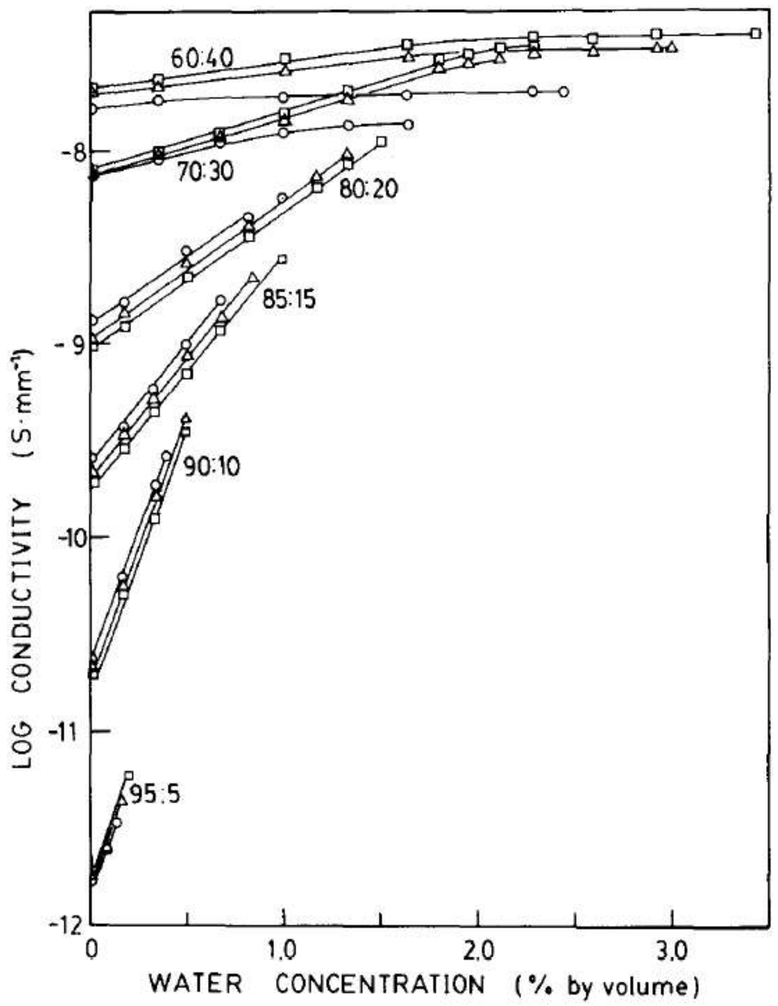

Fig. 2. Electrical conductivity of gasoline as a function of ethanol and water content. *Source:* D. W. Kirk, Fuel 62, 1512–1513 (December 1983).

A simplified representation of solubility as a function of ethanol concentration in gasoline is shown in Fig. 3. The wide shaded horizontal band in the chart represents the range of solubility parameters, expressed as total Hansen Solubility Parameter (HSP) for many dispenser polymers, especially elastomers. Epoxies, such as those used as the matrix materials for underground storage tanks, have a total HSP value around $24(\text{MPa})^{1/2}$, which is noticeably higher than the HSP for polymers. The implication for UST resins is that the solubility of the epoxy in the fuel will be highest for gasoline containing around 80% ethanol.

As the ethanol concentration increases from zero to 15%, it effectively raises the solubility parameter and approaches the solubility parameter of most dispenser polymers. Therefore, the propensity for the fuel to permeate into and dissolve polymeric components is enhanced. It is important to note that, in reality, solubility is determined from multiple thermodynamic factors, and that the highest level of mutual solubility for a given polymer does not necessarily match precisely with the theoretically-derived parameters which have been simplified in Fig. 3. Standard gasoline fuel delivery systems contain elastomeric materials having excellent compatibility and stability with hydrocarbon fuels. However, the ethanol molecule is relatively small and highly polar due to the –OH group. In addition the tendency to introduce hydrogen bonding is high. These features enable ethanol's permeation into and interaction with the elastomer structure, which can result in swelling and softening of elastomers. Another negative feature associated with permeation is that soluble components, especially plasticizers added to impart flexibility and durability in the elastomer, may be leached out, thereby affecting the mechanical properties of the compounded elastomer component and degrading the ability of the component to perform its intended function.

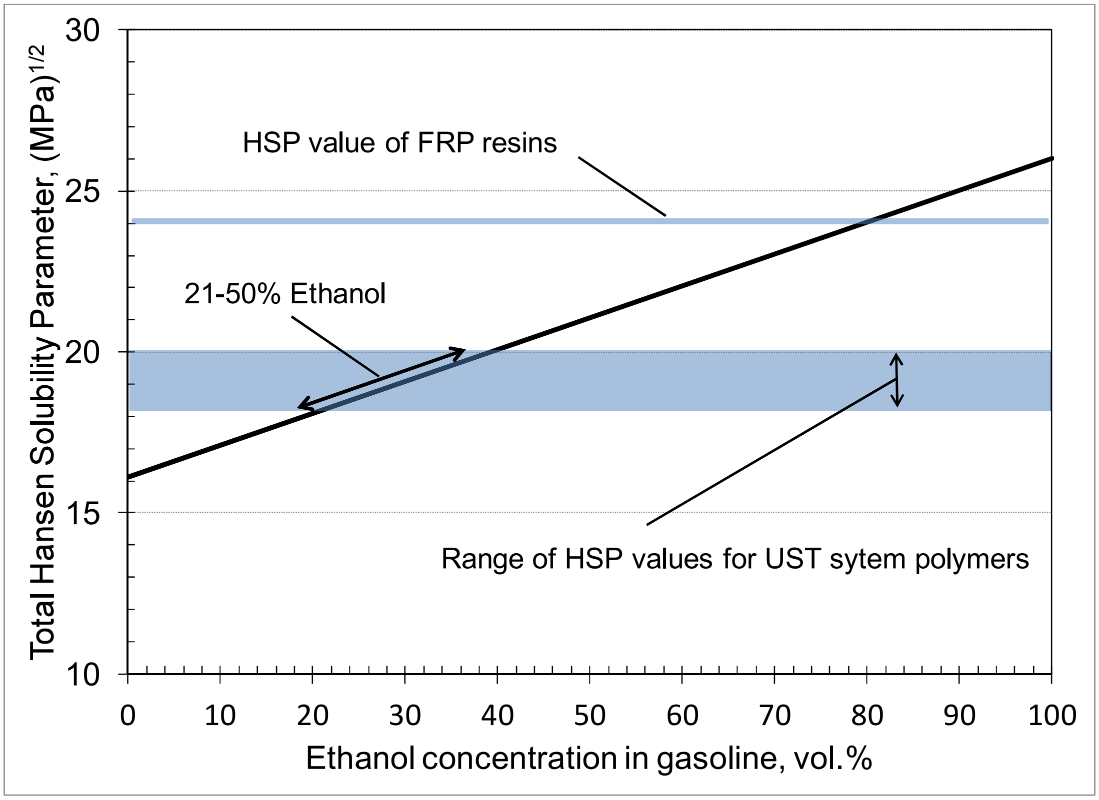

Fig. 3. Total Hansen Solubility Parameter as a function of ethanol concentration. The lower blue horizontal band represents the solubility range of many UST system elastomer and plastics. The upper blue band is representative of FRP resins.

Several studies have been undertaken to evaluate the compatibility of ethanol with engine materials, especially those used in fuel system components such as pumps, and much of this work has recently focused on the intermediate E15, E20, and E25 blends.[12–15] However, little work had been reported on the compatibility of these fuels to standard fuel dispenser materials, which subsequently became the focus of the ORNL-led materials compatibility study noted earlier.

1.3 FUELING DISPENSER MATERIALS AND ETHANOL COMPATIBILITY STUDY

As part of the ORNL intermediate-blend materials compatibility study, an extensive survey was performed to identify to the extent possible all materials used in the fueling dispenser infrastructure. A list of the materials identified and evaluated in the ORNL study is shown in Table 1, where those materials identified by the authors of this report for use in UST systems are highlighted. Most of the plastic materials are used as structural components in FRP tanks and in both FRP and flexible piping systems. The elastomeric materials most identified as seals and gaskets are Viton™ and Dyneon™ brand fluorocarbons, but NBR and rubberized cork may still be in use in legacy tank probes and overfill devices. Steel is used in tanks and piping and aluminum is also used in some applications, such as drop tubes.

It is important to note that while the researchers were able to discover and identify an extensive list of relevant materials over the course of this and other studies, it is possible, if not probable, that other materials used in legacy, and some new infrastructure systems, were not included in this investigation.

Table 1. List of materials evaluated in intermediate ethanol blends compatibility study. (Materials identified as being used in UST systems are highlighted.)

Metals/Alloys	Elastomers	Plastics	Sealants
304 stainless steel	**Viton™ fluorocarbon**	**High density polyethylene (HDPE)**	**PTFE-based sealants (two-types) with and without Teflon™ tape**
1020 carbon steel	**Dyneon™ fluorocarbon**	Fluorinated HDPE	
1100 aluminum	**Acrylonitrile butadiene rubber (NBR)**	Polypropylene (PP)	
Cartridge brass	Silicone rubber	Polyoxymethylene	
Phosphor bronze	Fluorosilicone rubber	**Nylon**	
Nickel 201	Neoprene rubber	**Polyvinylidene fluoride (PVDF)**	
Terne-plated steel	Styrene butadiene rubber (SBR)	**Polytetrafluoroethylene (PTFE)**	
Galvanized steel	Polyurethane	Polyphenylene sulfide (PPS)	
Cr-plated brass	**Rubberized cork**	**Polyethylene terephthalate (PET)**	
Cr-plated steel		Polybutylene terephthalate (PBT)	
Ni-plated		Polythiourea	
Ni-plated steel		**Isophthalic ester resin**	
		Terephthalic ester resin	
		Vinyl ester resin	
		Epoxy resin	

Of the all the test fuels investigated (Fuel C, CE10a, CE17a, CE25a, CE50a and CE85a), only the metal and elastomeric materials were subjected to each fuel type. The plastics were originally exposed to Fuel C and CE25a (and later to CE50a and CE85a) and the sealants were evaluated only in Fuel C, CE10a and CE25a. At a later point in this study, ORNL received sections of fiberglass USTs removed from use. Three UST sections were cut into test specimens and added to the final exposure runs of Fuel C, CE50a, and CE85a.

The test protocol consisted of immersing the specimen coupons in the test fuels and vapors for extended periods, 4 weeks for metals and elastomers and 16 weeks for plastics. During the exposure period the fuel temperature was maintained at 60°C in order to maintain consistency with the UL Subject 87A-E25 test standard used in by Underwriter Laboratories when assessing fuel compatibility.[16]

2. UNDERGROUND TANKS & PIPING SYSTEMS

Underground fuel storage tanks are composed either of steel or fiberglass reinforced plastic. Both of these materials, as well as flexible plastic, are also used in piping systems. A breakdown of the piping types using an analysis based on 22 state databases[5] is shown in Table 2. The overwhelming majority of installed piping (~71%) is either flexible or rigid fiberglass reinforced plastic. Of the remaining metal systems, approximately 18% of metal piping systems are steel. Copper makes around 2% of underground piping and approximately 8% is of unknown material construction.[19] The most common installed piping systems are rigid FRP and flexible plastic systems. Older piping systems were typically single-walled, but most newly installed systems are double-walled. FRP makes up approximately 58% of installed piping, while flexible plastic piping accounts for around 13% of all installed piping systems.[5]

Table 2. Breakdown of piping materials.[5,19]

Material Class	Approximate Percentage Used as of 2009
Steel	18
Rigid Fiberglass Reinforced Plastic (RFP)	58
Flexible Plastic Piping	13
Other (copper, PVC, etc.)	2
Unknown	8

A large percentage of leaks occur in the piping system between the tank and the dispenser.[17] These leaks typically occur at joints and connections where the stresses are highest. Contributors to stress include movement and forces exerted on piping from environmental factors which can be caused by changes in ground-water level and settling changes in the soil. Even a small change in the position of a UST will result in stress on the piping, especially at joints.[18] The level of stress will be higher for rigidly designed systems as opposed to flexible systems which can reduce stress through bending and relaxation. Outside of environmental contributions to stress, there are inherent changes caused by the piping materials' response to the fuel chemistry. As stated earlier, ethanol will raise the solubility parameter of the fuel so that the resulting potential for degradation of plastics is increased. Increased solubility will likely cause an increase in the volume of the plastic. This volume increase will place the component pipe under additional elongation and stress. Expansion of piping caused by solubility (even at low levels of approximately 2%) may be high enough to lead to failure based on life cycle studies of polymeric piping materials.[18]

2.1 METALLIC MATERIALS FOR TANKS, COMPONENTS, AND PIPING SYSTEMS

Steel is commonly used as a tank material for both legacy and newer systems, and steel piping is estimated to be used in approximately 18% of piping systems. The other metallic material that is exposed directly to E10 (and potentially E15) is aluminum which is used in submersible pumps. Both steel (carbon and stainless) and aluminum were included in the ORNL intermediate-blend materials compatibility study.

As shown in Fig. 1, the electrical conductivity for E10 and E15 is low in relationship to higher ethanol concentrations; however, when compared to each other, E15 is actually 10 times more conductive than E10. When water is added to levels approaching the solubility limit (as shown in Fig. 2), the conductivity is further increased. The test fuels used in the ORNL-intermediate blends study included relatively high levels of dissolved water (0.09% of the total ethanol volume) to account for this factor. In this study, steel and aluminum, along with the other metal coupons (tested either as single components or galvanic couples) showed negligible corrosion from exposure to the test fuels.[20] As a result, corrosion that does occur on metal tanks or piping systems is likely due to one of more of the following factors (none of which were included in the ORNL study):

1. Phase separation of water from the ethanol fuel blend
2. External water intrusion from rain, humidity, etc.
3. Contamination by other means such as road salt, dirt, etc.
4. Stress corrosion cracking

The potential for aqueous phase separation can be discussed relative to Fig. 2. As shown in Fig. 2, the level of water that can be dissolved into E15 is roughly twice the amount that can be dissolved in E10. The higher water content translates to a higher potential for corrosion.

2.2 POLYMER PIPING AND TANK SYSTEMS

As shown in Table 2, the majority of underground piping is constructed from plastic materials, which are categorized as two types, flexible piping and FRP piping. Although FRP systems are more established in the field, the majority of new piping systems installed today are flexible plastic systems because these systems are easier to install. As a result, the percentage of flexible piping is expected to grow relative to the other piping systems over the next 10 years. The piping arrangement can consist of either single- or double-walled systems. The majority of installed single-walled piping systems are legacy units, but new requirements are resulting in increased use of double-walled piping systems. Double-walled systems have an interstitial space between the walls that can be monitored for leaks.

2.2.1 Flexible Plastic Piping

Typical compositional arrangement of flexible piping includes an inner barrier liner within a layer of fiber reinforcement (to provide strength) and a cover to protect the inner layers from damage from handling and to prevent water intrusion. We surveyed the materials used in the construction of the outer wall for double wall plastic-based systems. In virtually every case, the outer wall is composed of inexpensive materials, known to be less chemically resistant to ethanol.

Multiple piping manufacturers and the materials used in their systems are listed in Table 3.[21-25] Some of the manufacturer and material information included in the table was taken from surveys dating to 1997, and therefore, may not reflect current construction.

Table 3. Flexible piping materials according to manufacturer.

Manufacturer	Permeation Barrier Material	Reinforcement	Primary Pipe Cover Material (Single-walled)	Secondary Containment Materials (double-walled)
Advanced Polymer Technology	Nylon 12	Nylon fiber wrap	Polyethylene	HDPE
Ameron	PVDF	Polyester braid polyethylene	Nylon	HDPE
Containment Technologies	Selar nylon (amorphous)	None	Polyethylene	HDPE
Environ	PVDF	Polyester braid	Nylon-coated polyethylene	Nylon coated polyethylene
Furon	PVDF	Polyester braid	Nylon II	
OPW	PVDF	Polyester braid	Nylon II	
PetroTechnik	Nylon	None	Polyethylene	Polyethylene
Total Containment	Carilon polyketone (product discontinued)	Polyester or Kevlar braid	Polyethylene	Polyethylene
Western Fiberglass	PVDF	Polyester braid	Nylon II	HDPE
XP-Piping	Nylon 12 and mylar (PET)	Nylon fiber	Mylar (PET) coated nylon 12	Nylon 12
Pisces	Kynar (PVDF)	Nylon fiber	Nylon	Nylon
Geoflex	Kynar (PVDF)		Nylon coated polyethylene	Nylon coated polyethylene

Of the flexible pipes reported in Table 3, the majority had inner barrier layers composed of PVDF. The three remaining designs incorporated nylon, either as nylon 12, Selar™ amorphous nylon, or a combination of nylon 12 and Mylar™ PET. For most systems the permeation barrier layer was externally reinforced with wound fibers composed of either nylon or polyester. This reinforcement, in turn, is usually coated with nylon or polyethylene. Likewise, the most common materials used for the outer wall are polyethylene and nylon.

One manufacturer used PET as the inner barrier layer. However, most materials are either nylon or PVDF. In reality the actual arrangement and location material arrangement for flexible piping is somewhat complex. A cutaway diagram showing the material arrangement for one commercially-available flexible pipe is shown in Fig. 4. In all flexible piping systems, there is an inner permeation barrier layer composed of a plastic material that has low solubility (i.e., high resistance) to petroleum fuels and alcohols.

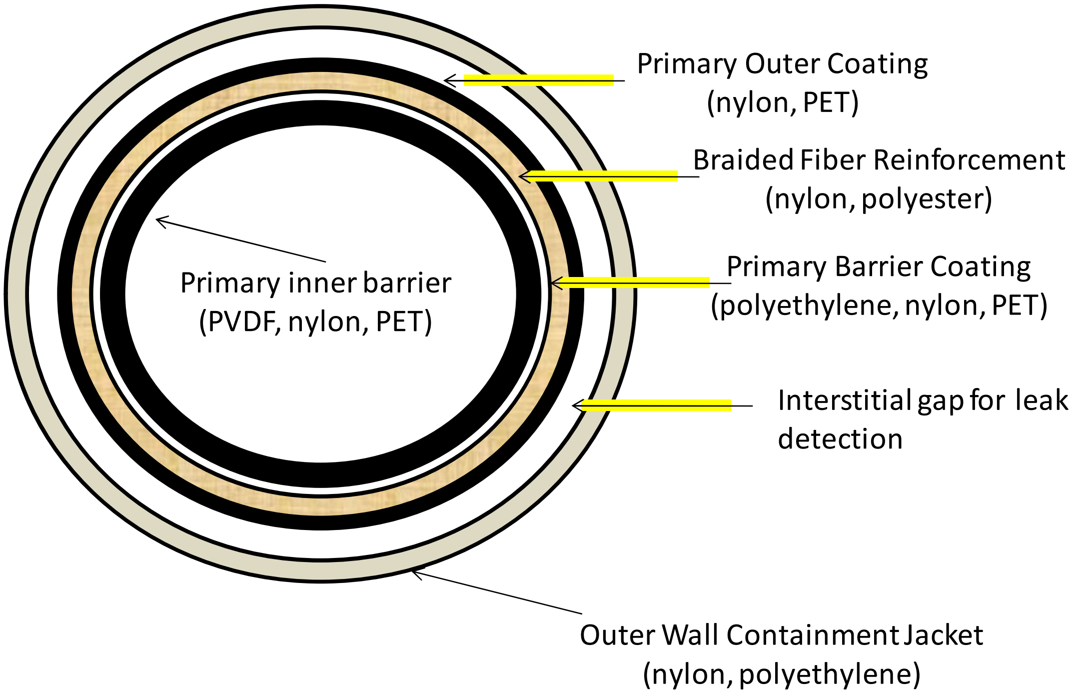

Fig. 4. Cross-section diagram of flexible piping showing an example of the layering position and arrangement of materials used in double-walled designs. A typical single-wall design is similar but would not include the outer wall containment jacket shown on the outside.

As stated earlier the two primary polymer types used in flexible fuel piping are nylon and polyvinylidene difluoride (PVDF). Other often used materials are polyketone and polyethylene terephthalate (PET). However, polyketone (Carilon™, Dupont) was discontinued and (to the best of our knowledge) the installed piping was removed and replaced. PET is more expensive than either nylon or PVDF, and as such, is not extensively used in piping applications. PVDF goes by the tradename, Kynar™ and is manufactured by Arkema, Inc. The other established material is the DuPont Selar™ nylon barrier material (which is amorphous grade of nylon).

Flex piping is easier to install and the flexible nature of the material allows the component to relax during swell. In contrast to fixed rigid piping systems, a flexible piping system can undergo small dimensional changes in volume and movement (relaxation), thereby reducing the stress load.

The ORNL intermediate blends compatibility study included samples of representative flexible pipe materials. These materials include PET, HDPE, nylon 6, nylon 6/6, nylon 11, and nylon 12. (Selar, which is an amorphous grade of nylon, was not evaluated.) These nylon grades are differentiated by the degree of molecular alignment (crystallinity), additives, and processing. In contrast to the other types, Nylon 11 is a unique specialty grade made from vegetable oil. Although Selar™ nylon was not specifically included among the test coupons, according to DuPont, its chemical resistance is comparable to other grades of synthetic nylon (nylon 6, 6/6, and 12).[26]

The ORNL materials compatibility study evaluated the response of selected plastic materials to Fuel C and CE25a only. Test fuels representing 10 and 15 percent aggressive ethanol were not exposed to plastics. Volume swell and hardness results are shown in Figs. 5 through 7 for common nylon grades, PET, PVDF, and HDPE exposed to Fuel C and CE25a.

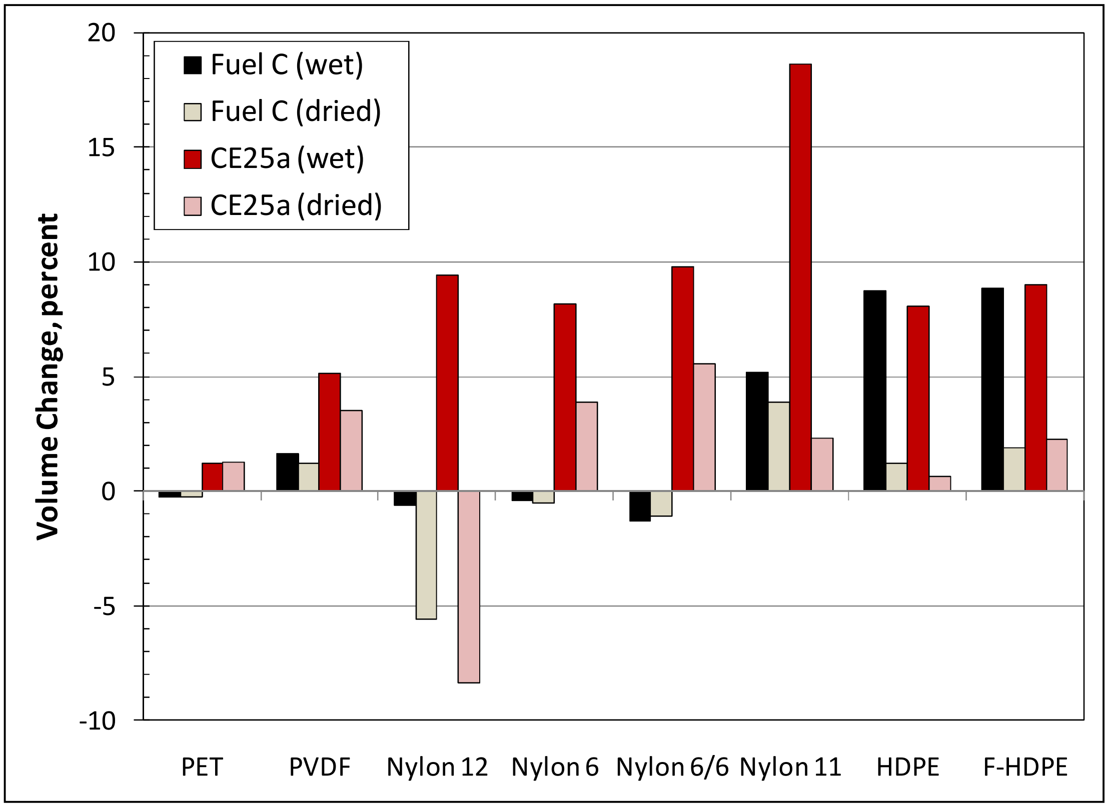

Fig. 5. Volume swell results for representative barrier materials used in underground piping.

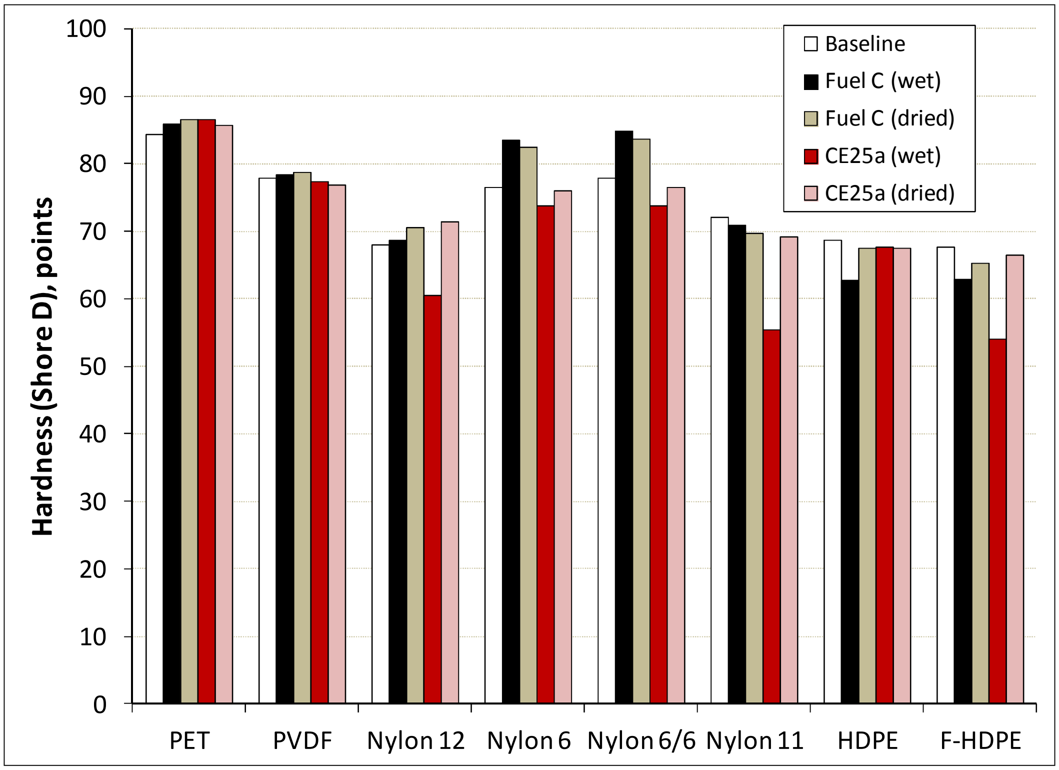

Fig. 6. Absolute hardness results for representative barrier materials used in flexible piping.

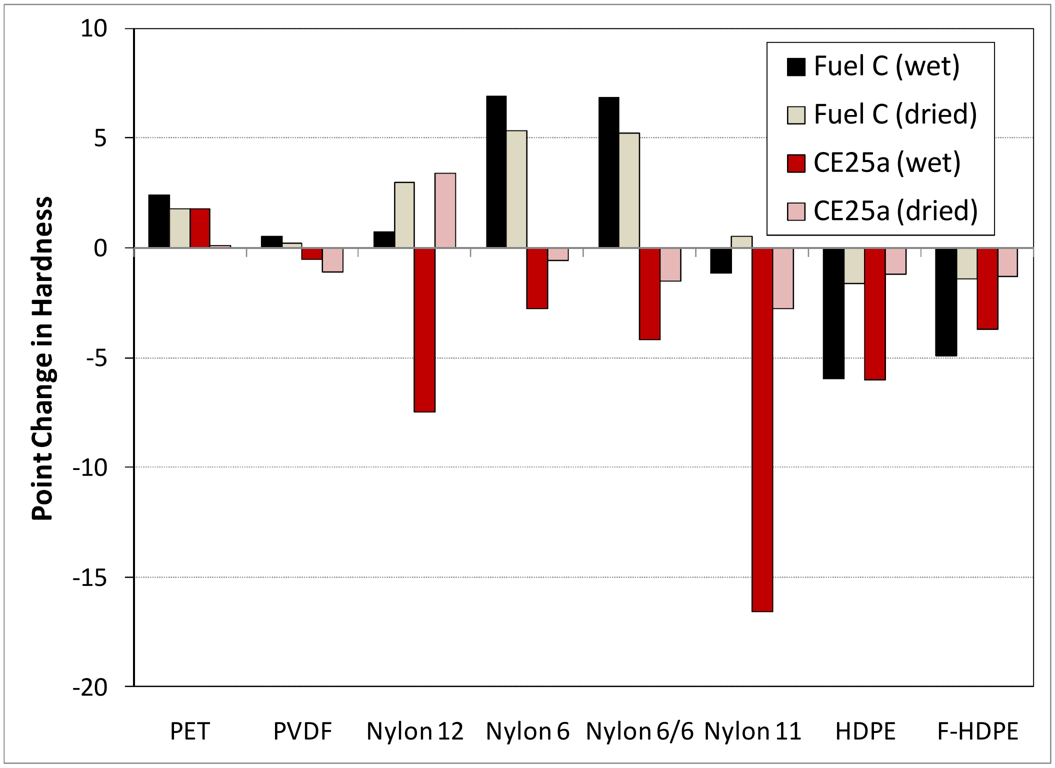

Fig. 7. Point change in hardness (from baseline) for representative barrier materials used in flexible piping.

As shown in Fig. 5, PET and PVDF experienced the lowest low volume swell (1.23% and 5.12%, respectively) following exposure to CE25a. In contrast, the nylon 6, nylon 6/6, and nylon 12, along with the HDPE samples swelled between 8 and 10 %. The highest level of volume swell occurred for nylon 11, and was around 18 %. Following dry out, these materials retained some fluid, as evidenced by the residual swell present in the dried samples. The one exception is nylon 12, which shrank from its original volume to over 5% from exposure to Fuel C and around 8% with CE25a. Such shrinkage is evidence that Fuel C and CE25a were able to dissolve and remove a significant portion of the solid material. The hardness results presented in Figs. 6 and 7 show that nylon 12 and nylon 11 both became softer with exposure to CE25. The decrease in hardness of nylon 12 was around 7 points, which is only marginally higher than the softening of the nylon 6, nylon 6/6 and the HDPE samples. However, nylon 11 dropped 17 points and this drop coupled with the high volume swell suggests that nylon 11 may not be acceptable for use in plastic piping, even for E0 formulations.

Although E10 and E15 test fuels were not evaluated, an estimation of the volume swell can be made using solubility parameters (obtained from the literature) and volume swell results in CE25a. Volume swell is a measurement of solubility. According to solubility theory, the difference between the solubility parameters is inversely related to the solubility between the solute (plastic) and solvent (test fuel). In other words, the closer match between the total Hansen Solubility Parameters of the solute and solvent, the more mutually soluble they are to each other. Using the known total HSP values for the plastic materials and E25, E15 and E10, and the measured volume swell in CE25a (as shown in Table 4), a calculated volume swell for each material in E15 and E10 can be made using the ratio of the differences in the total Hansen solubility parameters between the plastic and CE25a to the HSP difference between the plastic and CE15 and CE10. These calculated values are shown in Table 5.

The method for calculation of volume swell is as follows:

$$VS_{(EX)} = VS_{(E25)}\ (1-(\Delta HSP_{(EX)} - \Delta HSP_{(E25)}))/\ (\Delta HSP_{(EX)})$$

Where:

$VS_{(EX)}$ is the volume swell of the plastic sample after exposure to a fuel containing X percent of ethanol by volume.

$VS_{(E25)}$ is the volume swell of the plastic in CE25a

$\Delta HSP_{(EX)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing X volume percent ethanol

$\Delta HSP_{(25)}$ is the difference between the total Hansen Solubility Parameter values for the plastic and the fuel containing 25 volume percent ethanol

Table 4. Volume swell results for representative barrier materials used in flexible underground piping

Plastic	Hansen Solubility Parameter ($MPa^{1/2}$)	Volume Swell in CE25a (%)
PVDF	23.17	5.12
Nylon 6	20.3	8.15
Nylon 12	22.2	9.40
PET	20.8	1.23
Fuel Type	**Hansen Solubility Parameter ($MPa^{1/2}$)**	
E25	18.58	
E15	17.59	
E10	17.09	

Table 5. Measured and calculated results for PVDF and Nylon 6

Barrier material	HSP ($MPa^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10	Estimated vol. increase associated with increasing ethanol from E10 to E15
PVDF	23.17	5.12	4.1	3.6	0.5
Nylon 6	20.3	8.15	5.2	4.4	0.8
Nylon 12	22.2	9.4	7.4	6.7	0.7
PET	20.8	1.23	0.8	0.7	0.1

The results in Table 5 show that the expected increase in volume swell when going from E10 to E15 is less than 1 percent for the primary barrier liner materials used in flexible piping. The low additional volume swell is not likely to create much stress in the piping since these materials are able to relax due to the flexible nature of the piping. Based on these results, we do not anticipate any noticeable potential for release associated with going from E10 to E15. However, if the piping is rigidly constrained somehow, then stress buildup may occur to cause bucking (or cracking) of the piping. Most of the changes in swell (and hardness) will occur from moving from E0 to E10.

2.2.2 Fiber-reinforced Plastic Tanks & Piping

Fiber-reinforced plastic piping materials, design and construction are similar to those used in fiberglass tanks. The construction consists of first placing resin on a mandrel and later adding fiber reinforced resin to serve as the outer layer. A diagram showing layering and arrangement is depicted in Fig. 8.

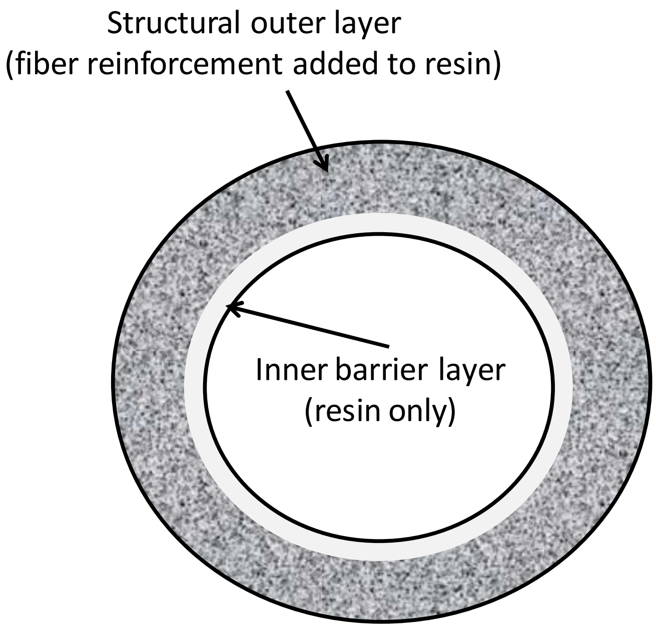

Fig. 8. Diagram of fiber-reinforced plastic piping.

As shown in Fig. 8, the inner barrier liner is approximately 0.5mm-thick resin layer surrounded by a much thicker (~6mm) layer of fiber-reinforced resin. For FRP systems used to contain petroleum fluids, the fiber reinforcing material is fiberglass.

ORNL tested several FRP resins to assess compatibility with CE25a. The resins that were evaluated included:

1. Isophthalic polyester resin (1 part isophthalic acid to 1 part polyester resin) known as Vipel F701-This resin type was used extensively in USTs prior to the 1990s.

2. Isophthalic polyester resin (2 parts isophthalic acid to 1 part polyester resin) known as Vipel F764-This resin type was used in USTs starting in the 1990s.

3. Terephthalic polyester resin (2 parts terephthalic acid to 1 part polyester resin) known as Vipel F774-This resin type was used extensively in 1990s.

4. Epoxy novolac vinyl ester resin known as Vipel F105-This is the most recently advanced corrosion resistant UST resin.

A survey of manufacturers shows that these resins are the most commonly used types for FRP UST construction.[27-30] It is important to note that for FRP tanks the construction does not consist of a multilayer structure similar to the arrangement used in flexible plastic piping. The inner barrier layer consists solely of the resin material, with fiberglass added to the thicker resin outer layer to provide strength and elasticity. The volume swell results are shown in Fig. 9 for these resins. (These specimens consisted of pure resin and did not contain fiber reinforcement.) Vipel F701 swelled to over 15 volume percent upon exposure to Fuel C. However, these samples fractured during dry-out making it impossible to ascertain accurate volume swell. For Vipels F764 and F774, the volume swell in Fuel C was around 9 percent and 7 percent, respectively. The most compatible grade was Vipel F085, which exhibited low volume swell (2%). When dried at 60°C for 20 hours, the volume swell was lower than the wetted condition, but still significantly higher than the starting condition. The increase in dry-out volume compared to the initial condition indicates that significant levels of Fuel C are contained within the resin. This fact is further illustrated in Fig. 10 which shows the corresponding mass change of the specimens before and after dry-out.

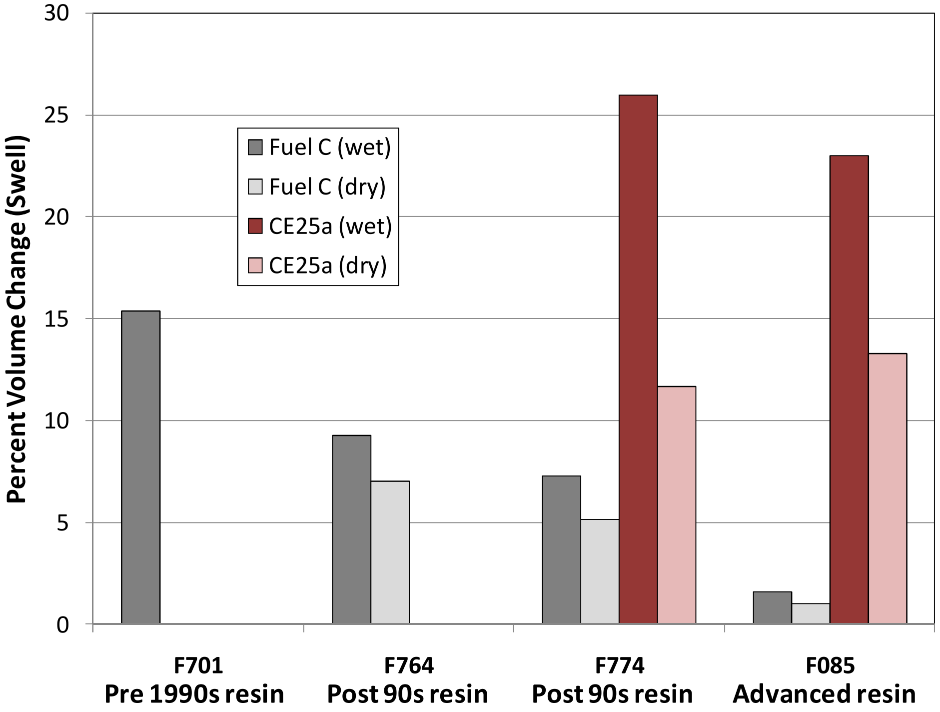

Fig. 9. Volume swell results for UST resins following exposure to Fuel C and CE25a.

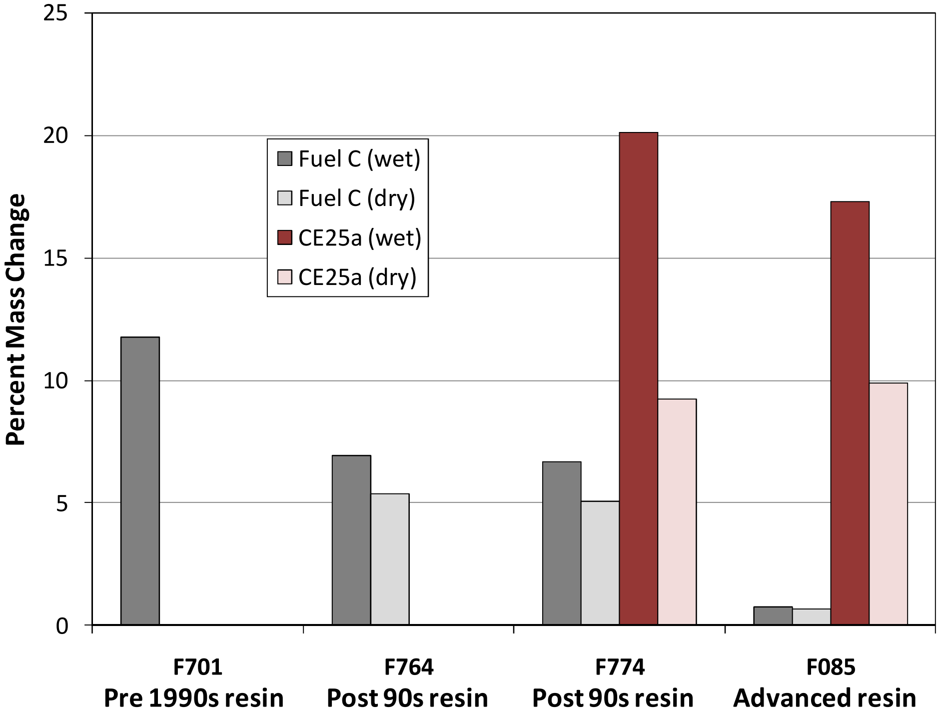

Fig. 10. Mass change for UST resins following exposure to Fuel C and CE25a.

Upon exposure to CE25a, Vipels F774 and F085 exhibited high degrees of swelling. F774 swelled to 26% while F085 swelled to around 23%. However, because the resins are reinforced with glass fibers, the actual swelling of the composite structure will be considerably lower. The inner barrier liner will be more susceptible to expansion, but the fiberglass reinforcement will prevent outward expansion of the resin barrier layer. However, inward expansion may occur and this effect may result in softening or cracking, or other forms of damage. It is important to note that the specimens which cracked in the test fuels (Vipel F701 and F764) were composed of pure resin, and these resins are not designed for use without fiberglass reinforcement. Fiberglass, by itself, is insoluble and is used in composite structures to provide modulus and strength. Fiberglass reinforcement would resist fuel permeation and elongation in the composite structure. As a result the level of swell in FRP systems would be expected to be much lower than for the pure resin. However, the inner barrier layer of an FRP tank (or FRP piping) is not reinforced and may experience degradation in the form of softening, spalling, or cracking.

The estimated volume swell for Vipel F774 and Vipel F085 in E10 and E15 was calculated using the Hansen Solubility Parameter-based method employed for estimating the volume swell for the flexible plastic materials. These results are shown in Table 6, and show that for the Vipel F774 and F085 resins, the difference in calculated volume swell associated with E10 and E15 is low (around 1.5% for both resin types). This means that in all likelihood there will be minimal effect when moving from E10 to E15. However, there is potential for a big difference when moving from E0 to E10.

Table 6. Measured and calculated results for UST resins Vipel F774 and Vipel F085

Resin material	HSP ($MPa^{1/2}$)	Measured volume swell (CE25a)	Calc. Volume Swell for E15	Calc. Volume Swell for E10a	Estimated vol. increase associated with increasing ethanol from E10 to E15
Vipel F774	24.1	25.99	22.0	20.5	1.5
Vipel F085	24.1	22.99	19.5	18.1	1.4

The change in hardness results for the UST resins are shown in Fig. 11. For each resin type, the hardness dropped slightly with exposure to Fuel C, but CE25a was shown to significantly lower hardness in the wetted condition. Vipel F701 and Vipel F764 exhibited greatest drop hardness (31 and 20 points, respectively) from the original condition. These values are considered high and since hardness is a measure of strength and elastic modulus, it is not surprising that these two specimens exhibited fracture following exposure to CE25a. Interestingly, Vipel F774 also experienced a relatively large decrease in hardness of around 15 points. The combination of reduced volume swell and lower change in hardness (relative to the F701 and F764 resins) were enough to prevent fracture of the F774 resin. The most advanced resin grade, Vipel F085 exhibited the least change in hardness of the resins tested.

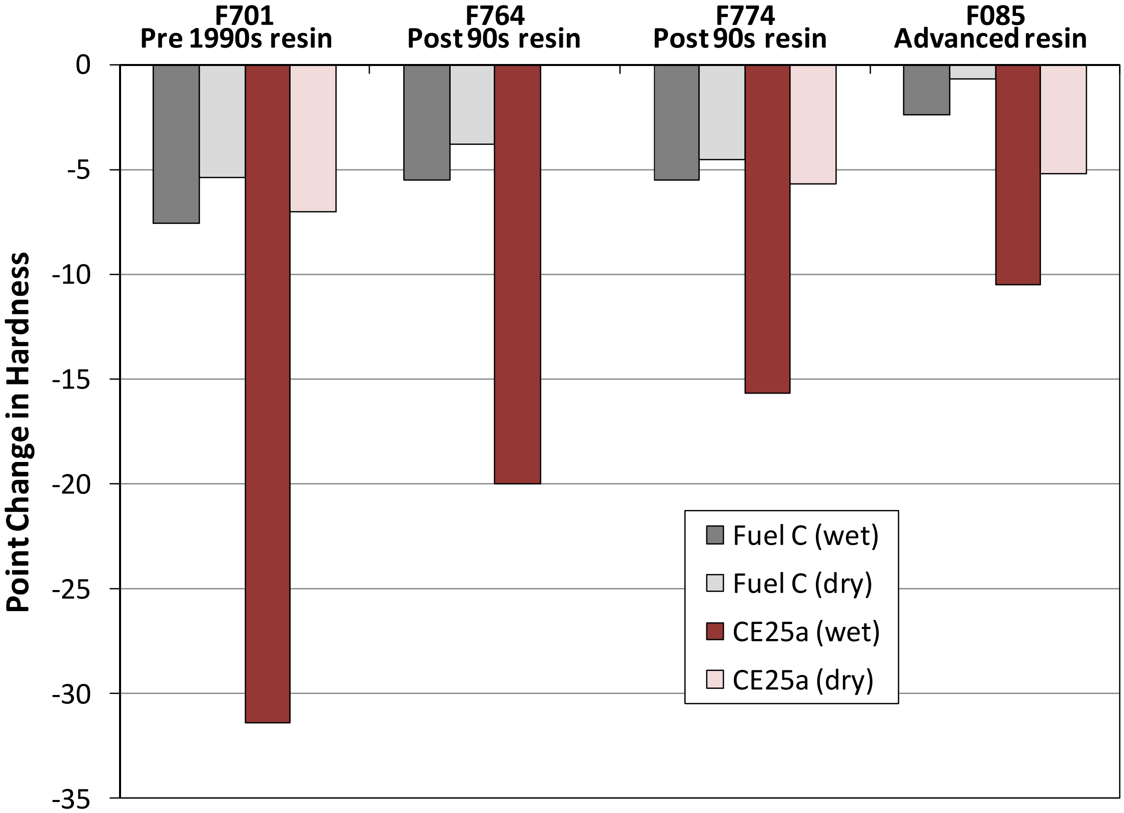

Fig. 11. Point change in hardness for the UST resin samples following exposure to Fuel C and CE25a.

Vipel F701 was used extensively in fiberglass reinforced USTs prior to 1990.[25] As such, it was designed primarily for gasoline use only and was not optimized for compatibility with ethanol-blended fuel. The volume swell and hardness decrease upon exposure to Fuel C would be considered acceptable for this resin type. F701 was replaced with more ethanol-resistant grades during the 1990s. Any legacy tanks composed of F701, or similar resin type, may be subject to ethanol degradation. Although the 30-year warrantee on tanks composed of F701 would have expired by now, many of these tanks are still in use. During the 1990s, many of the isophthalic resins were replaced by terephthalic-based and epoxy vinyl resins for improved performance.[28] The data provided by the materials compatibility testing shows that the terephthalic and vinyl resins are better suited for ethanol compatibility.

The ORNL intermediate-blend study also evaluated coupons taken from FRP underground storage tanks that had been removed from service. These tanks were cut into sections and sent to ORNL for evaluation. Photographs showing these specimens before and after exposure to the test fuels are shown in Figs. 12, 13, and 14. In each figure the baseline represents the unexposed sample.

Unfortunately the resin formulation of the UST sections was unknown, but the tanks were most likely pre-1990s vintage. Therefore, the resin formulations used in these tanks may not have been designed for use with ethanol-blended fuel. Over one dozen tanks were sectioned and sent to ORNL. All, except one, of these USTs were of amber coloration, similar to the pure resin coupons that were discussed previously, and nearly identical in appearance. There was one set of tank sections that was unique in that it was the only UST to have a corrugated plastic film adhered to the inner surface and was dark green in coloration. Test coupons were cut from three UST sections, which were labeled Batch 1, Batch 2, and Batch 3. Both

Batch 1 and Batch 2 were identical in appearance and of amber coloration, while Batch 3 was taken from the green section, which also contained the plastic film. Batch 3 was chosen since it represented an arrangement and coloration different from the rest.

Three coupons from each UST were evaluated in Fuel C, CE50a and CE85a test fuels. (The UST sections were not included in the earlier CE10a, CE17a, or CE25a test fluids, since this activity was started after these studies were completed.) These coupons were exposed in the test fluids for 16 weeks at 60°C along with other plastic specimens.

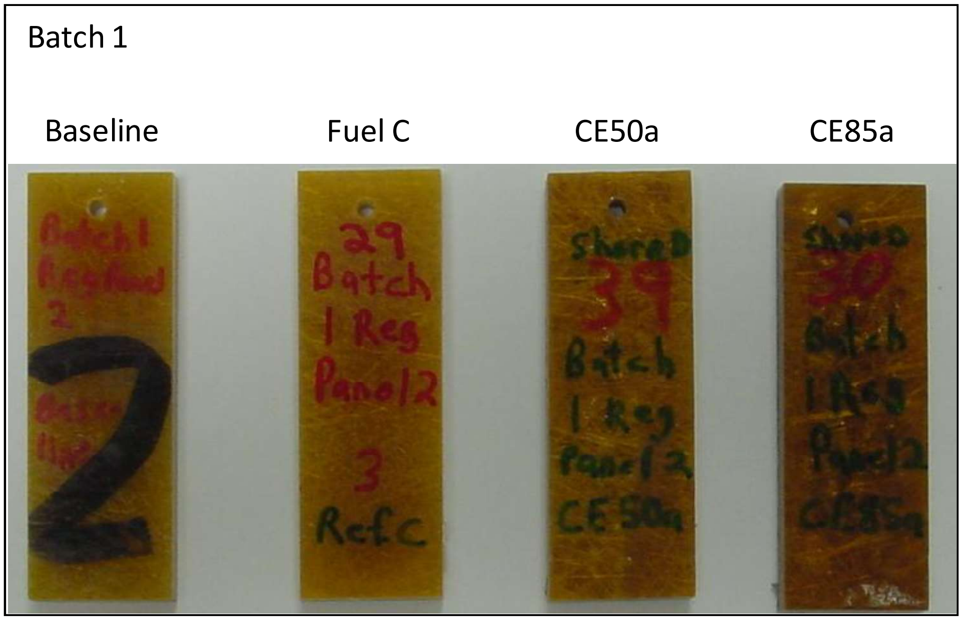

Fig. 12. Photograph showing the Batch 1 specimens before and after exposure to Fuel C, CE50a, and CE85a.

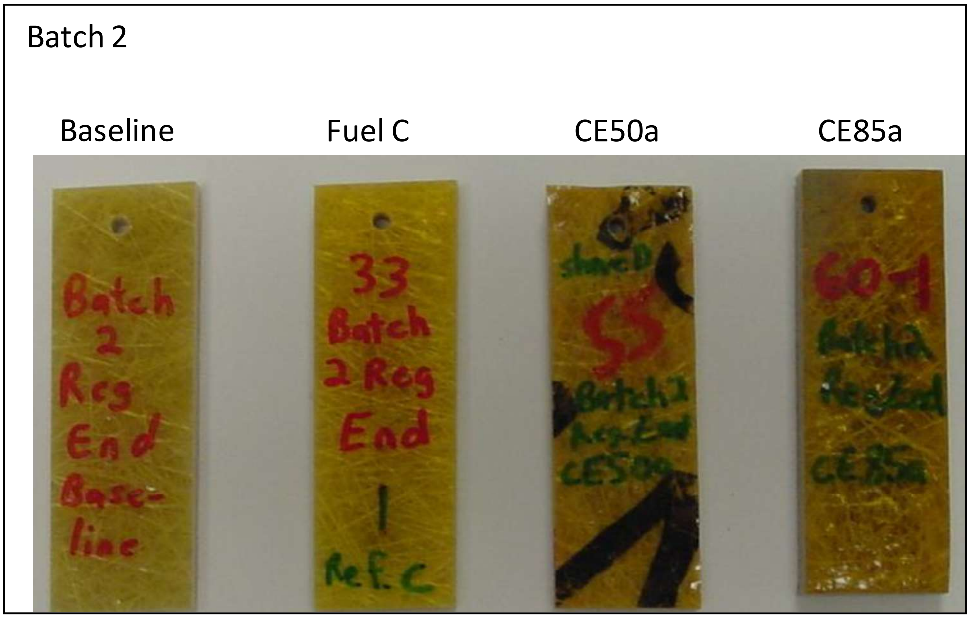

Fig. 13. Photograph showing the Batch 2 specimens before and after exposure to Fuel C, CE50a, and CE85a.

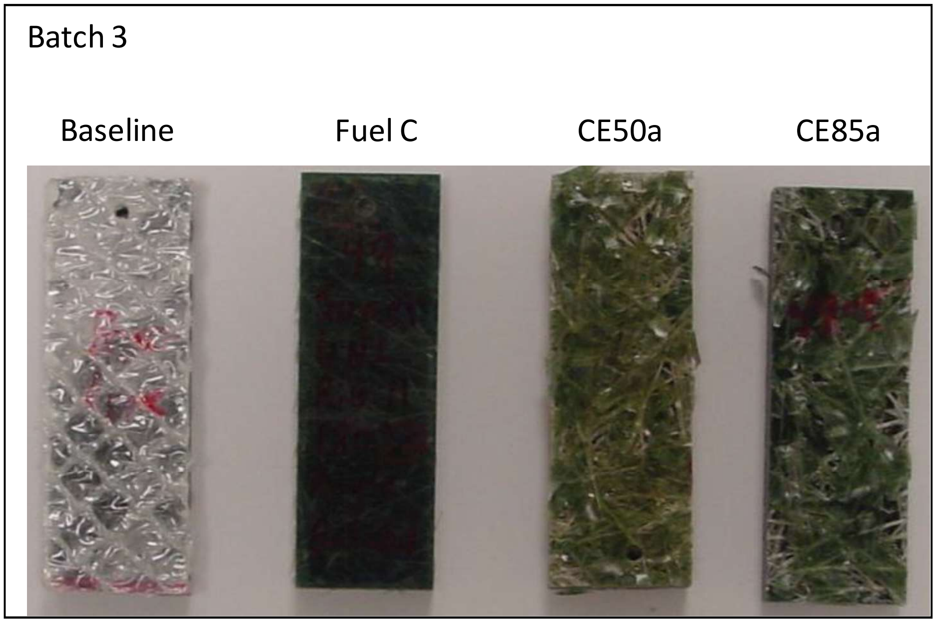

Fig. 14. Photograph showing the Batch 3 specimens before and after exposure to Fuel C, CE50a, and CE85a.

The photographs shown in Figs. 12 and 13 reveal that the amber resin specimens (Batch 1 and Batch 2) did not experience any observable degradation (outside of a slight change in color) from exposure to ethanol. However, the Batch 3 specimens (shown in Fig. 14) experienced massive degradation from the CE50a and CE85a test fuels. For this design, the corrugated liner was debonded by the Fuel C and the aggressive ethanol fuels. Interestingly, this liner survived exposure to the test fuels. However, the inner resin layer was removed and the resin surrounding the fiberglass reinforcement had dissolved to the extent that the fibers were completely exposed. It is important to note that, as depicted in Fig. 3, epoxy-based resins are likely to be more soluble in CE50a and CE85a fuels than for intermediate E10 and E15 levels. Therefore it is expected that the Batch 1 and Batch 2 USTs will be compatible to gasoline containing intermediate levels of ethanol. However, if the corrugated liner of the Batch 3 UST was damaged or breached, then it is likely that this UST has a high risk of leaking.

3. ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

3.1 ELASTOMERS

Although elastomers are ubiquitous in fuel dispenser components, especially as hoses and seals, they are not used extensively as primary piping materials in either FRP or flexible piping systems. However, these elastomers could be used as gaskets and seals in the submersible tank pump head. A survey of piping and coupling manufacturers listed Viton fluorocarbon as the only o-ring material sold today for use in couplings and fittings for gasoline delivery systems.[31] Other elastomer types were not mentioned as coupling materials for current and new UST piping systems, although they may be prevalent in legacy systems. Of the elastomers evaluated in the ORNL intermediate-blend materials compatibility study, fluorocarbons were found to be the most compatible to ethanol. The other elastomers, in particular nitrile rubbers (NBRs), showed moderate but significant increases (10-12%) in swell and increased softening with exposure to aggressive ethanol as shown in Fig. 15. However, the additional increase associated with CE17a exposure (compared to CE10a) was small (5 to 8%).

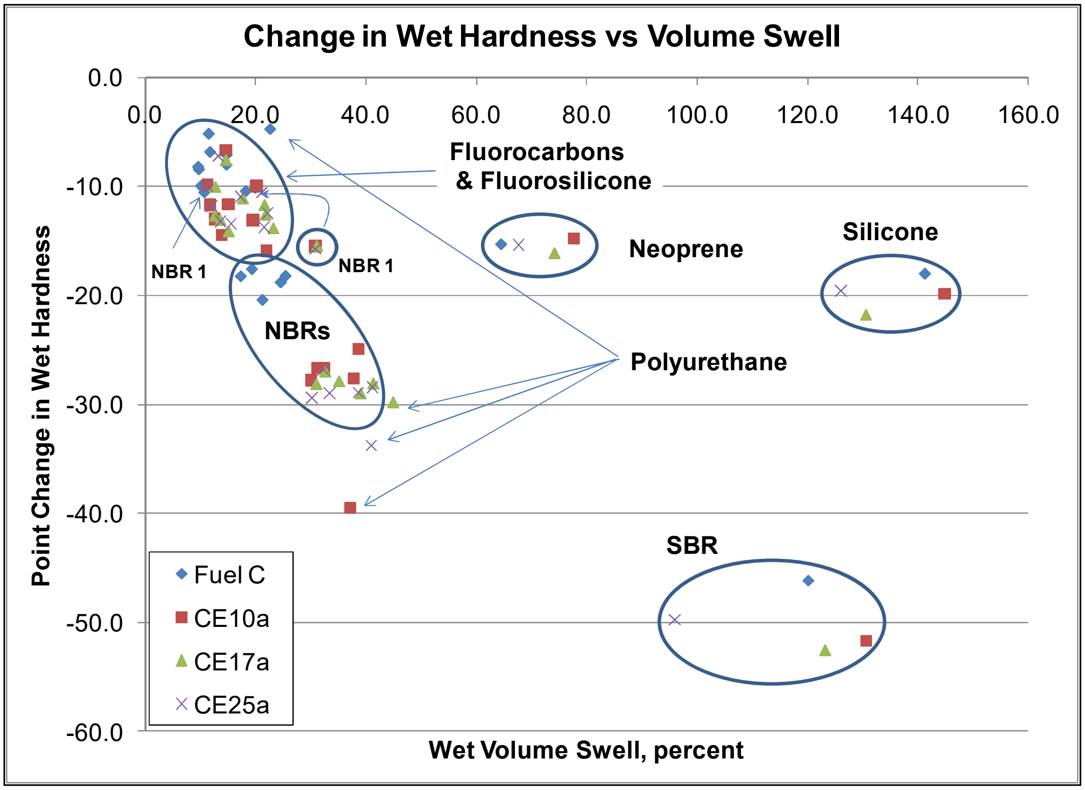

Fig. 15. Volume swell and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a.

During dry-out, elastomers such as NBR and neoprene exhibit moderate shrinkage and embrittlement (see Fig. 16) which is attributed to extraction of the plasticizer components. However the level of shrinkage or mass reduction associated is constant and independent of ethanol content. As a result, the increase in leak potential among the elastomers when moving from E10 to E15 is expected to be low. However, these materials (especially NBR, neoprene, and SBR) will exhibit a high increase in swell when moving from E0 to E10 (or E15). Therefore, care must be taken when placing ethanol-blended gasoline into a system that had only contained gasoline.

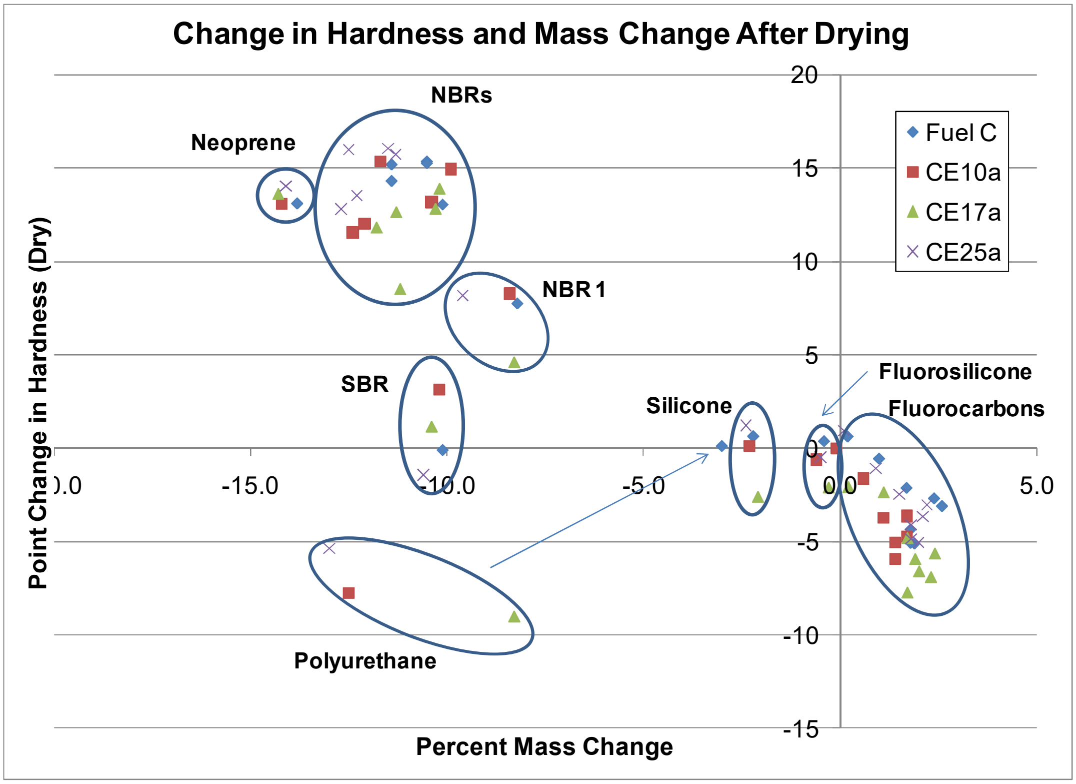

Fig. 16. Percent mass change and point change in hardness for elastomers exposed to Fuel C, CE10a, CE17a and CE25a following dry-out.

It is important to note that these elastomers are used solely as seals (i.e., o-rings, gaskets, etc.) and are not utilized as structural materials for UST systems. Additional swell for o-rings and gaskets in some cases does not degrade seals or diminish sealing potential, and may, to a small degree, improve the performance of the seal. These materials are not recommended for use as structural components of piping and UST systems, since even moderate levels of swell will create internal stresses which, even at low levels, can significantly reduce the lifecycle and durability of a component.

3.2 PIPE THREAD SEALANTS

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™) were originally developed for E0 use and were used extensively in legacy piping systems. These sealants have been shown to be incompatible for use with alcohols. In the ORNL intermediate-blend materials compatibility study, RectorSeal™ was shown to be incompatible with CE10a. This result strongly indicates that the pipe thread sealants used in the E0 legacy systems experienced leaking when exposed to E10. Ethanol compatible sealants such as GasOila ESeal™ were subsequently developed for ethanol-blended gasoline use and are now the industry standard. The ORNL study showed that the GasOila ESeal™ product is compatible with fuel containing up to 25 percent aggressive ethanol. It is very likely that the standard PTFE sealants used in the legacy systems were replaced with the ethanol-compatible products during the implementation of E10. There is no hard data to support this assessment, but based on the development and widespread use of the GasOila product, it appears to be the case. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, we do not foresee any added potential for releases when switching from E10 to E15.

3.3 COUPLINGS AND FITTINGS

One of the most susceptible locations of the underground storage tank systems are the couplings used to connect piping, fittings, and valves. There are two potential sources of leaks. One is where the coupling attaches to the piping and the other one is at the seal interface mating two couplings together. The interfacial seal issue was discussed under the elastomer section and is not considered to be a significant point of release if seals and gaskets are made of fluorocarbon materials and are properly installed.

Flexible plastic piping typically utilizes swage-type fittings to join piping and connect valves and flanges. A typical coupling assembly consists of a stainless steel insert with one or two o-rings, a stainless steel ferrule with one o-ring, and a swivel nut (or other means) to compress the ferrule against the outer pipe surface.[31] A simplified schematic is shown in Fig. 17. The compression of the plastic between the stainless steel insert and ferrule maintains a leak tight seal. In this configuration, the fuel is only exposed to the plastic piping, stainless steel coupling and the o-ring used to seal the coupling adjacent faces. Newer units were found to utilize fluorocarbon as the o-ring material, although legacy couplings may use other elastomers (such as NBR). These couplings usually require a special tool (from the piping supplier) to install properly. It is important to note that couples for FRP piping cannot be installed in this manner because the hard resin would fracture under high compression.

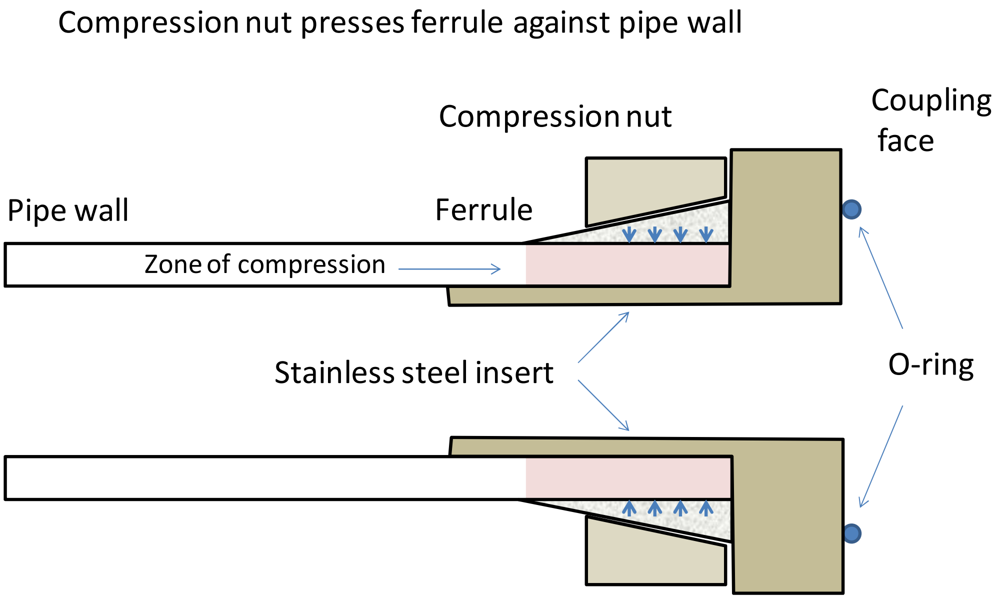

Fig. 17. Simplified schematic showing attachment of a coupling to flexible plastic piping.

The two most common methods for joining FRP piping and attaching couplings are adhesive bonding and butt and strap joints.[32] The butt and strap method is considered the most reliable means for joining FRP piping. Two pieces of pipe are butted together and layers of chopped fiberglass are wrapped around the pipe in a resin matrix similar to the pipe composition. A diagram depicting a butt and strap joint is shown in Fig. 18. If the butt and strap materials are similar or identical to the pipe materials, then compatibility performance is expected to be essentially the same and thus potential for further degradation due to E15 is minimal.

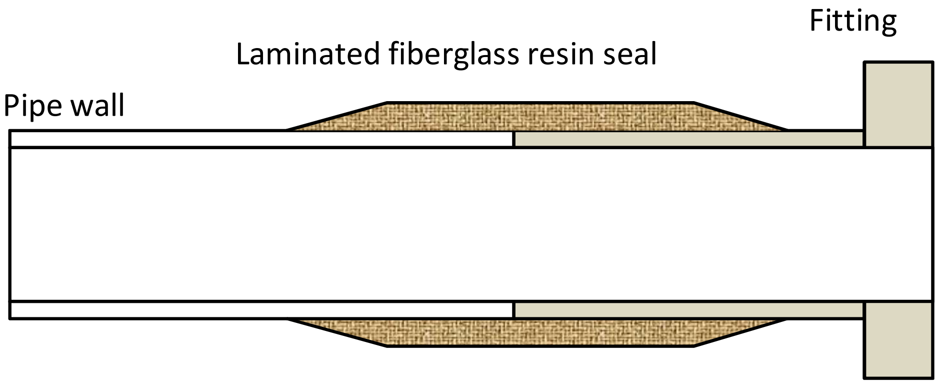

Fig. 18. Schematic diagram of the butt and strap joint.

The adhesive method involves adding an adhesive to glue a fitting or coupling to FRP. Because of its inherent weakness, this method is not used to join pipe sections, but is restricted to attaching fittings (such as flanges). Typically the outer surface of the pipe is sanded to allow better distribution of the sealant and to enable the adhesive to better grip the pipe surface and thereby form a strong mechanical bond. One application of this method is shown in Fig. 19. The adhesive maintains a seal between the fitting and the pipe end. At the fitting face, the adhesive will be exposed to fuel in the crevice region between the adjacent pipe ends. For some applications, the outer pipe walls are tapered at the ends to enable better fit between the pipe wall and fitting.

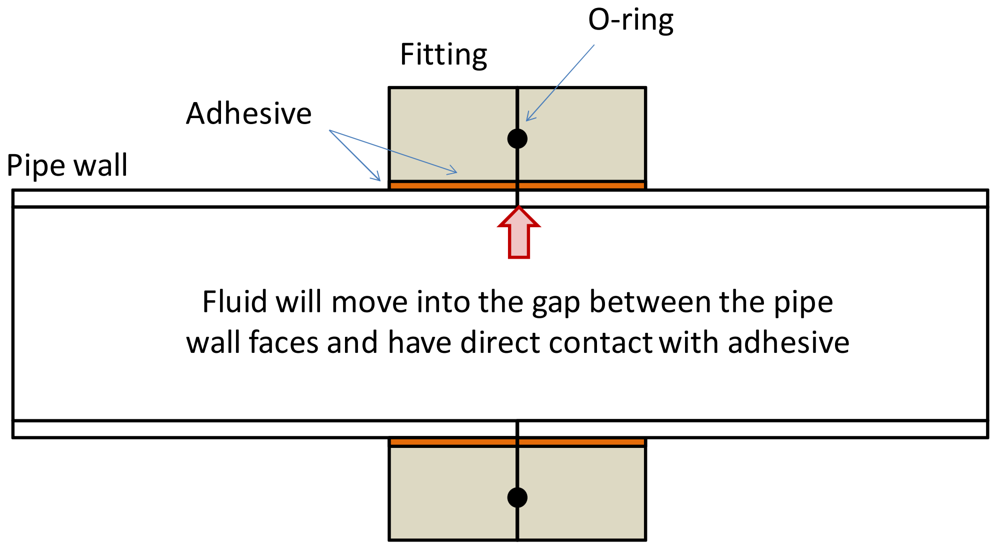

Fig. 19. Schematic showing a common arrangement of using adhesive on FRP piping.

The adhesives used for FRP systems contain a mix of inorganics (over 50%), such as clay, limestone, and silica and a mix of hydrocarbons.[33] The inorganic fraction imparts strength, rigidity and is resistant to attack from aggressive fuel components (including alcohols). The remaining hydrocarbons consist primarily of acrylic polymers, resins and distillate products. Information pertaining to adhesive resistance to ethanol was lacking and we were not able to ascertain ethanol compatibility.

4. CONCLUSIONS

The USEPA Office of Underground Storage Tanks commissioned a study at ORNL to evaluate whether an increased potential for leaking of USTs will occur when moving from E10 to E15 fuel. The original intention was to construct a probabilistic failure analysis tool to estimate the increase in releases, if any, if E15 replaced E10 in regulated UST systems. A key part of this process was to solicit opinions from a panel of industry and regulatory experts to identify critical variables that impact failure likelihood estimates. However, the lack of information on the performance of existing UST systems with E15 precluded the possibility that state/industry experts could speculate on E15's impact to UST systems. Therefore, the project objective was redirected to address the added leak potential (or incompatibility) of UST system materials when moving from E10 to E15. The data used to make this assessment were obtained primarily from the ORNL intermediate blend compatibility study. This study included metal and polymeric materials typically used in UST systems, and these materials were evaluated in aggressive test fuel formulations representing E0, E10, E15, E25, E50 and E85. Potential leak locations, such as pipe couplings were identified, and the elastomers and sealants used in couplings and joining were also studied.

4.1 CONCLUSION ON TANKS AND PIPING MATERIALS

Metallic materials included carbon and stainless steel and aluminum. A large number of USTs are composed of carbon steel, which is also used in approximately 18% of piping. Stainless steel is used in pipe couplings which are used to join piping sections and fittings. Aluminum, while not used as extensively as either carbon or stainless steels, is used in the construction of submersible pumps. However, failure of a submersible pump should not lead to leaking. The results from the ORNL intermediate-blends compatibility study showed that carbon and stainless steels, and aluminum will not undergo significant corrosion in either E10 or E15. However, it is important to note that the test conditions for these materials did not include stress or water-phase separation, both of which can contribute to increased corrosivity. In fact, if aqueous phase separation occurs, then the risk for corrosion will be higher for E15 since the maximum level of dissolved water is roughly twice that of E10.

Plastics are used extensively in underground piping systems. The two types of plastic piping, flexible and FRP, employ different types and grades of plastic materials. Flexible piping is primarily composed of various grades of nylon, PVDF, PET, polyester, and polyethylene. These materials were only tested in Fuel C and CE25a. As a result, the volume change, associated with CE10a and CE15a exposure, was estimated using the known swelling behavior at CE25a and Hansen Solubility Parameters for the plastics and test fuels. Nylon 11 exhibited the highest level of swelling (~18%) and would likely not be considered acceptable for use in USTs or flexible piping systems. Likewise, nylon 12 also may not be acceptable due to the significant loss of mass after drying. Other plastics, such as HDPE, F-HDPE, nylon 6 and nylon 6/6 exhibited relatively high swell (8-10%) and may not be suitable when switching from E0 to either E10 or E15. However, the calculated swell for nylon 6, nylon 6/6, PVDF, PET, and polyethylene indicated that the added increase in swell when moving from E10 to E15 was very low. This result suggests that the leak potential in E15 for flexible piping containing these materials will be low as well.

The performance of resins used in the construction of FRP tanks and piping is highly dependent on the type of resin. A pre-1990 legacy isophthalic polyester resin was visibly damaged with exposure to a test fuel containing 25% aggressive ethanol. Analysis of post-1990s resins (exposed to CE25a) were mixed; the resin composed of isophthalic polyester was damaged, while the resins composed of terephthalic polyester or vinyl ester were not. Interestingly, the two resins that were damaged from exposure to ethanol were both isophthalic polyesters. Based on these results, isophthalic polyester resins should be avoided in the construction of UST systems storing ethanol-blended fuels. The predicted level of volume swell associated with E10 and E15 was calculated for the terephthalic polyester and vinyl ester resins. The results suggest that the added volume swell associated with E15 (compared to E10) is extremely low and would not likely increase the potential for leaking with E15 fuel. ORNL was able to include three legacy UST samples in a later compatibility effort using CE50a and CE85a as test fuels. In one unique case, a legacy FRP UST that contained a separate plastic liner exhibited significant degradation of the resin material when exposed to high levels of ethanol. Although the liner was not visibly damaged, its performance with lower intermediate levels of ethanol-blended gasoline could not be ascertained. The other two UST sections were not damaged and would likely exhibit good compatibility with E10 or E15.

4.2 CONCLUSION ON ELASTOMERS, SEALANTS, COUPLINGS AND FITTINGS

A high leak potential also exists where piping sections are joined and fittings are attached. The structural material typically used in these applications is stainless steel and the sealing materials are either elastomers and/or pipe thread sealants. Modern joining units employ primarily fluorocarbons in o-ring and sealing applications; however some legacy systems may use NBRs and other elastomer types. The ORNL intermediate-blend ethanol compatibility study investigated the performance of fluorocarbons, fluorosilicone, NBRs, silicone rubber, styrene butadiene rubber, neoprene and polyurethane. These elastomers all showed significant swelling with exposure to ethanol. However, because elastomers are used solely as seals (i.e., o-rings, gaskets, etc.), swelling is not necessarily an indication of leak potential. Additional swell for o-rings and gaskets may improve the performance of the seal. Except for polyurethane (which is used as a coating rather than as a seal), the elastomers and sealants evaluated in the ORNL intermediate-blend materials study showed no significant increase in swell and softening when moving from E10 to E15. Therefore, for field applications and materials examined in this study, there should not be any corresponding potential for releases associated with increase the ethanol concentration in fuel gasoline from E10 to E15. The flanges used in coupling systems are composed of stainless steel and this material has been shown to have excellent compatibility with ethanol-blended fuels.

Pipe thread sealants are used for metal piping and some FRP piping systems. Standard PTFE sealants (such as RectorSeal™), used in E0 applications, were shown to be incompatible for use with E10. However, ethanol-compatible sealants (such as GasOila ESeal™) were compatible with fuel containing up to 25 percent aggressive ethanol. Although it is very likely that standard PTFE sealants used in legacy systems were replaced with the ethanol-compatible products during the implementation of E10, there may be systems still in use with the incompatible sealant material.

FRP piping joined using either a butt and strap configuration or an adhesive is used to secure a fitting on one end. The butt and strap consists of a FRP wrap that contains resin similar or identical to the FRP pipe resin, and therefore, should be compatible with ethanol-blended fuel. Adhesives consist of a mix of various organic and inorganic materials, and we could not assess their compatibility to ethanol since they were not included in the ORNL intermediate-ethanol blends compatibility study.

In general, several materials evaluated in this study were found to not perform well in fuel blends containing ethanol. These materials demonstrated incompatibility with E10 and should not be used for E15 (unless it can be demonstrated that a particular polymer grade is, in fact, compatible). Systems most susceptible to increased leakage will be those legacy USTs which are currently using E0 and will be switching directly to E15.

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Exhibit 9

UST Component Compatibility Library

In 2015 EPA published guidance regarding compatibility of underground storage tank (UST) systems with biofuel blends. The guidance discusses how owners and operators who wish to store gasoline containing more than 10 percent ethanol or diesel containing more than 20 percent biodiesel in their UST systems may demonstrate compliance with the compatibility requirement in 40 CFR 280.32. **Learn More**

Underwriters Laboratory has developed a fuel compatibility tool to assist manufacturers and fueling stations to meet EPA, state and other code fuel compatibility requirements. **UL Fuel Compatibility Tool**

Compliance Letters by Manufacturer

Acterra

Bravo Systems

- Fittings
- Sumps

Brugg Pipesystems

Caribbean Tank Technologies

Containment Solutions

Eaton

General Industries

Hamilton Tanks

Highland Tank

Icon Containment Solutions

J.L. Houston

KPS

Lancaster

Metal Products Company

Mid-South Steel

Modern Welding

- Biofuels
- Isobutanol

Morrison Bros.

- Ethanol
- Biodiesel

National Environmental Fiberglass

NOV Fiber Glass Systems

Nupi Americas

Omegaflex

Owens Corning

Petroleum Containment Inc.

Plasteel

Service Welding

Southern Tank

Stanwade

Steel Tank Institute

Tanques Antillanoes

TIPSA

Vaporless Manufacturing, Inc.

Watco Tanks

We-Mac

Western Fiberglass

Xerxes

EPA has determined that owners and operators must demonstrate that the following UST components are compatible with the fuel to be stored:

- Tank

- Piping
- Containment sumps
- Pumping equipment
- Release detection equipment
- Spill prevention equipment
- Overfill prevention equipment

Manufacturers who would like to be included should email their compatibility statements to **info@pei.org**. Preferred format is Adobe Acrobat PDF. When submitting, please note that your compatibility statement should:

1. Be on your company letterhead
2. Be signed by an officer of the company
3. Include the four elements required by EPA:
    - In writing
    - An affirmative statement of compatibility;
    - Specify the range of biofuel blends with which the component is compatible;
    - Be directly from the equipment manufacturer, not another entity (such as the installer or distributor)
4. Include complete contact information for the signing officer, in the event a user has questions
5. Be titled in as clear a manner as possible to help users quickly identify which components are covered in the statement.

Note: Just as a public library collects books without making any judgment on the appropriateness, accuracy, completeness or suitability of any of the volumes it maintains, PEI makes no judgment on the appropriateness, accuracy completeness or suitability of any statement included in the UST Compatibility Library. The Library is simply a repository of what has been submitted.

Please also remember that participation in the Library is voluntary. So, while we've worked to encourage as much participation as possible, PEI cannot guarantee that the Library is a complete listing of all approved products.

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Exhibit 10

ASTSWMO Compatibility Tool

About this Tool

This tool assists users in identifying UST system components that are compatible with specific motor fuels and biofuel blends containing greater than 10 percent ethanol and diesel containing greater than 20 percent biodiesel. The majority of the information included comes directly from equipment manufacturers and ASTSWMO is not responsible for the accuracy or completeness of any information provided by other parties.

The tool has multiple features:

1. Users can review compatible UST system components by fuel type. This information is based on manufacturer compliance letters.
2. Users can review compatible UST system components by manufacturer. (Under Construction)
3. Users can submit data to ASTSWMO on compatible UST system components for inclusion in this tool.

Review Compatible UST System Components by Fuel Type

Fuel Type (Select 1)

○ Diesel Blends (>B20)
○ Ethanol Blends (>E10)

Component (Select 1)

Select Component ⌄

Submit

Results:

Review Compatible UST System Components by Manufacturer (Under Construction)

Manufacturer (Select 1)

Select Manufacturer ⌄ Submit

Results:

Submit New or Update Current Data in Tool.

Use the form below to provide new documentation for inclusion into this tool, update current information, or if you observed errors.

Your Name

Agency/Organization

Email

Description of your submittal (if new documentation provide manufacturer, UST system component(s), and fuel type(s).)

Upload Document (PDF only)

Choose File No file chosen Submit

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Exhibit 11

Analysis of Ethanol-Compatible Fleet for Calendar Year 2022
Air Improvement Resource, Inc.

November 16, 2021

This study evaluates the size of the market that can consume E15 (a mixture of 15% ethanol and 85% gasoline (by volume) in calendar year 2022 in the U.S. The study computes the share of vehicles on the road in calendar year 2022 that can legally use E15. This is a combination of flex-fuel vehicles (FFVs) and non-FFVs of model years 2001 or later ("MY2001+"), since all FFVs are approved to use E15 regardless of model year, and all MY2001+ non-FFVs have been approved by EPA to use E15.

Vehicles on the Road in Calendar Year 2022 that Can Legally Use E15

A. FFVs on the Road

According to the U.S. Energy Information Administration's Annual Energy Outlook for 2021 (hereafter referred to as AEO2021), there are expected to be 20.409 million FFVs on the road in calendar year 2022, as shown in Table 1.[1]

Table 1. "Ethanol-Flex Fuel ICE" Stock (millions) in Calendar Year 2022

LDVs	LDTs	Total
4.673	15.736	20.409

B. Vehicles on the Road Approved for Use of E15

In October 2010, the U.S. Environmental Protection Agency (EPA) approved a waiver permitting the use of E15 (a gasoline mixture containing 15% ethanol) in model year 2007 and newer autos (light duty motor vehicles, LDVs) and light duty motor trucks (LDTs). In January 2011, the EPA extended the waiver to permit the use of E15 in 2001 to 2006 model year autos and light duty trucks. Thus, all MY2001+ vehicles may use E15. Of course, FFVs are also permitted to use E15, regardless of model year. E15 is not allowed in MY2000- non-FFVs.

We used the MOVES3.0.2 model September 2021 version) to estimate the percentage of MY2001+ vehicles on the road in calendar year 2022. This analysis was performed for 3 different parameters – population, vehicle miles traveled (VMT), and energy.[2] Results are shown in Table 2.

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[1] Annual Energy Outlook 2021 With Projections to 2050, U.S. Energy Information Administration, https://www.eia.gov/forecasts/aeo/index.cfm

[2] All 3 parameters were obtained from MOVES3 output.

Table 2. Analysis of Fleet by Model Year by Percentage				
Calendar Year	Parameter	Class	MY2000- (%)	MY2001+ (%)
2022	Population	LDV	3.33	96.67
		LDT	4.09	95.91
		Combined	3.68	96.32
	Vehicle Miles Traveled	LDV	1.75	98.25
		LDT	2.16	97.84
		Combined	1.95	98.05
	Energy	LDV	2.26	97.74
		LDT	2.91	97.09
		Combined	2.61	97.39

Table 2 shows that 96.32% of the combined LDV plus LDT on-road fleet are vehicles from the 2001+ model year group. Further, these vehicles accumulate 98.05% of the vehicle miles traveled, and use 97.39% of the energy of the on-road LDV+LDT fleet.

AEO2021 further shows that there are 257.161 million LDVs and LDTs on the road in 2022, of which 254.600 million are capable of using gasoline. If we subtract the FFVs from Table 1, we obtain 234.190 million. Table 3 shows these non-FFVs divided into model year 2000 and earlier, and model year 2001+, using the population fractions from Table 2.

Table 3. MY2000- and MY2001+ Non FFV LDV+LDT Populations in Calendar Year 2022			
Calendar Year	Non FFV LDV+LDT Population (millions)	MY2000- (millions)	MY2001+ (millions)
2022	234.190	8.668	225.522

The total number of vehicles available to use E15 is then the FFVs, plus the 2001+ non-FFVs from Table 3. This value is 20.409 million plus 225.522 million, or 245.931 million vehicles.

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Exhibit 12

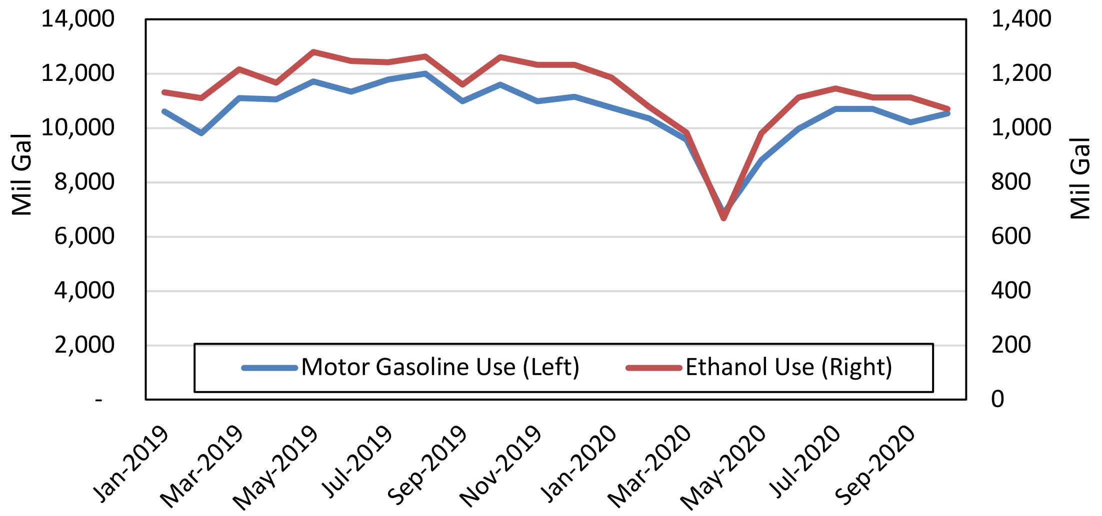
ABF Economics
Agriculture and BioFuels Consulting, LLP

CONTRIBUTION OF THE ETHANOL INDUSTRY TO THE ECONOMY OF THE UNITED STATES IN 2020

Prepared for the Renewable Fuels Association by
John M. Urbanchuk
Managing Partner, ABF Economics
February 2, 2021

The U.S. ethanol industry was slammed by the COVID-19 pandemic in 2020. The impact of the pandemic overshadowed most other issues facing the industry during the year. The widespread shelter-at-home orders in the Spring essentially shut the U.S. economy down, people stopped driving and both gasoline and ethanol demand fell sharply. As illustrated in Figure 1, the low point in demand was reached in April 2020 as motor gasoline and domestic ethanol demand fell by 38 and 42 percent from year earlier levels, respectively.

Figure 1
U.S. Motor Gasoline and Domestic Ethanol Demand



Source: EIA

As the economy slowly reopened in the second half of the year demand picked up but didn't recover to pre-pandemic levels and remained about 12 percent below year ago through October.

Ethanol producers responded to the collapse in demand by reducing operating rates, shutting plants, and idling capacity. According to the Renewable Fuels Association 45 percent of industry capacity was idled in April and May 2020. By year end roughly two dozen facilities were idle, and the industry was operating on an approximately 85 percent capacity utilization rate.

The weak and unsettled demand conditions undercut investment in the industry in 2020. While total capacity increased as capital expenditures in 2019 came online, relatively little new expenditures for expansion were made during 2020. Additionally, biofuels research and development activities were curtailed by COVID-related closures both in the public and private sectors.

The two other major factors impacting the ethanol industry in 2020 were weak export demand and regulatory issues. Both were overshadowed by the pandemic but nonetheless acted as a drag on the ethanol industry.

- Ethanol exports dropped sharply during the second half of the year as COVID affected motor fuel use in importing countries. Exports to the two largest U.S. markets – Canada and Brazil – fell with the largest decline posted by Brazil. Year-to-date exports of ethanol were 7 percent below 2019 levels through November and are projected to decline about 10 percent for the full year. The decline in volume was somewhat offset by higher export prices but the net impact was still adverse.
- On the regulatory front, the use of Small Refinery Exemptions (SREs) continued to be an impediment to increasing demand. Under the Trump Administration, refiners were relieved of 4 billion gallons of RFS blending obligations for compliance years 2016-2018, a sixfold increase over the volume exempted during the previous three years.[1] This resulted in a

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[1] Ethanol-equivalent gallons, or RINs, for exemptions granted through Dec. 2020. Does not include an additional 2018 exemption and two 2019 exemptions (of the 32 pending for 2019) granted in Jan. 2021. https://www.epa.gov/fuels-registration-reporting-and-compliance-help/rfs-small-refinery-exemptions

massive expansion of inventories of renewable identification numbers (RINs), the credits used to demonstrate compliance with the RFS, which refiners could use instead of blending physical gallons of biofuels.

According to the Renewable Fuels Association (RFA), at year's end the ethanol industry's 209 plants had a total capacity of 17.4 billion gallons. However, due to the factors discussed above, ethanol production for 2020 is estimated at 13.85 billion gallons, 12.2 percent below 2019 levels. Conventional feedstocks (e.g., corn and sorghum) accounted for the vast majority of ethanol production.

Despite these challenges, the ethanol industry continues to make a substantial positive contribution to the American economy. This study estimates the contribution of the ethanol industry to the American economy in 2020 in terms of employment, income, and Gross Domestic Product (GDP) directly and indirectly supported by the industry.

Expenditures by the Ethanol Industry in 2020

Ethanol producers are part of a manufacturing sector that adds substantial value to agricultural commodities produced in the United States and makes a significant contribution to the American economy.

Expenditures by the ethanol industry for raw materials, other goods, and services represent the purchase of output of other industries. The spending for these purchases circulates through the local and national economy, generating additional value-added output, household income, and employment in all sectors of the economy.[2] Ethanol industry expenditures can be broken into three major categories: construction of new production facilities, ongoing production operations, and research and development.

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[2] Expenditures for feedstock and energy were estimated using year-to-date 2020 calendar year average prices. Revenues were estimated using 2019 calendar year average prices for ethanol, Distiller's grains, and Distillers' corn oil. Prices were provided by USDA/ERS and AMS, and EIA.

1. Construction

   Industry capacity during 2020 expanded by about 500 million gallons largely as a result of capital expenditures made in the prior year. COVID-related closures and reduced operating rates reduced capital expenditures to an estimated $222 million in 2020, representing about 127 million gallons of capacity.

2. Ongoing production operations

   The industry spent $21.4 billion on raw materials, other inputs, and goods and services to produce ethanol during 2020, nearly 19 percent less than a year ago. The decline in production costs reflected by lower production and feed stock use and lower feedstock (corn) and energy prices. Production costs were based on a model of dry mill ethanol production maintained by the author of this report. These estimates are consistent with generic dry mill ethanol costs, such as those published by Iowa State University.[3] Table 1 details the expenditures by the ethanol industry in 2020.

Table 1
Estimated Ethanol Production Expenditures, 2020

Operating Costs	2019 Mil $	2020 Mil $	% CHG
Feedstock (corn)	$20,215	$16,405	-18.8%
Enzymes, yeast and chemicals	$1,199	$1,053	-12.2%
Denaturant	$350	$213	-39.1%
Natural Gas, electricity, water	$2,761	$2,050	-25.8%
Direct labor	$599	$565	-5.7%
Maintenance & Repairs	$502	$449	-10.6%
Transportation	$145	$130	-10.3%
GS&A	$598	$535	-10.5%
Total Operating Costs	$26,369	$21,400	-18.8%
$/Gallon	$1.67	$1.55	-7.6%

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[3] See the Ethanol profitability spreadsheet maintained by Don Hofstrand "AgDecision Maker D1-10 Ethanol Profitability" available at http://www.extension.iastate.edu/agdm/energy/xls/d1-10ethanolprofitability.xlsx

The largest share of spending was for corn and other feedstocks used as raw material to make ethanol. The ethanol industry used 4.8 billion bushels of corn (and corn equivalent) on a gross basis in 2020, valued at $16.4 billion. Reflecting this, the ethanol industry continues to be a major source of support for agricultural output and farm income. Together, feedstock and energy accounts for about 85 percent of ethanol production costs.

This analysis estimates both the total production effect and the crop price (farm income) effects of ethanol production on agriculture based on a structural model of U.S. agriculture maintained by the author. The impact of demand for corn to produce ethanol on farm income was adjusted so as to not overstate the impact of ethanol demand on revenue for the corn sector.

The remainder of spending by the ethanol industry for ongoing operations is for a range of inputs such as enzymes, yeast and chemicals; electricity, natural gas, and water; labor; transportation; and services such as maintenance, insurance, and general overhead.

3. Research and Development

The renewable fuels industry is a significant engine for research and development (R&D) both in the public and private sectors. Much of the R&D activity in the biofuels industry is aimed at discovering and developing advanced biofuels feedstock and the technology needed to meet RFS2 targets for cellulosic and advanced biofuels. The primary public-sector agencies underwriting R&D in biofuels are the U.S. Departments of Energy (USDOE), Agriculture (USDA), and Defense (DOD). In addition to the federal government, many states are funding R&D in feedstock development as well as infrastructure. These public funds typically are leveraged by private sector firms undertaking research in a wide range of biofuels activities. The disruptions to economic activity caused by the pandemic have likely had an adverse impact of R&D spending during 2020. We have assumed that R&D spending on biofuels declined sharply during 2020. Reflecting this we estimated that industry R&D outlays totaled less than $150 million in 2020

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4. Co-product value
   Most ethanol is produced by dry mills that also produce valuable co-products in the form of distiller's dried grains DDGS and distiller's corn oil (DCO).[4] There is significant ongoing research directed at improving these co-products, notably DDGS, to increase inclusion rates in swine and poultry and enhancing suitability as a feed ingredient in markets such as aquaculture. The ethanol industry produced an estimated 32.2 million short tons of DDGS and nearly 3.2 billion pounds of DCO in 2020 with an aggregate market value of $6.1 billion. Increases in DDGS and DCO prices in 2020 helped offset lower ethanol prices.

Spending associated with ethanol production, expansion and new construction activity, and R&D circulates and re-circulates throughout the entire economy several-fold, stimulating aggregate demand, and supporting jobs and household income. The economic activity associated with export activity adds to this impact. In addition, expanded economic activity generates tax revenue for government at all levels.

Methodology

We estimate the impact of the ethanol industry on the American economy by applying expenditures by the relevant supplying industry to the appropriate final demand multipliers for value added output, earnings, and employment.

To understand how the economy is affected by an industry such as ethanol production, it is necessary to understand how different sectors or industries in the economy are linked. For example, in the renewable fuels production sector, the ethanol industry buys corn from the agriculture sector, which in turn, buys inputs from other suppliers such as fertilizer and pesticide producers that also purchase products from a range of other industries. These are referred to as backward linkages. For example, grain production is linked through both forward and backward linkages to other economic sectors in each state's economy.

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[4] DDGS and corn distillers oil production is reported monthly in the USDA Grain Crushings and Co-Products Production report. http://usda.mannlib.cornell.edu/MannUsda/viewDocumentInfo.do?documentID=1899

The household sector is linked to all sectors as it provides the labor and management resources. In turn, changes that affect incomes of the household sector typically have significant impacts compared to a change in the sales of other sectors. This is because households typically spend most of their income on both retail and service goods and this is a critical component of the national economy.

This study uses the IMPLAN (Impact Analysis for Planning) multiplier database to develop a model of the national economy, including sectors that support the ethanol industry, the links between them, and the level of national economic activity. IMPLAN is a commonly used economic input-output (I-O) model. I-O models are constructed based on the concept that all industries in an economy are linked together; and the output (i.e., sales) of one industry becomes the input of another industry until all final goods and services are produced. I-O models can be used both to analyze the structure of the economy and to estimate the total economic impact of projects or policies. For this analysis, a model for the U.S. economy was constructed using current IMPLAN software and data.

As in the past, we continue to treat industry earnings as an addition to the household sector since the income is paid to owners of operating ethanol plants. As a result, the impact of corporate earnings is estimated using multipliers for the household sector and incorporated into direct GDP.

IMPLAN models provide three economic measures that describe the economy: value added, income, and employment.

- Value added is the total value of the goods and services produced by businesses in the country and is generally referred to as GDP
- Labor income is the sum of employee compensation (including all payroll and benefits) and proprietor income (income for self-employed work). In the case of this analysis, demand for corn and other feedstock to produce ethanol supports farm income through higher crop receipts than would be the case without ethanol production.
- Employment represents the annual average number of employees, whether full or part-time, of businesses producing output. It is expressed in full-time equivalent jobs. Value added including labor income and employment represent the net economic benefits that accrue to the nation because of increased economic output.

There are three types of effects measured with a multiplier: direct, indirect, and induced effects. Direct effects are the known or predicted changes in the economy associated with the industry directly involved (in this case, ethanol). Indirect effects are the business-to-business transactions required to produce direct effects (i.e., increased output from businesses providing intermediate inputs). Finally, induced effects are derived from spending on goods and services by people working to satisfy direct and indirect effects (i.e., increased household spending resulting from higher personal income).

We also continue to reflect the additional value of output of co-products (DDGS and DCO) in the analysis. Since these are co-products the backward linkages for their production are accounted for in the expenditures for ethanol production. Consequently, the value of DDGS and DCO was treated as income and value added only, and we applied income multipliers to the employee compensation portion to avoid double counting.

As was the case in our previous studies, we incorporated the explicit impact of ethanol and DDGS exports in the economic impact analysis. The methodology for estimating the impact of trade differs from that used for industry output.[5] We estimated the impact of ethanol and DDGS exports by applying USDA Agricultural Trade multipliers for output and employment to the estimated value of exports for 2020 reported in the USITC trade databases. Since ethanol and DDGS are outputs of the organic chemical industry we used the USDA trade multipliers for the other organic chemicals industry. The USDA multipliers have three major components (or margins): production, transportation and warehousing, and wholesale/retail trade. Since IMPLAN already incorporates the impact of ethanol and DDGS production, to avoid double counting impacts we only applied the margins for transportation and trade to the value of exports. This represents the post-production (or ex-plant) impacts from exports.

Results

Table 2 summarizes the impact of ethanol industry production and exports on the U.S. economy in 2020. The full impact of the spending for annual operations of ethanol production, co-product output, exports, and R&D is estimated to have contributed nearly $35 billion to the nation's GDP in 2020, 19 percent less than in 2019. The primary reason for the lower GDP impact can be traced to reduced

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[5] https://www.ers.usda.gov/data-products/agricultural-trade-multipliers.aspx

spending associated with reduced output. Agriculture remains a significant source of industry economic impact. This reflects the importance of ethanol demand to total corn utilization, the aggregate value of crop production, and crop receipts and farm income. The manufacturing activity of ethanol production alone contributed $9.5 billion to the U.S. economy.

Table 2
Economic Impact of the Ethanol Industry: 2020

	GDP (Mil 2020$)	Jobs FTEs	Income (Mil 2020$)
Ethanol Production	**$9,548**	**71,010**	**$5,096**
Direct	$3,055	8,303	$1,321
Indirect	$3,387	23,489	$1,749
Induced	$3,106	39,218	$2,026
Construction	**$319**	**3,367**	**$212**
Direct	$118	1,473	$96
Indirect	$81	668	$49
Induced	$120	1,227	$68
Agriculture	**$18,759**	**213,550**	**$10,056**
Direct	$3,238	51,936	$1,559
Indirect	$9,799	98,289	$5,269
Induced	$5,722	63,325	$3,229
R&D Expenditures	**$205**	**1,742**	**$132**
Exports (Total)	**$5,834**	**15,110**	**$3,092**
Total Ethanol	**$34,665**	**304,780**	**$18,588**
Direct	$6,487	62,180	$3,029
Indirect	$19,156	138,070	$10,195
Induced	$9,022	104,530	$5,364

Employment

Jobs are created from the economic activity supported by ethanol production. The ethanol production is not a labor-intensive industry (accounting for fewer than 10,000 full time equivalent direct jobs nation-wide)[6]. However, the economic activity of supporting industries generates a substantial number of jobs in all sectors of the national economy. When the direct, indirect and induced jobs supported by ethanol production, construction activity, agriculture, exports, and R&D are included, the ethanol industry supported nearly 305,000 jobs in 2020.

Since ethanol production is more capital intensive than labor intensive, the number of direct jobs supported by the ethanol industry is relatively small and is concentrated primarily in manufacturing and agriculture. Most agriculture jobs supported by the ethanol industry are jobs in support activities related to crop production, ranging from farm advisors, producers and distributors of crop protection products, fertilizer, and farm equipment, and other service providers. In addition, jobs supported by income generated and spent by employees supports a significant number of jobs in seemingly unrelated sectors such as retailers and service sectors. In general, as the impact of the direct spending by the ethanol industry expands throughout the economy, the employment impact expands significantly and is spread over a large number of sectors.

Income

Economic activity and associated jobs produce income for American households. The economic activities of the ethanol industry put nearly $19 billion into the pockets of Americans in 2020. As is the case with employment, the direct impact on income by the ethanol industry is largely concentrated in manufacturing and services. In many respects, this mirrors the employment structure of the American economy. The most significant impact of the ethanol industry continues to be increased income to farmers who benefit from the demand for feedstock, which leads to both increased production and increased prices, as well as earnings from locally owned ethanol plants.

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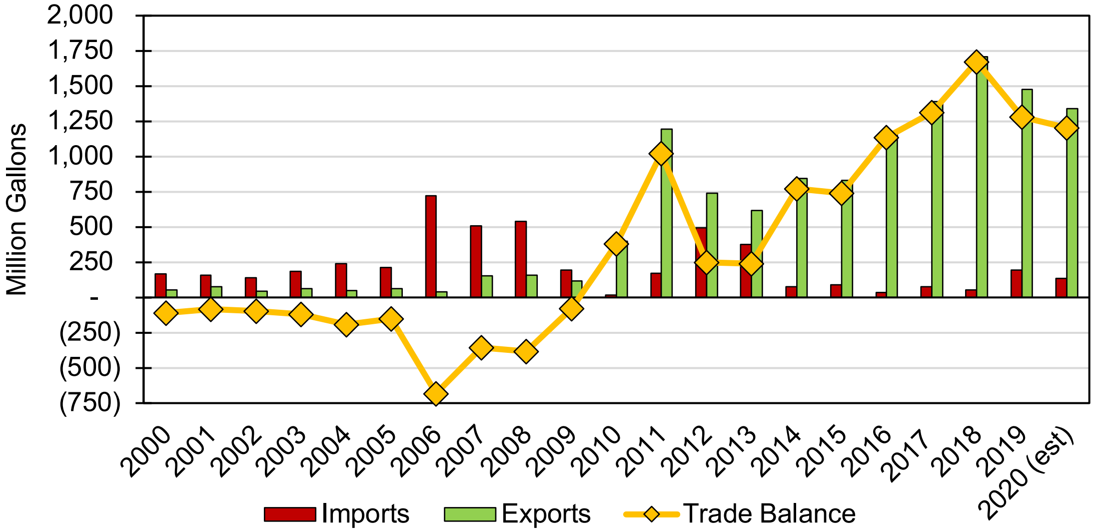
[6] The Census Bureau does not report employment in ethanol production. This analysis conservatively assumes the average ethanol plant employs approximately 50 full-time equivalent employees.

Exports

Ethanol exports dropped sharply during the second half of the year as COVID affected motor fuel use in importing countries. Exports to the two largest U.S. markets – Canada and Brazil – fell 6 percent and 34 percent, respectively. Year-to-date exports of ethanol were 10 percent below 2019 levels through October. The decline in volume was offset by higher export prices for both ethanol and DDGS.

U.S. ethanol exports have expanded significantly over the last decade and continue to post a substantial trade surplus. Ethanol exports in 2020 are projected to total more than 1.3 billion gallons with an export value of $2.1 billion. The projected 11 million metric tonnes of DDGS that are exported were valued at $2.3 billion. Moreover, the ethanol industry continues to generate a trade surplus that helps reduce the nation's trade deficit. Figure 2 illustrates the growth in ethanol exports, imports and trade balance.

Figure 2
U.S. Ethanol Trade



Source: Foreign Agricultural Service. Global Agricultural Trade System (GATS)

Exports of ethanol and distillers' grains generate economic activity largely through the requirements to transport output from plants to ports and final destinations. This largely involves truck, rail, barge, and ocean shipping. Additional impacts are generated by labor, administrative and financial requirements necessary to support export activity. These impacts are categorized as indirect since they are subordinate to production. Using the USDA Trade Multipliers suggests that the $4.4 billion of export value added $5.8 billion to GDP and supported 15,100 jobs in all sectors of the economy. Most of these jobs are concentrated in transportation and export trade related administrative and financial industries.

2020 was a difficult year for other major ethanol producers. A recent FAPRI forecast indicates that world ethanol production is projected to decline nearly 9 percent in 2020.[7] As indicated earlier production in the U.S., the world's largest producer, decreased 12.1 percent in 2020 while output in Brazil, the world's second largest producer, fell nearly 8 percent in 2020. Canada overtook Brazil as the leading export market for U.S. ethanol in 2020 accounting for 24 percent of U.S. exports. India was the third largest market for U.S. ethanol followed by South Korea, the Netherlands, Colombia and Mexico. Exports to China have dropped sharply over the past several years because of tariffs placed on U.S. ethanol and, as a result of the U.S. – China trade tensions, exports of ethanol to China in 2020 displayed little growth. As shown in Figure 3, seven markets account for more than 80 percent of total U.S. ethanol exports, although the U.S. shipped ethanol to roughly 90 countries in 2020.

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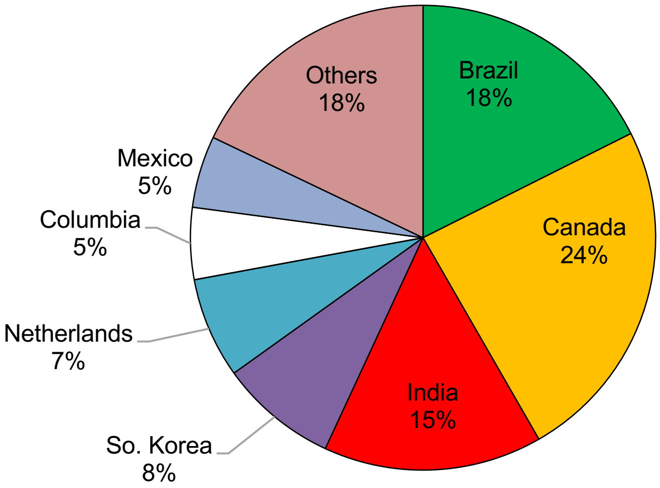
[7] FAPRI Baseline Review 2020. December 2020. Food & Agricultural Policy Research Institute, University of Missouri

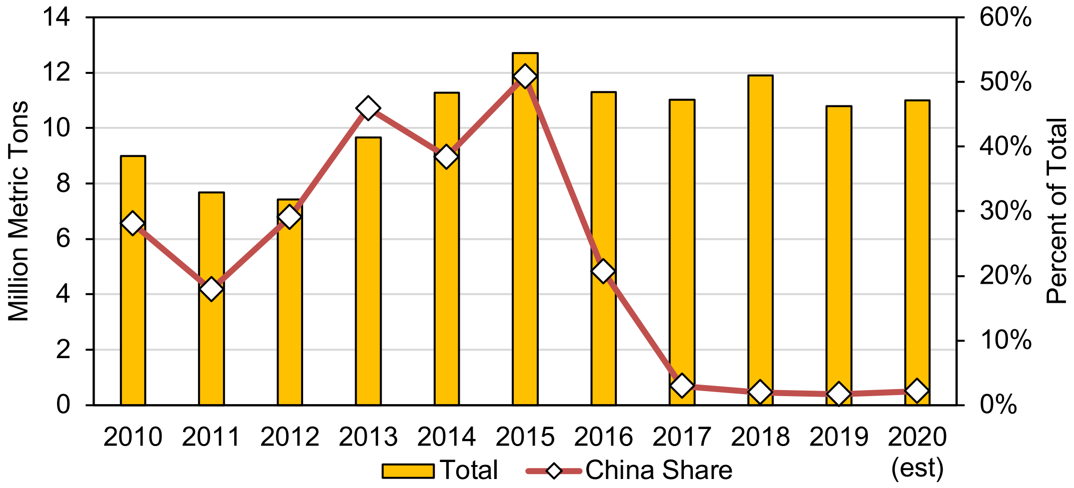
Figure 3
U.S. Ethanol Exports, Jan-Oct 2020



Source: FAS GATS

DDGS exports through October 2020 increased 0.6 percent from year earlier levels and are projected to total about 11 million metric tonnes for all of 2020. Higher world prices for DDGS led to an increase of about 2 percent in the value of exports. Exports of DDGS to Mexico, the largest market for U.S. DDGS fell 14 percent through October while exports to Canada, another major market, fell nearly 42 percent. The Chinese market for U.S. DDGS remains stagnant. Exports to China which had accounted for more than half of U.S. exports as recently as 2015 totaled about 206,000 metric tons through October 2020, or 2.2 percent of total U.S. exports. Figure 4 illustrates the level of U.S. DDGS exports and the share of market accounted for by China.

Figure 4
U.S. DDGS Exports



Source: USDA Foreign Agricultural Service Global Agricultural Trade System (GATS).

Tax revenue

The combination of GDP and household income supported by the ethanol industry contributed an estimated $3.3 billion in tax revenue to the Federal Treasury in 2020. State and local governments also benefit from the economic activity supported by the ethanol industry, earning $3 billion in 2020.

Crude oil displacement

Ethanol also plays a positive role in reducing our dependence on imported oil, expands the supply of motor gasoline, reduces the U.S. trade deficit, and reduces greenhouse gas emissions relative to conventional gasoline.

Ethanol displaces crude oil needed to manufacture gasoline and expands the volume of motor gasoline available to consumers. According to the Energy Information Administration (EIA), U.S. dependence on imported oil and refined products has dramatically declined since peaking in 2005 and the U.S. became a net exporter of oil and refined products in 2020. The use of domestic biofuels (ethanol and biodiesel) continues to be a contributor to the nation's energy independence. The production of 13.8 billion gallons of ethanol displaced 465 million barrels of crude oil needed to produce gasoline in 2020. The value of the crude oil displaced by ethanol is estimated more than $17 billion in 2020.[8] This money stays in the American economy and, when combined with the GDP generated by ethanol production, is helping keep America strong.

State Level Impacts of Ethanol Production

The ethanol industry has diversified geographically in recent years. At the end of 2020, RFA reports an aggregate industry capacity of 17.4 billion gallons with 209 operating plants producing nearly 13.9 billion gallons. Each of these plants is essentially a bio refinery that is an integral part of the other basic organic chemicals industry in the U.S. manufacturing sector. As such, the expenditures on feed grains and other feedstocks and inputs generates economic activity, income and supports job creation.

The calculation of state-level economic activity generated by ethanol production employed a different methodology than in previous years. The major change involved using state-specific economic impact multipliers for the Other Basic Organic Chemical Manufacturing industry (of which ethanol is a part) provided by the Bureau of Economic Analysis Regional RIMS II system. These replace the national average multipliers from IMPLAN used in previous years. The use of state-specific multipliers permits a more representative estimate of economic impacts at the individual state level. After identifying the multipliers for GDP, employment and income we estimated state-level output adjusted for idled capacity resulting from COVID impacts. This was accomplished using base year-end capacity and estimates of COVID related idled capacity provided by RFA. Expenditures were calculated by multiplying the national average per gallon cost of production adjusted output. Estimates of GDP, income and employment were calculated by multiplying the appropriate state-level RIMS II multipliers for the Other Basic Organic Chemical Manufacturing industry to the estimated operating expenditures by state. Since two different multiplier systems were used, the RIMS results were allocated over the national economic impacts based on state shares. The results represent only the impact of ethanol production and agriculture and exclude new construction activity, exports and R&D. The economic impacts are

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[8] Ethanol directly competes with and displaces gasoline as a motor fuel. According to the EIA, one 42-gallon barrel of crude oil produced 19.7 gallons of gasoline in 2020. Ethanol has a lower energy content (76,700 btu per gallon LHV) than gasoline (114,000 btu per gallon LHV), and thus it takes 1.48 gallons of ethanol to provide the same energy as one gallon of gasoline. Therefore, 15.8 billion gallons of ethanol are the equivalent of 10.4 billion gallons of gasoline. Since one barrel of crude produces 19.7 gallons of gasoline, it takes 465 million barrels of crude to produce 9 billion gallons of gasoline, the amount displaced by ethanol. This oil was valued at the 2020 year-to-date average composite acquisition cost of crude oil by refiners of $37/bbl.

rough estimates for several reasons. Chief among these is that the state-level analyses used multipliers for only one industry, other basic organic chemicals, and does not reflect other supplying industries. As might be expected, the impact on a state's economy is generally proportional to ethanol production. Table 3 details these results for states with at least 100 million gallons of production capacity.

The results in Table 3 are generalized impacts. The impacts of comprehensive analysis of any individual state will differ from these results. The reason for this is complex. First, the structure of each state economy is unique, economic impact multipliers reflect this and will differ from national-level multipliers for any given industry. This analysis uses multipliers for only one industry, other basic chemicals manufacturing, and does not reflect other supplying industries. Additionally, there are regional differences in feedstock costs, ethanol and DDGS prices, and other input costs that have not been explicitly considered. Relatively few states procure all of their feedstock and other inputs locally. Consequently, the analysis does not factor in leakages (spending that takes place out-of-state for inputs imported from a neighboring state). This means, for example, that the impacts may be overstated for a corn-deficient state like California or Texas to the extent that the dollars spent for corn imported from other states represent income for farmers in supplying states and are not netted out of the analysis. Similarly, corporate and co-op income is generated by plants domiciled in a particular state and ownership varies from state-to-state. Finally, the analysis does not allocate construction and R&D expenditures or exports on a state-by state basis since these are not likely equally distributed over all states.

Table 3
Contribution of Ethanol Production to Individual State Economies, 2020*

State	Capacity (Mil gal)	Plants	GDP (Mil $)	Earnings (Mil $)	Employment Jobs
IA	4,601	44	$6,571	$3,555	68,483
NE	2,300	26	$3,211	$1,718	33,052
IL	1,858	14	$3,753	$1,975	32,657
MN	1,378	19	$2,349	$1,288	23,526
IN	1,336	15	$2,235	$1,212	23,818
SD	1,235	16	$1,679	$906	16,873
OH	676	7	$1,446	$779	15,579
KS	618	13	$1,316	$656	13,021
WI	603	9	$934	$514	10,528
ND	537	7	$908	$460	7,925
TX	375	4	$486	$258	4,301
MI	353	5	$540	$301	6,280
MO	296	6	$523	$263	5,712
TN	237	3	$520	$272	5,215
CA	217	5	$384	$218	3,432
NY	165	2	$227	$115	1,711
CO	142	4	$280	$154	2,870
GA	120	1	$221	$120	2,267
PA	120	1	$240	$128	2,140
Others	264	8	$485	$262	5,171
U.S.*	17,431	209	$28,307	$15,152	284,560

*Excludes construction, exports and R&D

Conclusion

Despite the disruptive effects of the COVID pandemic, economic and regulatory challenges in 2020, the ethanol industry continued to make a significant contribution to the economy in terms of job creation, generation of tax revenue, and displacement of crude oil and petroleum products. The importance of the ethanol industry to agriculture and rural economies is particularly notable. A return to growth and expansion of the ethanol industry through the application of new technologies and feedstocks will enhance the industry's position as the original creator of green jobs and will enable America to make further strides toward reducing greenhouse gas emissions and positively dealing with climate change.

Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 13

Economic Impact of Nationwide E15 Use

June 10, 2021

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Economic Impact of Nationwide E15 Use

June 10, 2021

Prepared by ABF Economics LLP

Executive Summary

One of the most significant challenges and opportunities for the ethanol industry lies in expanding demand by increasing use of higher blend levels. Most of the motor gasoline used in the U.S. contains 10 percent ethanol (E10). The USEPA approved the year-around sale of 15 percent ethanol blends (E15) for use in model year 2001 and newer vehicles and the number of retail stations selling E15 has been increasing.

Increasing the blend level of ethanol from E10 to E15 nationwide will increase ethanol use by nearly 6.2 billion gallons over baseline 2016-2020 average levels and will generate substantial economic benefits for the U.S. economy. Implementing nationwide E15 use will require an increase in production that will be reflected in higher demand for feedstocks (mostly corn) and other inputs and will necessitate an expansion of industry capacity.

The economic impact of expanding ethanol use results from the spending on goods and services to produce ethanol and build the new capacity required to support a larger industry. This study estimates the impact for the U.S. economy and consumers of expanding E15 use to the nation's entire motor gasoline supply.

The combination of producing an additional 6.2 billion gallons of ethanol and building the 3.3 billion gallons of new capacity will:

- Generate and additional $17.8 billion of value-added output (GDP) to the U.S. economy
- Support more than 182,600 jobs in all sectors of the economy with agriculture and construction leading the contribution.

- Put an additional $10.5 billion of income into the pockets of American households and save each household nearly $100 in lower gasoline prices at the pump.
- Generate an additional $1.8 billion in tax revenue for the Federal Treasury and $1.6 billion for State and local governments.

Economic Impact of Nationwide E15 Use

June 10, 2021

Prepared by ABF Economics LLP

Introduction

One of the most significant challenges and opportunities for the ethanol industry lies in expanding demand by increasing use of higher blend levels. Most of the motor gasoline used in the U.S. contains 10 percent ethanol (E10). In 2011 the U.S. EPA approved E15 for use in model year 2001 and newer cars, light-duty trucks, medium-duty passenger vehicles (SUVs), and all flex-fuel vehicles (FFVs). In May 2019 the EPA issued a final rule that allows the year-round sale of E15. Reflecting this the number of retail stations selling E15 increased 18 percent in 2020 to nearly 2,200 nationwide.

ABF Economics was asked by Growth Energy to examine the economic implications of expanding E15 use on a nationwide basis. The objective of this study is to estimate the impact for the U.S. economy and consumers of expanding E15 use to the nation's entire motor gasoline supply.

Methodology

Gasoline and E15 Use

Increasing the blend level of ethanol from E10 to E15 will increase ethanol use. This will require an increase in production that will be reflected in higher demand for feedstocks (mostly corn) and other inputs and will necessitate an expansion of industry capacity. The economic impact of expanding ethanol use results from the spending on goods and services to produce ethanol and build the new capacity required to support a larger industry. The first step in this process is to estimate the amount of E15 that would be needed to supply the nation's motor gasoline supply.

The Energy Information Administration (EIA) reported in 2005 that more than 95 percent of the nation's motor fuel supply contained at least 10 percent ethanol (E10). EIA does not track the use of E15 or other higher blends of ethanol and currently only two states – Iowa and Minnesota and Iowa report sales of E15 and other higher ethanol blends. A close examination of EIA data for motor gasoline and ethanol use suggests that ethanol is present in about 97 percent of U.S. gasoline.

We estimated the amount of E15 that would be required to replace E10 in the nation's motor gasoline supply by using data for the domestic use of finished motor gasoline and ethanol imputed from production, ending stocks, imports and exports published by EIA. Simply, domestic use is imputed when exports plus ending stocks are subtracted from total supply (beginning stocks plus production and imports).

Since ethanol is an additive to motor gasoline the demand for fuel ethanol is determined by the quantity of gasoline used and the ethanol blend level. The baseline for our analysis was a five-year average of domestic finished motor gasoline and ethanol demand. Our analysis also uses five-year averages for prices of industry inputs (corn, natural gas and electricity) and outputs (ethanol, DDGS and Distiller's corn oil).

EIA data indicate that American consumers used an average of 139.3 billion gallons of finished motor gasoline over the past five years. Over this same period total domestic fuel ethanol use averaged 14.1 billion gallons.[1] On the assumption that 97 percent of the nation's fuel supply currently contains 10 percent ethanol, E10 demand is estimated at 13.5 billion gallons (139.3 billion gallons times 97 percent (0.97) and then by 10 percent (0.1). As pointed out above while E15 currently is available in more than 2,000 stations in 31 states, EIA does not track sales. We estimate the amount of E15 (and other higher ethanol blends) by subtracting estimated E10 demand from total domestic ethanol use. This amounts to 578 million gallons

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[1] Imputed domestic use of finished motor gasoline and ethanol was calculated by constructing a supply and demand balance for each using production, imports, exports, and ending stock data taken from online EIA databases. In any year beginning stocks are the previous year ending stocks. Total supply is beginning stocks plus production and imports. Domestic demand is imputed by subtracting exports and ending stocks from total supply.

(14,089 million gallons less 13,511 million gallons of E10). Making E15 the standard ethanol blend in the nation's motor gasoline supply would require nearly 20.3 billion gallons of ethanol, 6.2 billion more than is currently being used. EIA reports that ethanol capacity reached 16.9 billion gallons on January 1, 2020. Meeting the 20.3 billion gallons of ethanol demand represented by nationwide E15 would necessitate adding 3.3 billion gallons of new production capacity and would boost corn demand by an additional 2.1 billion bushels. The amount of E15 needed to meet nationwide demand, new capacity, and corn requirements are detailed in Table 1.

Table 1
Calculation of E15 Nationwide Demand

	Ave 2016-20 (Mil Gal)
Imputed Gasoline Use	139,289
Imputed Domestic Ethanol Use	14,089
E10	13,511
Current E15	578
E15 Needed to Replace E10	20,267
Addl Ethanol to produce E15	6,178
Current (Jan 1, 2000) Ethanol Capacity[2]	16,924
New Capacity Required	3,343

Economic Impact

The use of E15 nationwide will increase demand for and production of ethanol. To evaluate this, we calculated the economic impact of the producing the additional ethanol required to meet an E15 standard and comparted that to a baseline that represents a realistic view of the current situation where virtually all motor gasoline used in the U.S. contains at least 10 percent ethanol (E10). As our base for comparison, we chose to use a five-year average (20116-2020) of

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[2] https://www.ers.usda.gov/data-products/us-bioenergy-statistics/Table 11-- Fuel ethanol production facilities capacity and utilization rates, by State, January 2020

ethanol production, use and prices rather than an individual year to avoid selecting an unusually “good” or “bad” year. The best example of this is 2020 when the economywide shutdowns prompted by the COVID-19 pandemic sharply curtailed driving. EIA data indicates that motor gasoline and ethanol demand fell 13.1 percent in 2020 to the lowest level in two decades.

The impact of the ethanol industry on the American economy was estimated by applying expenditures by supplying industries to the industry-level final demand multipliers for value added output, earnings, and employment.

To understand how the economy is affected by changes to output in an industry such as ethanol, it is necessary to understand how different sectors or industries in the economy are linked. For example, ethanol producers buy corn grown by farmers who in turn, buy inputs such as fertilizer and crop protection products whose producers purchase inputs and services from a range of other industries. Similarly, the construction sector purchases materials and equipment from suppliers who, in turn, purchase intermediate materials needed to produce the inputs. Finally, all sectors employ workers (labor) that are supplied by households who in turn spend wages and salaries throughout the economy. Industry earnings for ethanol producers are treated as an addition to the household sector since corporate income is paid to owners and shareholders of operating ethanol plants.

This analysis used the IMPLAN (Impact Analysis for Planning) multiplier database to develop a model of the national economy. This model describes the industry sectors that support and supply the ethanol industry. IMPLAN is a commonly used economic input-output (I-O) model. These models are constructed based on the concept that all industries in an economy are linked together; and the output of one industry becomes the input of another industry until all final goods and services are produced.

Multipliers typically measure three types of impacts: direct, indirect, and induced:

- Direct effects are the known changes in the economy from an activity such as ethanol production.
- Indirect effects are the business-to-business transactions required to produce direct effects (i.e., increased output from businesses providing intermediate inputs to ethanol producers such as feedstocks).
- Induced effects are derived from spending on goods and services by people working to satisfy direct and indirect effects (i.e., increased household spending resulting from higher income).

Economic impact models provide three economic measures that describe the economy: value added, income, and employment.

- Value added is the total value of the goods and services produced by businesses in the country and is generally referred to as GDP.
- Labor income reflects employee compensation (payroll and benefits). An important component of this is the income that is generated by increased demand for corn and other feedstocks used to produce ethanol. This supports farm income through higher crop receipts than would be the case without ethanol production.
- Employment represents the annual average number of employees, whether full or part-time, of businesses producing output and is expressed in full-time equivalent jobs.

It is important to note that the economic impacts of increased ethanol production and use are total estimates viewed at a point in time. That is, this includes the impacts of investing in 3.3 billion gallons of new capacity to produce the additional 6.2 billion gallons of ethanol needed to supply the nation's entire motor gasoline supply with E15. In reality the actual impacts will be spread over the number of years it will take to ramp up capacity and production. For example, it took seven years (2014 to 2020) for the industry to add 3.2

billion gallons of capacity. It is also important to note while the impacts from increased ethanol production are permanent and will continue to contribute with ongoing production, the construction impacts are temporary and will expire when new biorefineries and completed and become active.

Baseline: 2016-2020

Over the five-year 2016 to 2020 period the ethanol industry operated 196 biorefineries that spent an annual average of $24.5 billion on feedstocks and other inputs to produce an annual average of 15.4 billion gallons of ethanol. This level of activity provided the economic baseline against which implementing a nationwide 15 percent ethanol (E15) standard will be measured. The average annual economic contribution to national economic activity of producing 15.4 billion gallons is summarized in Table 2.

Table 2
Economic Impacts of Baseline E10 Ethanol Production (2016-2020)

	GDP (Mil 2020$)	Employment FTEs	Income (Mil 2020$)
Ethanol Production	**$11,587**	**86,979**	**$6,203**
Direct	$3,711	9,797	$1,617
Indirect	$4,129	28,670	$2,140
Induced	$3,747	48,511	$2,445
Construction	**$880**	**9,298**	**$586**
Direct	$326	4,067	$264
Indirect	$224	1,844	$135
Induced	$330	3,387	$187
Agriculture	**$21,262**	**242,046**	**$11,398**
Direct	$3,670	58,866	$1,766
Indirect	$11,107	111,404	$5,972
Induced	$6,486	71,775	$3,659
R&D	**$1,506**	**12,778**	**$966**
Exports (Total)	**$5,898**	**15,150**	**$3,126**
Total Ethanol	**$41,133**	**366,251**	**$22,279**
Direct	$8,266	76,161	$4,040
Indirect	$21,759	160,837	$11,639
Induced	$11,108	129,252	$6,600

E15 Analysis

The ethanol industry will spend nearly $32.2 billion on feedstocks and other inputs and $5.8 billion of additional capital expenditures to produce 20.3 billion gallons of ethanol represented by nationwide E15 use. This is nearly 6.2 billion gallons more than was produced on average over the past five years. As these dollars circulate through the economy, they generate value added output (GDP), income, and support employment in all sectors of the economy. The impacts of nationwide E15 use are summarized in Table 3. These represent the effects on major supplying industries and the entire national economy of producing the ethanol that would be required if E15 replaced E10 in the nations motor gasoline supply. The impact on GDP, employment, and income over and above current levels of ethanol use are simply the difference between Tables 2 and 3.

Table 3
Economic Impact of Nationwide E15 Use

	GDP (Mil 2020$)	Employment FTEs	Income (Mil 2020$)
Ethanol Production	**$15,220**	**114,250**	**$8,148**
Direct	$4,874	12,869	$2,124
Indirect	$5,424	37,659	$2,811
Induced	$4,922	63,721	$3,212
Construction	**$8,404**	**88,796**	**$5,598**
Direct	$3,113	38,841	$2,525
Indirect	$2,138	17,607	$1,287
Induced	$3,153	32,348	$1,786
Agriculture	**$27,929**	**317,937**	**$14,972**
Direct	$4,820	77,323	$2,320
Indirect	$14,589	146,334	$7,844
Induced	$8,520	94,280	$4,807
R&D	**$1,506**	**12,778**	**$966**
Exports (Total)	**$5,898**	**15,150**	**$3,126**
Total Ethanol	**$58,956**	**548,911**	**$32,809**
Direct	$13,367	132,464	$7,362
Indirect	$28,450	220,519	$15,334
Induced	$17,139	195,928	$10,113

Value-Added

The full impact of the spending for ethanol and co-product output, production of agricultural feedstocks, and construction of new capacity is projected to contribute an additional $17.8 billion to GDP over what the ethanol industry has provided over the past five years under an E10 standard. The economic activity of moving to an E15 standard will account for a total of nearly $59 billion of GDP. Implementing an E15 standard will increase the size of the economy by $17.8 billion compared to the E10 baseline. The direct effect of ethanol production accounts for about a quarter of the GDP generated from E15. The largest contributor to the additional GDP will be the agriculture sector. The importance of agriculture reflects the fact that corn and other feedstocks account for more than 70 percent of the direct costs of producing ethanol. Most of this contribution will come from indirect and induced impacts as the dollars spent to produce ethanol circulate throughout the entire economy.

Employment

Jobs are created from the economic activity supported by ethanol output, additional agricultural output for feedstock production and construction activity for new capacity. Ethanol production is not a labor-intensive industry (accounting for fewer than 13,000 full time equivalent direct jobs nation-wide)[3]. However, the economic activity of supporting industries supports a substantially larger number of jobs in all other sectors of the national economy.

Over the five-year E10 baseline period the full impact of ethanol industry supported more than 366,000 jobs in all sectors of the economy. Moving to an E15 standard would support nearly 182,700 additional jobs. These represent not just the direct jobs associated with ethanol production but also the indirect and induced jobs supported by the economic activity created by additional ethanol demand and production.

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[3] The Census Bureau does not report employment in ethanol production. This analysis conservatively assumes the average ethanol plant employs approximately 50 full-time equivalent employees.

Income

Economic activity and associated jobs produce income for American households. Moreover, the profitable operation of ethanol production will generate corporate income that will be paid to shareholders of public companies and owners of locally owned ethanol plants. The economic activities associated with E15 will put $10.5 billion of additional income into the pockets of American households and an estimated $1 billion in corporate income. As is the case with employment, the direct impact on income provided by the ethanol industry is largely concentrated in agriculture, manufacturing, and services.

The impact of increased ethanol production will be compounded by the benefits consumers will experience from lower prices at the pump. Blending ethanol into motor gasoline lowers retail gasoline prices. Recent reporting of average pump prices of gasoline with no ethanol, E10 and E15 suggests that E15 enjoys a 9 cents per gallon discount relative to E10. EIA statistics indicate that the average U.S. household spends nearly $2,800 on gasoline annually. Adopting an E15 standard nationwide will save consumers $12.2 billion annually or nearly $96 per household.

Economic Impact by Sector

- Ethanol Biorefining (Manufacturing)

  Ethanol plants are essentially biorefineries that are a component of the manufacturing sector. Ethanol manufacturing is projected to contribute about a quarter of the increase in GDP, or $11.6 billion more than the E10 baseline. Two-thirds of this impact will come from induced and indirect activities. That is, the impact of larger demand for supplying industries and the spending of employees and their families for the full range of goods and services provided by the economy will have a greater impact on the economy than manufacturing alone.

Ethanol production is not a labor-intensive industry. The average ethanol biorefinery employs an average of 50 full-time employees. The direct employment impact of producing the additional ethanol needed to supply the nation with E15 is fewer than 13,000 jobs, about 3,000 more than the E10 baseline. The induced and indirect impacts are significantly larger so that E15 production is expected to support an additional 24,200 jobs for a total impact of 114,250 jobs in all sectors of the economy.

- <u>Agriculture</u>

Agriculture will provide the most significant source of economic impact from implementing an E15 standard. This reflects the importance of ethanol demand to total corn utilization. Feedstocks, notably corn, account for more than three-quarters of operating costs of producing ethanol. Over the past five years ethanol has accounted for about 37 percent of total corn utilization. The increase in ethanol demand will increase corn prices which, in turn, can be expected to provide a significant incentive for farmers to increase area planted to corn. The aggregate value of crop production, and crop receipts to farm income. The $27.9 billion of GDP generated by producing an additional 2.8 billion bushels of corn will account for nearly half the impact of E15 on GDP.

Agriculture is projected to support nearly 318,000 jobs in the entire economy under nationwide E15 use, nearly 76,000 jobs more than the E10 Baseline. The direct employment in production agriculture resulting from economy wide E15 is about 77,000. Most agriculture jobs supported by the ethanol industry are those in support activities related to crop production, ranging from farm advisors, producers and distributors of crop protection products, fertilizer, and farm equipment, and other service providers. The jobs supported by income generated and spent by employees supports a significant number of jobs in seemingly unrelated sectors such as retailers and service sectors. In general, as the impact of the direct spending by the ethanol industry expands throughout the economy, the employment impact expands significantly and is spread over many sectors.

- Construction

  The third major impact of expanded E15 use will be provided by the spending associated with adding 3.2 billion gallons of new ethanol production capacity. At an estimates cost of $1.75 per gallon of new conventional ethanol capacity this amounts to about $5.8 billion in spending for plant and equipment.[4] Some of this will come from expanding current capacity and increasing utilization. However, a significant share is expected to come from new plant and equipment. Construction is a more labor-intensive industry than ethanol manufacturing and the new capacity needed to produce the additional ethanol for E15 is expected to support more than 28,700 direct jobs in construction related industries and nearly 37,000 additional jobs in other sectors of the economy. The relatively large marginal impact of E15 on construction is explained by the substantial increase in capacity that will be needed to produce ethanol for E15.

  As pointed out earlier this is likely to take time so the impact will be spread out over several years. The economic impact from construction is not permanent and will last until the capacity comes online. The full impact of the estimated $5.8 billion in capital expenditures to build 3.2 billion gallons of new industry capacity will generate an additional $7.5 billion of GDP, support nearly 89,000 jobs and $5.6 billion in household income.

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[4] We are assuming conventional starch-based ethanol capacity. The expenditure for cellulosic and other new technologies is considerably higher.

- Exports and R&D

  Exports of ethanol and the principal co-product Distillers dried grains with solubles (DDGS) have grown in importance over the past decade and are providing a noticeable economic contribution. We have assumed no change in the volume or value of exports, or the expenditures associated with Research and Development. R&D activities have largely been directed at the development of new production technologies and feedstocks. It is likely that additional demand for ethanol will at a minimum maintain R&D spending at E10 Baseline levels. Exports, particularly of DDGS, are likely to grow as supplies increase with additional ethanol production.

- Tax revenue

  The combination of GDP, household, and corporate income supported by E15 will contribute an additional $1.8 billion in Federal tax revenue and $1.6 billion more for State and local governments relative to the E10 Baseline. Combined, E15 will increase revenue to Federal and State coffers by more than $11 billion.

Conclusion

Nationwide use of E15 will expand ethanol production and require a substantial increase in new production capacity relative to current E10 use. This expansion also will stimulate demand for agricultural feedstocks that will directly benefit farm income. The economic benefits from nationwide E15 use are significant increases in GDP, jobs supported in all sectors of the economy, household income and tax revenue.

Growth Energy Comments on EPA's Proposed Renewable Fuel Standard Program: Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 14

COMMODITIES

APRIL 12, 2018 / 2:29 PM / UPDATED 4 YEARS AGO

Exclusive: Chevron, Exxon seek 'small refinery' waivers from U.S. biofuels law

By Jarrett Renshaw, Chris Prentice

NEW YORK (Reuters) - Global energy giants Chevron Corp and Exxon Mobil have asked U.S. regulators for exemptions to the nation’s biofuels policy that have historically been reserved for small companies in financial distress, according to sources familiar with the matter.

FILE PHOTO: A Chevron gas station sign is seen in Del Mar, California, in this April 25, 2013 file photo. REUTERS/Mike Blake/File Photo

The requests will add fuel to a raging dispute between Big Oil and Big Corn over how the Trump administration should manage the U.S. Renewable Fuel Standard - a 2005 law that requires oil refiners to mix biofuels such as corn-based ethanol into the nation’s fuel supply, or buy government-awarded credits from other energy firms who do the blending.

The U.S. Environmental Protection Agency (EPA) has already issued an unusually high 25 hardship waivers to small refineries in recent months, according to an agency source, driving blending credit prices down and helping the oil industry reduce compliance costs.

But the agency won’t name the firms receiving the exemptions, citing a concern over disclosing private company information.

Both Chevron CVX.N and Exxon XOM.N, among the world′s most profitable energy companies, have asked EPA for waivers for their smallest facilities - Chevron′s 54,500 barrel-per-day refinery in Utah and the Exxon′s 60,000 bpd refinery in Montana, two sources briefed on the matter told Reuters on condition of anonymity.

The exemptions would free the plants from their obligation to hand in blending credits earned or purchased for 2017, which came due this year, the sources said.

The disclosure of the Chevron and Exxon applications, which have not been previously reported, follow a Reuters report this month that the EPA has exempted three of ten refineries owned by Andeavor ANDV.N, one of the biggest U.S. refining companies.

The waivers could save Andeavor $50 million or more in regulatory costs for the company’s 2016 obligations under the biofuels law.

Husky Energy - a Canadian oil giant backed by a Hong Kong billionaire - will also be seeking an exemption, this one covering the 2018 requirements for its small Superior, Wisconsin plant, spokesman Mel Duval told Reuters, disclosing the waiver for the first time.

Duval said Husky inherited a 2017 exemption when it bought the 50,000 bpd Superior refinery from Calumet Specialty Products Partners CLMT.O for $435 million in November.

The waivers are intended for facilities producing less than 75,000 barrels per day (bpd) that can also prove compliance with the policy would cause them “disproportionate economic hardship.”

A spokesman for Chevron, Braden Reddall, declined to confirm or deny the application, but said waivers provide an edge.

“Several competitors have reportedly received exemptions from the RFS,” he said in a written statement to Reuters. “If true, any refinery which has not been exempted from the RFS will be at a competitive disadvantage.”

Exxon spokesman Dan Carter declined to comment.

The exceptions and the EPA’s refusal to disclose them have infuriated the corn lobby, which argues the waivers hurt farmers by undermining demand for corn and should be used only sparingly for tiny facilities in dire straits.

“EPA is hiding behind poor excuses about proprietary business information to shield big oil companies from public scrutiny,” five Republican senators, including Chuck Grassley and Joni Ernst from Iowa, wrote in a joint statement Thursday.

“This looks like just another backdoor attempt by (EPA) Administrator (Scott) Pruitt to destroy the Renewable Fuel Standard and circumvent congressional intent.”

Bob Dinneen, head of the Renewable Fuels Association said there is nothing ‘small’ about Exxon and Chevron, both of which rank in the top 20 of the Fortune 100.

“For these two behemoth oil companies to claim economic hardship is downright offensive and insulting to the hard-working farm families and ethanol producers that depend on the RFS,” Dinneen said.

Slideshow (2 images)

It’s unclear whether the EPA has approved the Exxon or Chevron application. EPA spokeswoman Liz Bowman declined to comment on which firms have applied for or received exemptions.

She said the agency considers any application to exempt a refinery of less than 75,000 bpd - regardless of the size of the company that owns it.

“EPA decisions on waivers are based on refinery-specific information,” she said in an email. “We continue to work through petitions received for 2017.”

Exxon reported net profits of $19.7 billion last year. Chevron reported earning $9.2 billion.

Both bill themselves as globally integrated companies, and neither breaks out the financial details for their individual facilities in the public disclosures they are required to file with the Securities and Exchange Commission.

Republican Senator John Barrasso, of Wyoming, home to several small refineries, praised the expansion of the exemption program in a statement on Thursday. He did not address the controversy over the exemptions granted to some of the nation’s largest refiners.

“I applaud Administrator Pruitt and Secretary Perry for recognizing the burdens of this program. They know that we can’t allow it to hurt our nation’s small refineries,” Barrasso said.

‘DEMAND DESTRUCTION’

The EPA has historically doled out fewer than ten hardship exemptions per year to U.S. refineries, according to a former U.S. official who spoke on condition of anonymity. A current EPA official, however, said the number reached 20 for 2016.

The EPA has come under pressure for being stingy with the waivers in the past. A successful lawsuit last year by Sinclair Oil Corporation led a federal court to order EPA to expand its definition of “economic hardship” - opening the door for more facilities to be eligible.

The Trump administration has also signaled a willingness to help refining companies reduce their biofuels compliance costs - which industry players say has encouraged a surge in recent applications.

Trump hosted a series of meetings with advocates for the corn and oil industries at the White House since late last year aimed at reforming biofuels regulations in a way that cuts costs for refiners without reducing overall biofuels demand. The effort failed to yield a deal due to protests from corn industry representatives.

Obtaining a waiver helps refiners in two ways: they no longer have to earn or purchase blending credits, called RINs, to prove compliance, and they can sell any RINs they have on hand into the open market. That can provide a company with a benefit ranging into the tens of millions of dollars.

Other big oil companies including Phillips 66 PSX.N also own refineries small enough to be eligible for a waiver, as does CVR Energy CVI.N which is owned by billionaire investor and Trump ally Carl Icahn.

Officials for those companies did not respond to requests for comment on whether they are seeking exemptions.

Icahn’s efforts last year to overhaul the biofuels program - while acting as an adviser to Trump on regulatory issues - drew scrutiny from federal investigators after lawmakers said it raised ethical concerns.

Biofuels proponents including U.S. Department of Agriculture Secretary Sonny Perdue has criticized the use of RFS exemptions as “demand destruction” for corn-based ethanol. Ethanol demand has been vital to farmers who are buffeted by low commodities prices and the threat of a global trade war.

The American Petroleum Institute, which represents big oil companies like Exxon and Chevron, has also opposed small refinery exemptions in the past, arguing for a level competitive playing field.

Reporting by Jarrett Renshaw and Chris Prentice; Editing by Richard Valdmanis and Brian Thevenot

Our Standards: The Thomson Reuters Trust Principles.

Growth Energy Comments on EPA's
Proposed Renewable Fuel Standard Program:
Renewable Fuel Standard Annual Rules

Docket # EPA-HQ-OAR-2021-0324

Exhibit 15

Potential Increased Ethanol Sales through E85 for the 2019 RFS

Prepared for

Growth Energy

By

Stillwater Associates LLC
Irvine, California, USA

August 17, 2018

Disclaimer

Stillwater Associates LLC prepared this report for the sole benefit of Growth Energy. Growth Energy may submit it to the Environmental Protection Agency in connection with any proposed rulemaking or other agency action.

Stillwater Associates LLC conducted the analysis and prepared this report using reasonable care and skill in applying methods of analysis consistent with normal industry practice. All results are based on information available at the time of presentation. Changes in factors upon which the report is based could affect the results. Forecasts are inherently uncertain because of events that cannot be foreseen, including the actions of governments, individuals, third parties and competitors. NO IMPLIED WARRANTY OF MERCHANTABILITY SHALL APPLY.

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Executive Summary

This analysis was conducted to examine the feasibility of increasing ethanol consumption through E85 by an additional 0.38 bg by 2019, an annual rate that if continued through 2022 will increase ethanol consumption through E85 by 1.5 bg. The analysis reviews and updates Stillwater's July 11, 2016 evaluation which examined the potential for E85 and E15 sales increases. This updated analysis finds that by the end of 2018, 1,500 new E85 stations will have been built since 2016. This number, added to the 3,000 E85 stations that were in place at the time of our 2016 analysis becomes a total of 4,500 stations, which is sufficient to handle a 0.38-billion-gallons (bg) increase in sales of ethanol in 2019 through the new sales of 0.57 bgy of E85. E85 dispenser utilization for these sales will increase to 21%. Achieving these additional sales requires the federal renewable fuel standard's (RFS) D6 renewable identification numbers (RINs) price to be high enough to encourage consumers to make these purchases.

1 Introduction

This analysis was conducted to examine the 2019 impacts of increasing ethanol consumption through E85 by an additional 1.5 billion gallons (bg) by 2022. E85 offers the biggest increase of new ethanol used per gallon of fuels sold, so new E85 sales will be the primary route to increased ethanol usage.

2 Potential New E85 Sales

The E85 portion of this analysis examines the volumes that, given sufficient yet reasonable financial incentives, can increase ethanol by 1.5 bg in 2022 from increased E85 sales. Given a steady rate of increase in E85 sales through 2022, the 2019 increase in ethanol consumed would be 0.38 bg of E85. First, we quantify the E85 and ethanol volumes required in addition to the 350 million gallons per year (mgy) in existing E85 sales for 2017 and predicted by the U.S. Environmental Protection Agency (EPA) for 2018.[1] In order to reach a targeted 0.38 bg increase in ethanol usage in 2019, E85 sales need to increase by 0.57 billion gallons per year (bgy). This addition of new E85 sales in 2019 is shown in Table 1 below. The conversion of the increased annual ethanol volumes into E85 gallons was calculated using a factor of 1.51 gallons of E85 necessary to consume one (1) gallon of incremental ethanol (i.e. additional ethanol over the ethanol in the displaced E10).[2] Finally, the new E85 requirements are added to the existing E85 sales to determine the new E85 sales target for 2019. The result is that 0.92 bg of total E85 needs to be sold in order to consume an additional 0.38 bg of ethanol.

Table 1. Ethanol and E85 Sales Targets for 2019

	2017	2018	2019
Current E85 Sales, bgy	0.35	0.35	0.35
New E85 Sales, bgy			0.57
new Ethanol sold, bgy			0.38
Total E85, bgy	0.35	0.35	0.92

Next, we determine the number of E85 dispensers needed in place each year to accommodate the increased volumes. According to EPA there will be an estimated 4,535 E85 stations by the end of 2018.In older stations, the E85 dispensers were standalone units; stations built or rebuilt since 2016, however, use E85 blender pump dispensers, and these dispensers can also dispense E15. The result is that for 2018 and beyond there are at least 4,500 E85 stations.[3] Undoubtedly, with sufficient financial drivers, many more E85 stations could be added from 2019-2022, but this analysis is just using the E85 stations expected to be in place by the end of 2018.

While not much is known about the number of E85 dispensers in older E85 stations, newer E85 stations in the BIP have 3.3 dispensers on average.[4] For the purposes of this analysis, we have conservatively assumed only 1.0 E85 dispenser per station for the 3,000 pre-2016 E85 stations and 3.3 dispensers per E85 station for the 1,500 2016-and-newer stations. As shown in Table 2, the result is an average of 1.8 dispensers per E85 station in 2018-and-beyond which results in a minimum of 7,950 E85 dispensers for 2018-and-beyond.

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[1] U.S. Environmental Protection Agency. Renewable Fuel Standard Program: Proposed Standards for 2018 and Biomass-Based Diesel Volume for 2019. July 21, 2017. Page 34235 column 3. https://www.gpo.gov/fdsys/pkg/FR-2017-07-21/pdf/2017-14632.pdf

[2] This factor was documented in the Stillwater report: Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017. July 11, 2016, p. 4

[3] David Korotney, "Market Impacts of biofuels in 2019," (June 26, 2018), EPA-HQ-OAR-2018-0167-0025. EPA bases its estimate on an assumption that there were 3,571 E85 stations as of June 2018. We note that, according to the NACS 2017 Retail Fueling Report there were 4,300 E85 stations in 2017, so EPA's data may be conservative.

[4] U.S. Department of Agriculture. Biofuel Infrastructure Partnership: List of States Receiving BIP Grants. Accessed July 5, 2018. https://www.fsa.usda.gov/programs-and-services/energy-programs/bip/index

Table 2. E85 Stations and Dispensers

	2017	2018	2019
Pre-2016 E85 Stations	3,000	3,000	3,000
2016-2017 E85 Stations	800	800	800
New 2018 BIP Stations	-	700	700
New Non-BIP Stations	-	-	0
Total E85 Stations	3,800	4,500	4,500
Dispensers/Station	1.5	1.8	1.8
Total E85 Dispensers	**5,640**	**7,950**	**7,950**

Finally, we examine the E85 sales volumes per dispenser to determine dispenser utilization rates. Table 3 shows the results of dividing the total gallons of E85 which must be sold each year by the available E85 dispensers. The result is a fairly low E85 volume per dispenser. This point is made clearest in the bottom line in the table which shows the average percent utilization of E85 dispensers. This utilization percentage was determined by using a typical dispenser rate of 45,000 gallons per month.[5] The result is that in 2019, using existing stations and dispensers, just 21% of the average dispenser's capabilities will need to be used for dispensing 0.92 bg of E85 in order to use an additional 0.38 bgy of ethanol.[6] Thus, new E85 sales projected in Table 1 can be achieved without requiring any new E85 infrastructure. Note that if utilization were to increase to 31%, that could result in sales of 1bg of E85 or 670mg of incremental ethanol. The only requirement is that E85 (plus the RIN value) be priced as necessary to create these sales volumes.

Table 3. E85 Dispenser Utilization

	2017	2018	2019
Total E85 (bgy)	0.35	0.35	0.92
Total E85 Dispensers	5640	7950	7950
Average E85 per Dispenser (mgy)	0.062	0.044	0.115
Average Dispenser Utilization	11%	8%	21%

2.1 Flexible-Fuel Vehicle (FFV) Usage of E85

One of the potential limiting factors for the growth of E85 is the fact that this fuel can only be used in FFVs. Currently, there are about 21 million FFVs in the U.S. vehicle fleet.[7] If the 0.92 bg of E85 (.35 bg of existing sales plus 0.57 bg of new sales) used in this analysis for 2019 is spread across the 21million FFV fleet, it would mean that, on average, all FFVs in 2019 will have to be filled with E85 about 8%[8] of the time. In addition, as we explained in a prior report, work by Bruce Babcock and Sebastian Pouliot used detailed data regarding the geographic distribution of FFVs and E85 stations to demonstrate that there are sufficient FFVs near E85 stations to consume volumes of E85 of 1.2-1.3 billion gallons of E85.[9] Since the Babcock analysis, the number of FFVs and E85 stations have grown. Thus, FFV numbers should place no limitations on the sales of E85.

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[5] This factor was documented in the Stillwater report: Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017. July 11, 2016. p.3.

[6] Note that this utilization would only have to increase slightly if there was less E85 station growth than EPA anticipated by the end of 2018.

[7] Air Improvement Resource, Inc. Analysis of Ethanol-Compatible Fleet for Calendar Year 2019. Prepared for Growth Energy. August 16, 2018.

[8] Assuming an average of 12,000 miles per year and an average FFV fuel economy of 24.0 miles per gallon.

[9] Stillwater report: Infrastructure Changes and Cost to Increase Consumption of E85 and E15 in 2017. July 11, 2016. p.4.

3 Conclusions Regarding Potential E85 Sales in 2019

1. Existing E85 stations at the end of 2018 will be sufficient to support the sale of 0.57 bg of new E85 and total E85 sales of 0.92 bg. This will result in the usage of 0.38 bg of new ethanol and total ethanol of 0.61 in 2019.
2. At these E85 sales volumes, the stations and dispensers will only be 21% utilized in 2019.